AN INTEGRATED APPROACH, USING ISO 9001, TO ACHIEVE THE MANAGED AND OPTIMIZING LEVELS OF CAPABILITY MATURITY MODEL -- MODEL, IMPLEMENTATION AND VALIDATION

Thesis

Submitted in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

By

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Under the Supervision of

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE

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DEDICATION

This thesis is dedicated to two generations – my parents and my son. Firstly, to my late mother (who would have been so happy at seeing her youngest son submit a Ph.D. thesis) and my father whose sense of caring, values and hard work continues to inspire our entire family even today and secondly, to my son Rajeshwar who will hopefully work in a world where software quality will be so omnipresent that one would not even have to talk about it – it would be a given, not a pleasant surprise as it is today.

ACKNOWLEDGEMENTS

Working towards my Ph.D and producing this thesis has been a very enjoyable experience for me. When we talk of the Quality journey, we always say that the fruits of the journey is in the journey itself i.e., even before attaining ISO 9001 or CMM, the benefits of improving quality would already be seen. It is the same feeling I had when I was doing my Ph.D – that this is a learning journey and the fruits keep on coming along the way.

These fruits helped me tremendously in my consultancy work with my clients – in getting new insights and applying academic rigor to the problems faced by the companies I worked with. Who does one thank for this? I think that the Ph.D process itself at BITS Pilani has to be thanked for this. It provides an excellent opportunity for students to bring about industry insights to academic work and vice versa.

The concept of 'Guru' has been central to our culture all through the ages. In Dr Mukul Sinha, I found that concept truly realized. I was indeed fortunate to have him as my Guru. Not only did he inspire me to do my Ph.D (at a time when my focus was to build my consultancy practice) but he was always at my side to guide me, exhort me, even scold me, to ensure that I did not falter in my academic pursuits. I remember with fondness the innumerable brain storming sessions that I used to have with him and how he used to bring clarity to the problems we were faced with. He always said that a Ph.D has to be earned, not merely received. I hope I have not belied his expectations. I cannot thank him enough for all that he has done for me.

I worked with several companies helping them move towards ISO 9001, CMM Level 4 and Level 5. Their support and co-operation helped me in my research. I would especially like to thank the senior management and quality chiefs of HCL Perot Systems, Delhi, TCG Software, Calcutta, ITIL, Delhi, Hughes Software, Delhi, RS Software, Calcutta, Oracle, Bangalore, EDS, Chennai, Future Software, Chennai, BFL Software, Bangalore and Tata Interactive Systems, Mumbai for this. There are many other companies which I have not listed but which have been very helpful during my research.

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My heartfelt thanks go to Ms. Monisha Bhattacharjee and Sona Dutta who provided excellent support in producing this thesis. It was they who had to bear the brunt of my disordered ways and decipher my scribbles written on a bumpy flight back to Delhi (from wherever). They relieved me of the burden of the "production aspects" of the thesis.

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BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE
PILANI (RAJASTHAN)

CERTIFICATE

This is to certify that the thesis entitled : "An Integrated Approach, Using ISO 9001 to Achieve the Managed and Optimizing Levels of Capability Maturity Model – Model, Implementation and Validation

and submitted by : Rajiv Nag, ID No.: 1996 PHX F005

for award of Ph.D Degree of the Institute, embodies original work done by him / her under my supervision.

Signature in full of

the Supervisor ----------

Name in capital

block letters : DR MUKUL SINHA

Date : March 10, 2000 Designation Managing Director, E.S.C. Ltd.

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ABSTRACT

The Capability Maturity Model has attracted tremendous interest in the past few years in the Indian software industry. Most software organizations in India have set their sights on becoming a CMM Level 3 or Level 4 organization, if not at Level 5.

The Capability Maturity Model provides implementation directions for organizations to move up the maturity path. This is based on a step by step progression from Level 1 to level 2, then Level 3, 4 and ultimately Level 5. (We have called this the "traditional" route). However, India is witnessing a unique phenomenon in that software companies are going in for ISO 9001 first and then SEI CMM Level 4. While it is generally believed that this is due to marketing pressures alone, in the sense that software companies go in for ISO 9001 for the European markets and CMM for the US markets, we postulate that this route of ISO 9001 first and then SEI CMM level 4 is actually an easier and more sensible way than the traditional route. We have provided insights into the nature of problems that one may encounter by adopting the traditional route and why these would not be encountered in the "ISO first, then CMM" route. Building on these insights, we have provided a complete methodology of first implementing ISO 9001 in a software organization and then moving on to CMM.

An essential feature of the CMM and one that software organizations need to address is in the area of software measurements. At all maturity levels, an organization needs to institute measures to be able to assess specific process performance and effectiveness. We have identified, in this thesis, a generic set of metrics which would enable a company to reach CMM level 4 and level 5.

We also had the opportunity to implement this approach (of ISO first and then CMM) in several companies in India in the course of our consultancy work. All of these have already been assessed at Level 4 and some others are on their way to implement Level 5 requirements by May 2000. Results from some of these companies, as well as the metrics models they adopted are reported in this thesis.

Part I

LAYING THE FOUNDATION

CHAPTER 1: QUALITY CONCEPTS

CHAPTER 2: ISO 9001 FOR THE SOFTWARE INDUSTRY

CHAPTER 3: THE CAPABILITY MATURITY MODEL

CHAPTER 1

QUALITY CONCEPTS

1.0 Introduction

Software today plays an extremely crucial role in the daily life of all sections of society across the world. Because of this, the realization has set in that quality of software is an issue that both producers and customers should be equally concerned about. As long as software had a marginal effect on society, the impact of poor quality of software was not felt very highly. However, as software usage rapidly gained centre stage in all aspects of our daily life, the potential impact of software failures also increased tremendously. The impact of a software failure can range from relatively minor costs of failure (like rework and increased after sales service costs etc.) to major costs. Examples of major costs could be:

- Lost production (in most process plants – petrochemical, fertilizer, steel etc., a disruption of a continuous stream even for a short while may mean several days of lost production in bringing the stream back)
- Failed business (information technology plays such a dominant part in a large number of industries like freight and forwarding services, banks, financial institutions etc., that a software failure can even result in the business having to wind up completely)
- Lost wars (in the case of software for military purposes),
- Lost lives (in the case of safety critical applications like aircraft control, nuclear plant control applications etc.

The problem of poor quality is one that is especially acute in the software industry. Robert Glass, in a very interesting book titled "Software Runaways" [GLASS-98] describes some "spectacular" failures. Software runaway is described by KPMG as "A runaway project is one which has failed significantly to achieve its objectives and/or has exceeded its original budget by at least 30 percent [KPMG 1995]."

The example is given of several runaway projects, interesting amongst them were :

- The Denver International Airport project. Work on building a new international airport at Denver, Colorado was started in November 1989. The original schedule opening date was October 1993. The opening was delayed three times in 7 months because the baggage system software had not been readied in time. In May 1994, work began on back-up system for baggage handling since the original system was thought to be inherently risky. The system was finally inaugurated on February 28th 1995, with not one integrated baggage handling system but three separate systems each one doing only a part of what was intended. The software vendor BAE was faced with several legal cases on account of the delay.

The failure to implement the software on time led to the airport project being 16 months behind schedule and almost 2 billion dollars over budget. The international airport was supposed to have worked economic wonders for the city of Denver. A software project laid low all these expectations. It is now believed that the economic boom in Atlanta was primarily due to the Denver project being behind schedule by such a large margin. All this happened because of the failure of the software.

- The US Federal Aviation Administration announced an advanced automation program in the year 1981 to modernize air traffic control all over the USA. 15 years and billions of dollars later the Advanced Automation Centre (AAC) had become an icon of everything that could go wrong with air traffic modernization. Without going into the reasons for the delay it is interesting to note that even when it was finally implemented in late 1997, it went in line with a much reduced set of specifications than was originally thought of; 3 major software developers were involved namely, Hughes, IBM and Loral Corp. The FAA had lost 1.3 billion dollars by June 1994 and it is believed that the total losses is much much higher.

- The Florida Online Recipient Integrated Data Access system known as FLORIDA is a system that processes applications for aid to families with dependent children, food stamps and medic aid. This system led to 60 million dollars in over payments and 58 million dollars in under payments in 1 year alone. It had erroneously sent medic aid cards to around 2,35,000 people who were no longer eligible. These improper issued cards were used to obtain more than 28 million dollars in health care services in a 6 month period in the year 1992. 41 managers were fired because of this, EDS the software vendor lost 19 million dollars and a legal case is now going on to judge if the state of Florida can get some compensation from EDS on this matter. The situation took a specially ugly turn when Hurricane Andrew hit southern Florida in late 1992 and the number of people desperately in need of aid increased substantially.

Enlightening as these examples are, it is also important to bear in mind that for one spectacular failure, there are hundreds and thousands of other failures every day, which although not so spectacular, cause an equal degree of heartburn for customers and producers alike. (At the same time, it is definitely not the intent to suggest that the software industry does not have any success stories – after all, had there not been successes, software would not have played such an influential role in society as it does today; at the end of the day, for each instance of a software failure, there would probably be many instances of software having eventually worked successfully).

The realization of the impact of poor quality has led the software industry, in recent years, to look for ways and means so that quality is sustainable and repeatable throughout the organization.

KPMG, one of the "Big Six" consultancy firms and actively involved in the software quality movement across the world, made a presentation to NASSCOM in November 1999 where the enablers of Quality were defined from the organizational perspective [KPMG-99]. The perspective is shown in Fig 1.1

Organizational Excellence

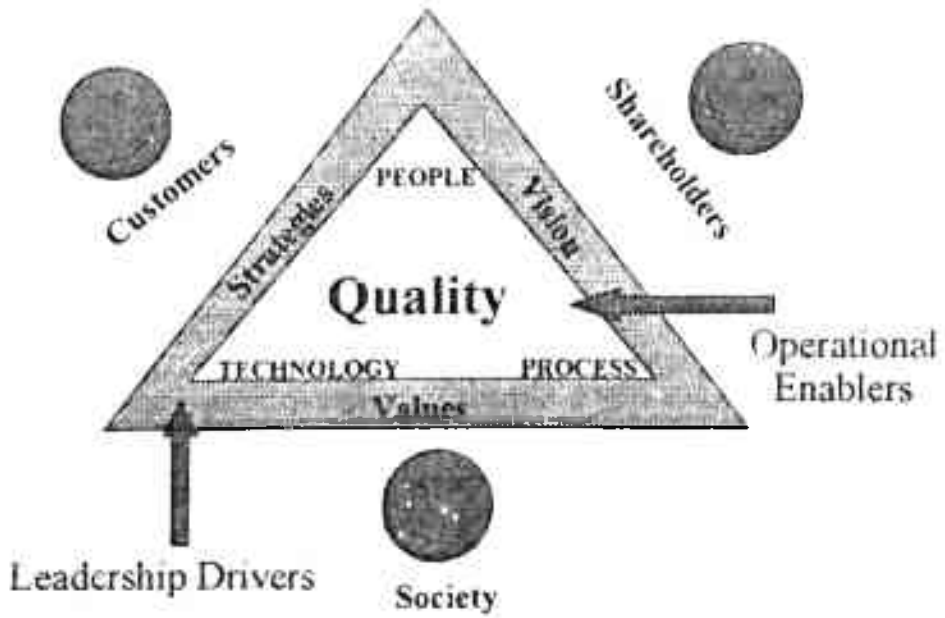

Fig 1.1

The objective of quality is to achieve organizational excellence to bring satisfaction to its stakeholders. We shall define quality in detail in the next section. However, as we shall see, quality means satisfying the needs of all who are affected by the product or service that the organization renders, i.e. customers, shareholders and society. To be able to do so, certain "Leadership drivers" need to be in place which are:

- Values, so that the interests of society are never compromised
- Vision, so that the organization moves in the direction that the shareholders of the company wish it to
- Strategies, which may be much more focussed than vision and are geared to meet the needs of the customer

Once these leadership drivers are in place, an organization needs to have "Operational Enablers" so that quality can be achieved. These enablers are:

- Processes
- Technology
- People

Quality is achieved by a synergistic mix of processes, people and technology. One, without the other, will not suffice and hence, each of them is a necessary condition to ensuring that the organization achieves and continues to achieve quality in all its products and services. It is for this reason that an organization may have the best of technology and yet may fail to achieve sustainable organizational excellence. On the other hand, the best of processes may exist but without adequate attention paid to the role of human resources, the organization will not be able to meet the needs of its stakeholders.

There are various models which seek to bring about improvements in each of these areas. This is represented below (KPMG1):

Contemporary Models

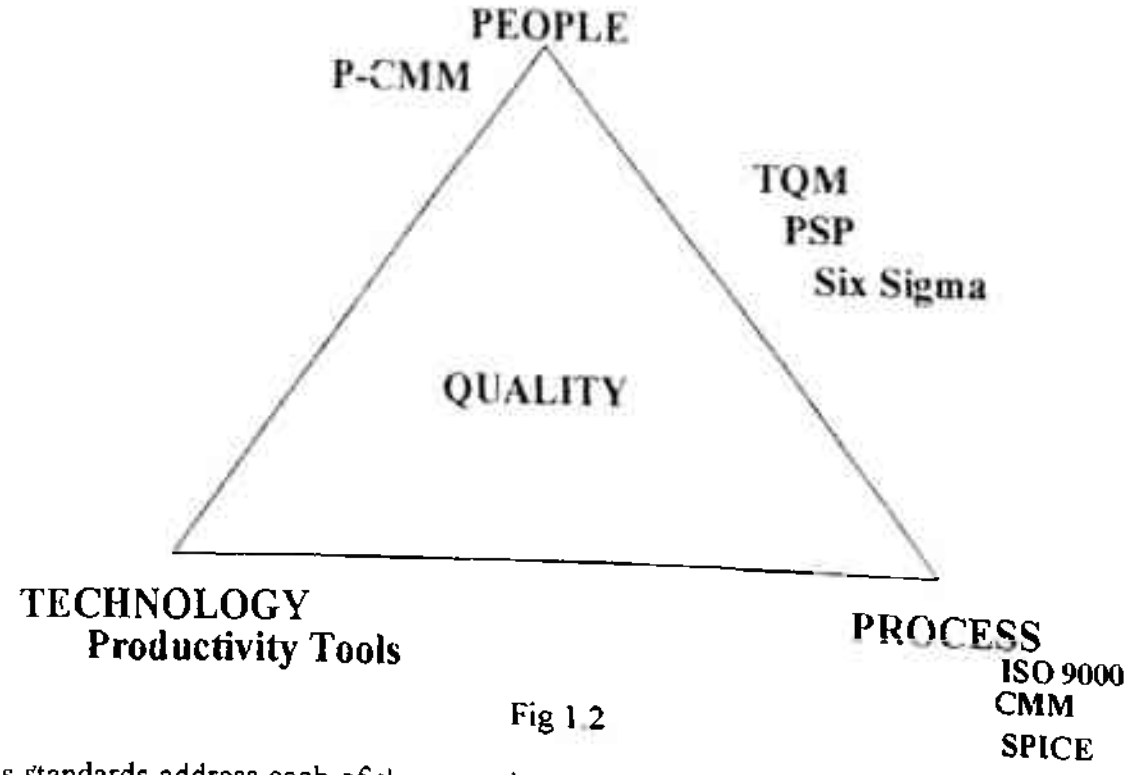

Fig 1.2

Various standards address each of the operational enablers. Our focus here is only on processes. The ISO 9001 and the Capability Maturity Model are two important process quality models and are frameworks which enable an organization to move towards higher levels of sophistication in the use of processes and also allow the other two ingredients of quality viz. People and technology to function in an optimal and effective manner. Both the models have their respective strengths and weaknesses and an organization may choose to adopt any one or both in their search for continuous process improvements. As explained briefly in the abstract, the purpose of

this thesis is to show that the approach of ISO 9001 first and then CMM is more efficient than any other route.

Before going into detail, it is important to lay the foundation for an understanding of the proposed model. This chapter, Chapter 1 defines and explains the key terms that one comes across in any discussion on quality. Chapter 2 provides an explanation of the family of ISO 9000 standards while Chapter 3 discusses the Capability Maturity Model.

1.1 Quality

Philip Crosby (CRO-79) defined **quality as "conformance to requirements"**. The word "requirements" here may be construed to mean either stated requirements or real requirements. By stated requirements, we mean those requirements that have been agreed upon between the customer and the producer. The real requirements would mean the stated requirements as well as those requirements that may have been left unstated.

According to Crosby, quality should meet the real requirements of a customer. Adopting the "stated requirements" definition may not be sufficient since the customer may have certain unstated requirements which, if not met, may lead to dissatisfaction with the product or the service rendered. Many needs are so fundamental that they are not put down in black and white or at least stated specifically by the customer; yet if these are not met by the product or the service delivered by the producer, the customer is left with a feeling of dissatisfaction.

An example often quoted here is that of the doctor who was asked to operate upon a patient to remove a gall bladder stone. The doctor removed the stone as specified (met the stated needs) but the patient died on the operating table (failed to meet an unstated but real requirement - the implied need - which was that the patient should survive). Although this, being anecdotal, could be viewed as an extreme case, the fact remains that the producer must meet the real requirements - both the stated and implied needs - if he is to render satisfaction to the customer.

Joseph Juran [JUR-89] captured it well when he defined quality as **Fit for Use**. This implies that it is no use meeting the stated requirements if the product produced is not fit to be used since it does not meet the needs of the customer. A car manufacturer's requirements sheet for tyres would have detailed specifications on the percentage of carbon black required, the depth of tread, the nature of radials etc. but will probably not specify that the tyres must be round. The tyre producer could meet the specified requirements by producing square tyres but this would lead to a product unusable by the customer (in this case, the car manufacturer).

A comprehensive definition that combines both Juran's [JUR-89] and Crosby's view of quality is given in the ISO [ISO8402-86] family of standards which defines quality as: "The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs."

This takes a larger view of the needs of a customer than merely the specifications agreed upon with the customer. It recognises the fact that implied needs also should be met to provide quality. Another dimension that it brings out is that of "totality of features and characteristics..". This recognises that it is not only functional attributes of a product that are important but other

attributes like usability, reliability, maintainability etc., of a product should also be considered by the producer.

This is also embodied in McCall's [MCC-78] listing of attributes of quality of software (called McCall's quality factors) which are:

i) Functionality (Correctness)
ii) Maintainability
iii) Reliability
iv) Flexibility
v) Usability
vi) Testability
vii) Integrity
viii) Portability
ix) Efficiency
x) Reusability

The ISO definition can thus be viewed as a succint amalgamation of Crosby's, Juran's [JUR-89] and McCall's [MCC-78] views, central to which is that quality must lead to customer satisfaction; if customer is not satisfied, quality has not been achieved. In doing so, one must keep in mind the implied needs, for if these are not met, customer satisfaction would not be obtained. (Recall the examples given earlier of the patient and his stone removal as well as the manufacturer and the square tyres). The ISO definition views needs as:

User needs = Stated needs + Implied needs

Quality means meeting the total set of User needs, which includes implied needs as well. As producers, we would have done our job as requirements analysts well if we were able to reduce the set of implied needs to zero so that all the needs are known and stated. Getting to know, and thus to satisfy, implied needs is generally the more difficult task since these needs tend to be amorphous in nature and not well defined.

Diagramatically, this can be represented as:

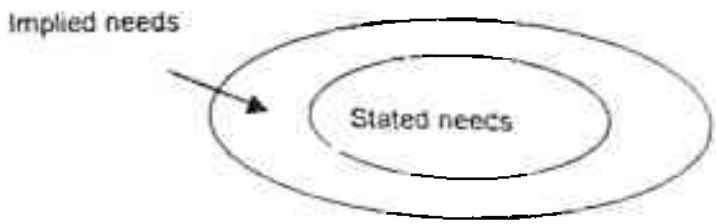

Fig 1.3

The challenge before the producer is to ensure that the outer envelope viz The implied needs collapses to zero and all the needs are stated and known upfront so that they can easily be met.

1.2 Process & Product

1.2.1 General Definition And Explanation

A process is defined as :

"*A set of planned and systematic activities implemented to achieve certain goals or objectives*".

These objectives may be either developing, or producing a product, or providing a service. Hence, a process may be viewed as just a way of doing things or, in other words - a set of steps or tasks followed to achieve an output. The only stipulation that one would put in here is that the set of tasks would be a planned and systematic set of tasks, and not an *ad hoc* set of tasks. Other terms used for a process are a methodology, a procedure or a system. These terms are not exactly the same as a process but they convey more or less the same meaning.

A product is defined as :

"The result or output of a process or set of processes".

Hence, any process will always have a product coming out of it, either an intermediate product or the final product. Thus, the definition not only includes the deliverables made to the customer but any other output of a set of activities.

Examples of processes and products may be given both from within an organization and from daily life. Thus an organization may have a production process (with several sub processes therein), a marketing process, a delivery process and many others, each with their specific products or services delivered. In our daily life, we may have a process so mundane as getting ready and coming in to office, a cooking process, a house cleaning process etc.

The point that is emphasized here is that processes need not be thought of as only the documented procedures that we come across in many places but they are any set of well thought out and pre planned activities.

1.2.2 Processes In A Software Organization

It would be pertinent for us to reflect on processes that may be applicable to a software project. The processes in a software organization are heavily project centric, since most of the work done in a software organization is project oriented. (Even product-centric software organizations have several projects which are aimed at development of the various components of the product).

A software organization may have the following categories of processes :

- Project life cycle processes

These are the "production processes" of a software organization, commonly called the project life cycle processes in a project. In a development project, the software development life cycle processes like requirement analysis, system design, coding, testing etc., would be applicable while in a maintenance project, life cycle processes like impact analysis, coding, testing and release would be applicable.

- Project support processes

Processes like project planning, project monitoring and control, configuration management, etc., are grouped in this category. These are processes that happen throughout the project life cycle, and hence, may be viewed as umbrella processes in a project.

- Organization support processes

These are processes like recruitment, training, procurement, facilities management, etc., which are not project specific but support the needs of the entire organization. The recruitment function in an organization does recruiting for the entire organization, training meets the needs of a gamut of projects etc. Of course, there may often be project specific requests e.g. "Project A requires that 5 persons be trained on Java" etc. but the organization wide process is still being used.

1.3 Quality Assurance and Quality Control

1.3.1 Definition:

Quality Assurance is defined as: "All those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy given requirements for quality" while Quality Control is defined as: "The operational techniques and activities that are used to fulfil requirements for quality" (Ref ISO 8402).

1.3.2 Explanation:

The key difference between Quality Assurance and Quality Control is that Quality Assurance is aimed at *prevention of defects* while Quality Control is aimed at *detection of defects*. Since QA is a preventive process, it has to be carried out ex ante, i.e., before the process (which may introduce the defect) is even carried out and also during the process. On the other hand, QC, being a detective process, has to be an ex post process, i.e., it is done only after the relevant process is carried out.

Examples of QA activities are:

- Define processes,
- Coordinate and facilitate process implementation,
- Provide Training on processes.,
- Gain an understanding of process compliance by audits, and
- Bring about improvements in processes.

Examples of Quality control activities are:

- Reviews
- Testing

It could be argued that reviews are really QA in that they prevent defects from being transmitted to the next stage of the project. However, the primary purpose of a review is to detect defects in the reviewed document. Also, it is done ex post i.e. done after the document has been produced and is done on the product (in this case, the document to be reviewed). Thus, by all the characteri9stics we mentioned earlier for QC, a review would be a QC process.

It should also be borne in mind that any QC process would have an associated preventive side to it. e.g. Testing prevents a defective product from being shipped to the customer; a traffic policeman flagging down a car that has jumped the traffic lights (he is performing a QC function in that he is *detecting* transgressions of the law) has thereby prevented an accident happening down the road.

Thus, both reviews and testing are QC processes, the difference being that reviews are an early form of QC in that these generally happen during the early phases of the project (reviews of Software Requirement Specifications, SW Design Document, etc.,) while Testing is a later form of QC (unit testing, system testing etc.)

The differences between QA and QC may be summed up as follows:

Quality Assurance	Quality Control
Preventive	Detective
Ex ante	Ex post
Process	Product
Staff function	Line function

However, the view of Software Quality Assurance is slightly different in the Capability Maturity Model. Although we have discussed this aspect more in detail in Chapter 3 and Chapter 4, suffice it to say at this point that the SQA role defined in the CMM includes work product audits as well.

1.4 Metrics and Measures

1.4.1 Definition

A measure is defined as " a quantified observation on some attribute or aspect of the software product, process or project"

A metric is defined as "a quantitative determination of the extent to which a system, component or process possesses a certain attribute – generally a ratio" – IEEE standards (IEEE610-90).

1.4.2 Explanation

A measure, according to the definitions above, provides a quantitative insight into any z

A simplistic example could be that the height of an individual in a class is a measure but the average height of the boys in the class would be a metric. Although this is the technical difference betwcen the two terms, it is good to also keep in mind that, in practice, this differentiation is not strictly adhered to. In fact, IEEE uses the terms "computed measures" and "primitive measures" to describe metrics and measures respectively. Most practitioners use these terms interchangeably and we shall also do so in this thesis.

Having defined the terms above, let us study some of the Quality models like ISO 9001 and SEI CMM in the following chapters.

CHAPTER 2

ISO 9001 FOR THE SOFTWARE INDUSTRY

2.0 Introduction

Recognizing that quality of a product or of a service is heavily dependent on the processes used to produce it, the International Organization for Standardization (ISO), decided in 1986, to focus on developing a set of process based quality models which could then be adopted by all member countries. The emergence of the European Common Market in the mid 80s and the concept of free trade among all member EC countries further fuelled this need. Once there was free trade, there was a need to ensure common product quality which, given the immensely wide variety of products that could be traded, was better achieved through the use of process standards. A committee called TC 87 (Technical Committee 87) was formed for this purpose.

A word on the ISO: The ISO is based in Geneva and comprises of more than 100 member countries that are represented on this body through their national standards institutions. The Bureau of Indian Standards (BIS) represents India, the British Standards Institute (BSI) represents the UK, and ANSI represents the USA etc., in the ISO.

Using the ideas propounded by quality experts like Deming [DEM1], Juran [JUR1-89], Crosby [CRO-79], Ishikawa [ISH-85] and others, the committee came up with a series of standards against which companies could get themselves certified. This series is called the ISO 9000 series which has been explained below.

This chapter begins with the structure of the process standards in Section 2.1 below, (and the ISO 9001 standard is explained in detail in Section 2.3). The differences between ISO 9001, 9002 and 9003 are explained in Section 2.2.

2.1 The Structure of ISO Process Standards

The International Organization for Standardization (ISO) has divided process standards into "Standards" and "Guidelines". The standards are quality models against which an external audit may be carried out while guidelines are provided to aid greater understanding. Thus, the chosen standard would be mandatory while guidelines may be used by the organization as it sees fit.

These standards and guidelines have been numbered ISO 9000 onwards, with the exception of the standard ISO 8402 that defines the Quality Vocabulary to be used. The year in which a specific standard was formally issued is also written along with the ISO number, e.g., ISO 9001:1987 refers to the original ISO 9001 standard issued in 1987 while ISO 9001:1994 refers to the revised standard issued in 1994.

Member countries of the ISO, in turn, adopted these standards. It was adopted in India by the BIS as the IS 14000[1] series, in UK by the BSI as the BS 5700 series, in Australia as the AS 3700 series etc. These were complete adoptions, i.e., without any modification whatsoever, except for a preamble section. The Indian Standard, for example, is exactly the same as the International Standard except for an additional section called the "National Foreword" which testifies to the fact that the ISO standard has been formally adopted. However, it would be relevant to point out that ANSI in the US has a standard called the QS 9000 series which is the ISO 9000 series, and four extra clauses. The QS 9000 is extensively used in the automobile industry.

The numbering scheme used by BIS was initially different from the ISO numbers. The numbers used by BIS started from IS 14000 onwards[2]. The numbers started with "IS" indicating that these are the Indian Standards. Please note the difference between the ISO and the Indian standards numbering system. The complete set of standards and guidelines are as follows :

The relevant Process Standards are:

- **ISO 9001:1994; IS 14001:1994** - Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing
- **ISO 9002 : 1987; IS 14002:1988** - Quality Systems - Model for Quality Assurance in Production and Installation.
- **ISO 9003:1987; IS 14003:1988** - Quality Systems - Model for Quality Assurance in Final Inspection and Test

The relevant Guidelines are:

- **ISO 8402:1986 ; IS 13999:1988** - Quality Systems Vocabulary
- **ISO 9000:1987; IS 14000:1988** - Guidelines for Selection and Use.

This has several parts e.g. ISO 9000-3 (called ISO 9000 part 3) provides guidelines for software companies

- ISO 9004: 1987; IS 14004:1989 - Guidelines for Quality Management
- ISO 9004-2 : 1991; IS 14004 Part 2:1992 - Guidelines for Services
- ISO 10011:1990; IS 14011:1991 - Guidelines for Auditing Quality Systems

However, BIS has recently renumbered the standards and guidelines to be consistent with the ISO and we now have IS 9001, IS 9002 etc.

In the diagram on the following page, the relationships among the ISO standards are shown.

[1] This series has now been renumbered by BIS as ISO 9000 series
[2] The exception to this was ISO 8402:1986 which became IS 13999: 1988 in the BIS numbering scheme

It is important to note that it is only ISO 9001[3] *[ISO9001-94], 9002 [ISO9002-87] and 9003 [ISO9003-97] that are the standards (and therefore certification can be obtained against these), while the rest are only guidelines.*

The ISO 9000 [ISO9000-87] *document is only a guideline and not a certification standard as is commonly believed.*

As explained above, ISO 8402 defines all the terms used in the quality standards. ISO 9000, which consists of ISO 9000-1 and ISO 9000-2, provides guidance on the selection and use of standards, e.g., it tells us when to use ISO 9001, when to use ISO 9002 etc.

The software industry had voiced their inability to use ISO 9001 without adequate guidelines, and hence, ISO 9000-3 was brought out to provide guidance to the software industry. The relationship between the standards and the guidelines is diagrammatically represented below :

ISO 9000 FAMILY OF STANDARDS

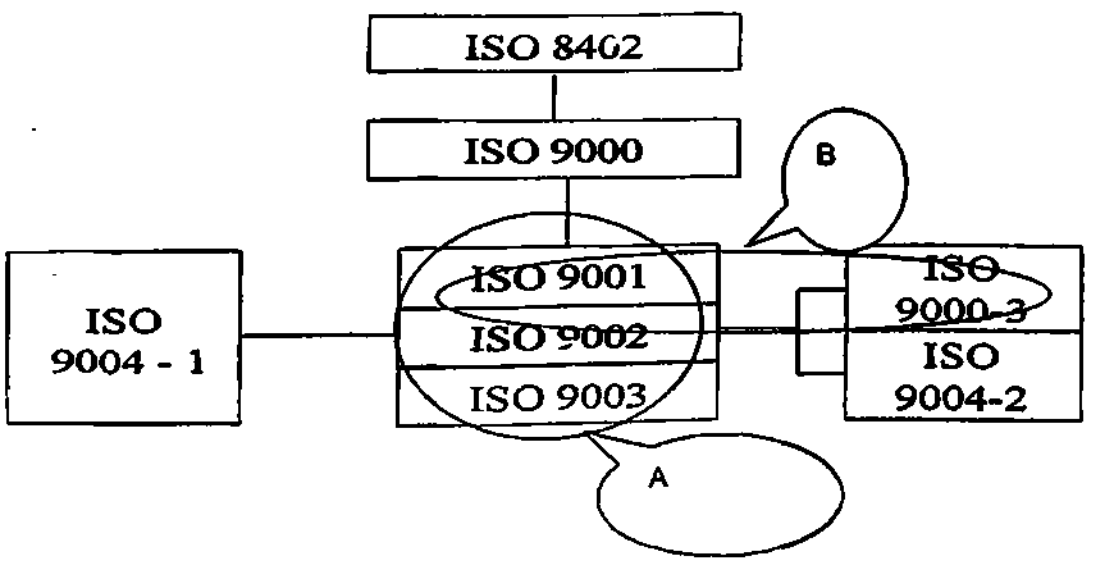

Fig. 2.1

The standards are given within the envelope A. All documents outside the envelope are guidelines. The documents applicable to the software industry are given in the oval B.

[3] ISO 9001:1994 has now been replaced by ISO 9001: 2000. However, both versions will be in use concurrently till 2003

2.2 Selection of standards – differences between ISO 9001, 9002 and 9003

a) ISO 9001 is to be used when the organization is involved in all the following stages of work, viz.,

- Design
- Development
- Production
- Installation
- Servicing

the assurance of quality is to be provided in all the above stages. This may be graphically represented as below.

Scope of ISO 9001

Product Design, Development And Service

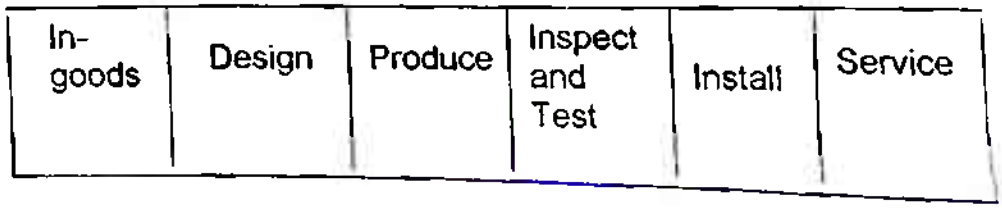

Fig 2.2

This shows that if all phases apply, an organization should use the ISO 9001 model. A software organization does design (understand requirements of customer and translate these into a design), produce (coding), testing, install and service (software maintenance). Thus ISO 9001 is the applicable standard for the software industry

b) However, if an organization is involved *only in production and installation activities* and therefore is required to assure quality only in these stages of work, ISO 9002 is applicable. Such an organization is generally a manufacturing or engineering organization that work on established design

This is graphically shown as below:

Scope of ISO 9002

- Production and Installation

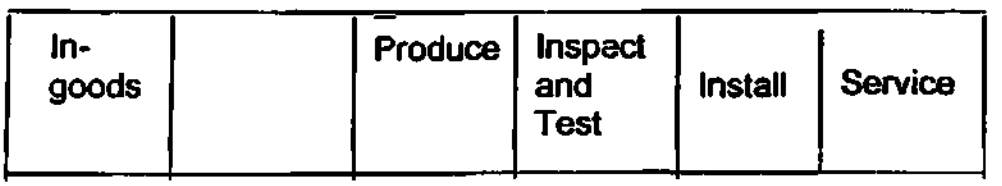

Fig 2.3

c) In a situation when the organization is required to assure quality only in the *final inspection and testing stage*, ISO 9003 is to be used. An example of such an organization is a trading house or a testing organization. A trading house buys goods, inspects and then installs or delivers to its customer. For these organizations, ISO 9003 should be used. This is graphically shown below.

Scope of ISO 9003

- Inspection and Testing

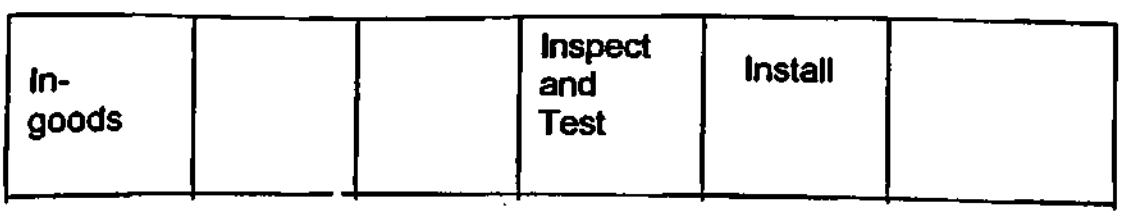

Fig 2.4

2.3 Detailed Explanation Of ISO 9001

ISO 9001 : 1994; – Quality Systems – Model for Quality Assurance in design, development, production, installation and servicing :

As explained briefly in Section 2.2 above, this standard defines a model of an organization where conformance to specified requirements is to be assured during several stages which include:

- Design and development
- Production
- Installation
- Servicing

This is therefore applicable to an organization which goes through the entire life cycle of a product. Hence, this is the standard to be used by all software development organizations.

ISO 9001 is divided into 4 sections – the major one being Section 4. This, in turn, has 20 Clauses – Clause 4.1 to Clause 4.20. These clauses embody the characteristics of a quality system, and are based on total quality management principles, especially as propounded by Deming [DEM86]. A study of these clauses also shows that these are essentially sound business and management principles which, if followed, minimize the risk of a defective product. Being shipped to a customer.

These clauses are explained below:

2.3.1 ISO 9001:1994 - Clause 4.1: Management Responsibility

This clause focuses on the important role that top management has to play in ensuring quality. The leadership has to provide a vision and quality objectives, show commitment towards quality, and conduct reviews to ensure continued suitability and effectiveness of the quality system.

2.3.2 ISO 9001:1994 – Clause 4.2: Quality System

This clause refers to the need for the quality system to be documented in the form of a quality manual. This manual should : (i) cover all the requirements of ISO 9001, (ii) make reference to procedures followed by the company, and (iii) outline the structure of the documentation used in the quality system being followed.

2.3.3 ISO 9001:1994 – Clause 4.3: Contract Review

This clause refers to the need for any contract that the organization enters into, to be reviewed to ensure that all requirements of the customer are adequately defined, and that capability exists to meet the contract requirements.

2.3.4 ISO 9001:1994 – Clause 4.4: Design Control

In this clause, ISO 9001 refers to the need for maintaining documented procedures to control and verify the design of the product. The need for project planning is highlighted along with clear identification of the design inputs and outputs.

The quality control mechanisms to be used at appropriate stages of design also needs to be defined; these may be review of results, verification or validation.

2.3.5 ISO 9001:1994 – Clause 4.5: Document and Data Control

An essential part of any quality system is the need for configuration management, i.e., the need to be able to track and control all documents, data, records, versions of the product being produced etc. The absence of this increases the risk of designing, producing and delivering a defective product to the customer. Again Clause 4.5 requires the organization to establish and maintain documented procedures to control all documents and data including those of external origin like customer drawings etc.

2.3.6 ISO 9001:1994 – Clause 4.6 : Purchasing

The absence of a process to ensure that the purchased product conforms to specified requirements constitutes a risk factor as well (of not meeting customer requirements). Hence this clause requires a purchasing procedure to be established. Specifically a system for evaluating vendors / subcontractors and for checking of purchased products has to be set in place.

2.3.7 ISO 9001:1994 –Clause 4.7: Control of Customer Supplied Product

This clause is similar to Clause 4.6 with the addition that it requires procedures for storage and maintenance of the customer supplied product as well.

2.3.8 ISO 9001:1994 – Clause 4.8: Product Identification and Traceability

This is again a configuration management concern, similar to Clause 4.5. However, this clause relates to the product, either in its finished form or intermediate form, and requires that traceability exists for all stages, from receipt, and during all stages of production, delivery and installation.

2.3.9 ISO 9001:1994 – Clause 4.9 : Process Control

Having addressed the issues of design, purchasing and partly of configuration management, the ISO standard now addresses the production, installation and servicing processes. Not only does it require documented procedures to exist for production, installation and servicing (to the extent that absence of these procedures could adversely affect quality), but also the use of appropriate

equipment and provision of a suitable working environment. This clause also require procedures for maintenance of equipment and criteria for workmanship in the form of standards, templates etc.

2.3.10 ISO 9001:1994 – Clause 4.10: Inspection and Testing

Procedures should exist for inspection and testing (called I & T hereafter) activities to ensure that the product meets specified requirements. This includes receiving I & T for products or subassemblies produced elsewhere and used in the final product, in process I & T to ensure that the product is being produced in accordance to pre- specified requirements or design considerations, and final I & T before delivering the product to the customer.

Clause 4.10 Sub Clause 4.10.5 requires I & T records to be maintained. This again is a configuration management issue and, as can be seen, the configuration management issue comes up time and again in various clauses.

2.3.11 ISO 9001:1994 – Clause 4.11: Control of Inspection, Measuring and Test Equipment

The need for controlling, calibrating and maintaining equipment used for I & T is emphasized here. This includes test software and test hardware. In instances of measurement uncertainty, the extent of uncertainty should be known as well.

2.3.12 ISO 9001:1994 – Clause 4.12: Inspection and Test Status

The I & T status of any product should be known at all times. This may be in accordance with the quality plan, or known deviations from it. This status should be maintained throughout the life cycle to ensure that only products that have passed the required I & T are delivered, used, or installed [a]

2.3.13 ISO 9001:1994 – Clause 4.13 : Control of Non conforming Product

This is again a configuration management issue which requires procedures to exist to ensure that products found defective during any stage of quality control (design reviews or I & T) are not used unintentionally. Examples of these are erroneous design specifications being used for software programming

2.3.14 ISO 9001:1994 – Clause 4.14: Corrective and Preventive Actions

Documented procedures should exist to take corrective and preventive actions when a quality related problem occurs. This action needs to be commensurate with the risks encountered, and shall include procedures for effective handling of customer complaints and product defect reports, root cause analysis to determine the source of the problem and determination of action required.

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[a] In case the required tests are not passed, the product may be delivered to the customer only under an authorized concession.

There may also be a need to change processes and increase training in which case preventive action should be initiated by doing these. Potential non conformities are also under the purview of this clause.

2.3.15 ISO 9001:1994 – Clause 4.15: Handling, Storage, Packaging, Preservation and Delivery

Procedures shall exist for all these activities since the absence of any of these activities may increase the risk of not being able to meet the needs of the customer. A key factor should be to prevent deterioration and damage to the product after production is complete.

2.3.16 ISO 9001:1994 – Clause 4.16: Control of Quality Records

Quality records are the results of all the quality control activities carried out during the design, production, installation and servicing activities. This clause requires all quality records to be maintained in an easily retrievable form.

2.3.17 ISO 9001:1994 – Clause 4.17: Internal Quality Audits

As a means of evaluating if the activities are being carried out according to the planned arrangements, either as laid down in the procedures, or in a project or quality plan or any other plan document, internal audits shall be carried out. These audits shall also determine the effectiveness of the quality system deployed.

An audit schedule shall be drawn up and shall be carried out by personnel having responsibilities independent of the area being audited. Follow up action in the form of corrective and preventive action shall be taken.

2.3.18 ISO 9001:1994 – Clause 4.18: Training

ISO 9001 takes into account the fact that training is a very important factor in ensuring that quality product is produced. It thus lays down that training shall be imparted to all personnel requiring it. Training shall be a planned activity and training records maintained. Procedures for doing the above shall be documented and followed.

2.3.19 ISO 9001:1994 – Clause 4.19: Servicing

Where servicing is a specified requirement, procedures need to exist to ensure that after sales service is provided. Means of verifying that service has met the specified requirements also shall be documented as well.

2.3.20 ISO 9001:1994 –Clause 4.20: Statistical Techniques

Dr. Deming [DEM-86], Joseph Juran [JUR-89], Dr. Ishikawa [ISH-85] and other leading exponents of total quality management have emphasized the use of measures and statistical analysis. These statistical analysis will help, first, to know the real situation, and second to aid in root cause analysis. This is the only way to ensure continuous process improvement. ISO 9001, in this clause, recognizes the need for using measures to continuously measure the process effectiveness and capability and the product characteristics.

It is this clause that underlines the use of metrics and lays the basis for organizations to build upon a bedrock of quality processes and keep on fine tuning them.

2.4 Differences Between ISO 9001, 9002 And 9003

As we have seen earlier, the difference between ISO 9001, 9002 and 9003 lie primarily in the gamut of processes covered. To recapitulate, ISO 9001 is applicable to companies involved in design, production, installation and servicing while ISO 9002 is for those companies where only production and installation activities are involved. ISO 9003 is applicable to those companies engaged in inspection and testing activities viz., trading houses.

2.4.1 ISO 9002: 1987 compared to ISO 9001: 1994

- Since ISO 9002 does not take design and product development activities into account, Clause 4.4 of ISO 9001 (Design control) is dropped in ISO 9002. All other clauses viz., Clause 4.5 to Clause 4.18, are moved up by one in ISO 9002, e.g., Clause 4.5 of ISO 9001 (Document and data control) becomes Clause 4.4 in ISO 9002.
- Since ISO 9002 does not take servicing into account, Clause 4.19 of ISO 9001 (Servicing) is dropped in ISO 9002. Hence, Clause 4.20 of ISO 9001 (Statistical techniques) becomes Clause 4.18 in ISO 9002.
- The ISO 9001 : 1994 talks about Corrective and Preventive action while ISO 9002 :1987 has only Corrective action mentioned.

2.4.2 ISO 9003 : 1987 compared to ISO 9001: 1994

Since ISO 9003 : 1987 refers to Inspection and Testing processes only, the following clauses of ISO 9001: 1984 are dropped in ISO 9003:

- ISO 9001, Clause 4.3 – Contract review
- ISO 9001, Clause 4.4 – Design Control
- ISO 9001, Clause 4.6 – Purchasing
- ISO 9001, Clause 4.7 – Control of customer supplied product
- ISO 9001, Clause 4.9 – Process Control
- ISO 9001, Clause 4.14 – Corrective and preventive action
- ISO 9001, Clause 4.17 – Internal quality audits
- ISO 9001, Clause 4.19 – Servicing

2.5 *Conclusion*

The study of the ISO 9000 series of standards show that good quality practices, as embodied in the writings and works of quality gurus like Deming [DEM-86], Juran [JUR-89], Ishikawa [ISH-85] and Crosby, have been built in the form of various clauses. Different sets of processes covering the entire life cycle of a product or parts thereof have been covered.

At the same time, supporting processes like configuration management, training, metrication etc., have also been outlined. The role of management commitment in ensuring quality has been emphasized as well.

A striking feature of the series of standards ISO 9001, 9002 and 9003 is that flexibility has been given to organizations to implement in any way appropriate to their own needs; as long as the principles enshrined in the twenty clauses are incorporated in the quality system. Flexibility has been given to ensure that organizations operating in different industries, in different environments and cultures, with different practices, with different history behind them and with varying technological strengths can all use these standards.

CHAPTER 3

CAPABILITY MATURITY MODEL

3.0 Introduction

The ability of a software development organization to develop software that consistently meet the real requirements of a customer and doing so on time and within the budget is generally recognized to be fairly low across the industry. As the software projects continue to increase in size and importance, this inability greatly increases the risk to the customer. This risk can only be reduced by the software development organization if a focused and sustained effort is made at building a process infrastructure of effective software engineering and management practices.

To build this process infrastructure, software producers need ways to appraise the capability of their processes to produce quality products. They also need guidance to improve their process capability. At the same time, customers need ways to evaluate the software producer organization so that customer risks are minimized.

To help achieve both the above, the Software Engineering Institute (SEI) at Carnegie Mellon University, Pittsburgh, USA has developed the Capability Maturity Model (CMM) that delineates the characteristics of a mature capable software process. The progression from an immature software process to a mature, well managed software process is described in terms of maturity levels in the model. Before going on to describe the CMM, however, let us briefly look at what the Software Engineering Institute (SEI) is and what does it do

The SEI is attached to the Carnegie Mellon University (CMU), Pittsburgh, Pennsylvania, USA. It is a federally funded research and development center, focusing on software engineering and technology issues. The US Department of Defense (DoD), being a major user of software and software services, funds most of the work of the SEI with the objective of promoting quality practices in the software industry, and thus, indirectly minimize the DoD's own risk as a software buyer. The SEI has a large number of publications to its credit. It regularly releases technical reports for public use

3.1 The Capability Maturity Model – ver 1.1

3.1.1 History

In November, 1986, the SEI, with assistance from the Mitre Corporation, began developing a process maturity framework. A team of dedicated software engineers like Dr. Watts Humphrey, Mark C. Paulk, Bill Curtis, Charles Weber, Suzanne Gracia etc., were actively involved in this project. (In fact, Watts Humphrey later came to be regarded as the "Father of the CMM").

In Sep. 1987, the SEI released a process maturity framework [HUMP-87] which was later also published in IEEE Software in March 1988 [HUMP-88]. A maturity questionnaire was also developed in 1987 to appraise software process maturity.

Humphrey's book "Managing the Software Process [HUMP-89] expanded upon these concepts and did much to popularize and propagate the maturity framework.

In 1991, after four years of experience with the maturity framework and feedback from the software industry, the SEI evolved the framework into the formal Capability Maturity Model for Software (CMM ver 1.0). This was embodied in two technical reports - [PAU1, WEB1].

In 1993, the Model was further refined and version 1.1 was released. This remains the latest version. Again two technical reports were released

- The Capability Maturity Model for Software ver 1.1 [PAU2]
- Key Practices of the Capability Maturity Model ver 1.1 [PAU3]

3.2 Overview Of The CMM

The CMM provides software organizations with guidance on how to gain control of their processes for developing and maintaining software and how to evolve toward a culture of software engineering and excellence. It is a framework that describes the key elements of an effective software process. The CMM describes an evolutionary improvement path from an adhoc, immature process to a mature, disciplined process.

Apart from providing guidance through describing the improvement path, the CMM also allows for assessment to judge, in a repeatable way, the level of maturity of an organization's software processes. Clear guidelines are available to perform self assessment as well as independent assessment.

The CMM can be used for:

- Software process improvement, where an organization plans, develops and implements process improvements,
- Software process assessments, in which a trained team of software professionals determines the state of an organization's current software process, determines the high priority software process related issues and obtains the organizational support,
- Software capability evaluations, in which a trained team of professionals identifies contractors who are qualified to perform the software work.

3.3 Structure of CMM ver 1.1

The CMM is composed of five **maturity levels**, numbered 1 to 5. Maturity increases from Level 1 progressively to Level 5.

Each level is composed of **Key Process Areas (KPAs)**, with the exception of Level 1.

Each KPA is organized into five sections called **Common Features**.

The common features specify the **Key Practices**.

These key practices, collectively addressed, accomplish the **goals** of the KPA.

The structure is represented in the following page in the SEI literature:

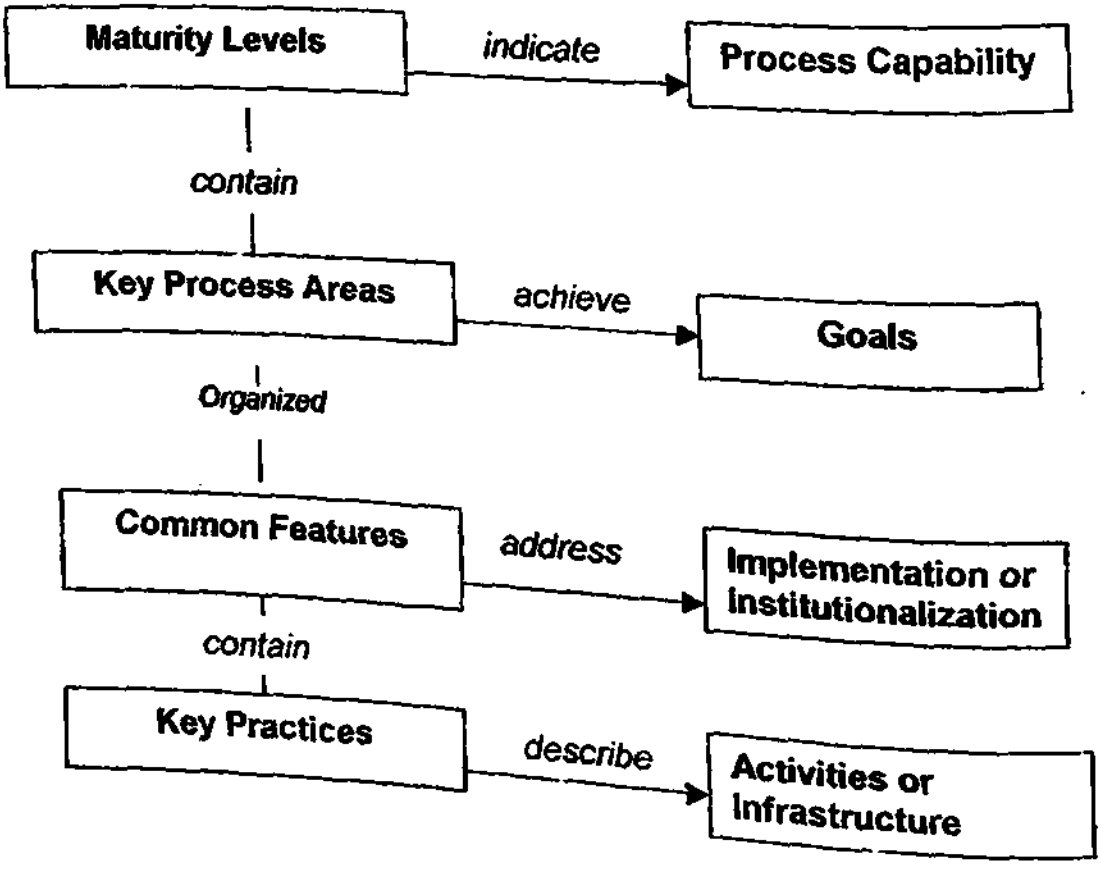


Fig 3.1

3.4 The CMM Maturity Levels

The five maturity levels are described below.

3.4.1 Level 1 - The Initial Level

At this level, the organization typically is characterized by lack of sound software engineering processes and ineffective planning. The individuals constituting the project team are a major factor in determining project success. Thus, within the organization, project success is not consistently assured.

The software process capability at this Level is unpredictable and adhoc, i.e., the software processes across various projects are not stable and consistent and are anyway constantly changed or modified as the work progresses. The organization achieves "quality by chance" rather than "quality by design". This Level has been variously termed as "chaotic" or "software development by black magic"

3.4.2 Level 2 - The Repeatable Level

At this level, a software project management system together with policies and procedures to implement those policies are in place. Project planning and control is based on experience with similar projects. Thus effective management processes are institutionalized, allowing organizations to repeat successful practices.

The process capability of organizations at Level 2 can be said to be disciplined with basic management controls in place. Planning is realistic, based on similar projects ensuring that earlier successes can be repeated.

It should be noted that only the management processes are addressed in this level. This implies the project management processes like Project Planning, Configuration Management etc. None of the processes which would have helped the project team to perform more effectively technically are yet to be put in place, e.g., training, product quality metrics etc.

3.4.3 Level 3 - The Defined Level

As organizations mature from Level 2 to this level, a standard process for the organization is developed and documented, which includes both software engineering, and project management processes and these are integrated into a coherent whole. This standard process is referred to as the organization process.

However, various management teams organization projects are free to tailor this process according to their specific project requirements and unique project characteristics. This project specific tailored process is referred to as the project's defined software process.

Since projects may have their tailored processes, does this lead to a situation akin to Level 1 where each project follows its own processes?

The difference here is that the software process is well defined which contains a coherent, integrated set of software engineering and management processes. Also, the project's defined

software process, by no means, is a departure from the organization process. Instead, it is a customized, tailored controlled and distilled version in which the organization wide process parameters are incorporated.

A company wide training program is implemented to ensure common understanding.

At Level 3 of CMM, the management has a good insight into technical progresses of all its on going projects.

3.4.4 Level 4 - The Managed Level

Software measurements are an important characteristic of this level. Since measurements are necessary for management, this Level is called the Managed Level At this level, the organization is able to set quantitative quality goals for both products and processes Productivity and quality are measured as part of an organization-wide metrics capture program. An organization wide software process database is used to collect and analyze the data available.

Based on the data available, acceptable quantitative boundaries can be set for product and process performance Projects achieve control by narrowing the variation in their performance to fall within these boundaries. The effect of "noise" in these measures are recognized and accounted for. Risks are carefully managed

Based on all these measures, predictive quantitative goals are set and variations managed The process capability of organizations Level 4 can therefore be summarized as "predictable". The products produced by this organization are of predictably high quality

3.4.5 Level 5 - The Optimizing Level

Based on the metrics now available within the organization and the continued analysis of this data and therefore, continued corrective action taken to ensure performance is within control limits, the organization is now focused on continuous process improvement Weaknesses and strengths are identified pro-actively and processes are fine tuned

Project teams in Level 5 organizations analyze their defects continuously to determine root causes and prevent these from happening.

The process capability of organizations at this level can be characterized as continuously improving.

Note that this is the only level where the present tense has been used in naming the level. An organization is forever in the "Optimizing" stage and can never be said to have optimized enough. This is in line with the continuous improvement concepts propounded by Deming [DEM-86] in the PDCA cycle.

3.5 Key Process Areas (KPAs)

The component below the maturity level in the CMM structure is the Key Process Area. Except Level 1, each maturity level is decomposed into several KPAs.

KPAs identify the issues that must be addressed to achieve a specific maturity level. Each KPA identifies a cluster of related activities that, when performed collectively, achieve a set of goals considered important for enhancing process capability. To achieve a maturity level, the KPAs for that level must be satisfied.

The KPAs at each level are listed below together with a brief statement of purpose.

3.5.1 Level 1 KPAs - None.

3.5.2 Level 2 KPAs

- *Requirements Management:*

  The purpose is to ensure that a common understanding of the customer's requirements is arrived at between the customer and the project team. Further, changes to these are managed, and forms the basis for project planning and control.

- *Software Project Planning:*

  The purpose is to ensure that reasonable plans are made for performing the software development activities, and for managing the project.

- *Software Project Tracking And Oversight:*

  The purpose is to ensure that actual progress is known and monitored against the plans so that adequate action can be taken as and when required.

- *Software Subcontract Management:*

  The purpose is to ensure that qualified software subcontractors are selected and managed. This applies in situations when the software organization subcontracts software development outside the organization.

- *Software Quality Assurance:*

  The purpose is to ensure that the management has adequate insight into the process being used by the project, and of building the products.

- *Software Configuration Management:*

  The purpose is to ensure that the integrity of all products of the project, whether intermediate or final products, are managed effectively.

3.5.3 Level 3 KPAs

The KPAs at this level are:

- *Organization Process Focus:*

  The purpose is to ensure that organizational responsibility for process activities is established.

- ***Organization Process Definition:***

  The purpose is to develop and maintain a usable set of software processes across the organization.

- *Training Program:*

  The purpose is to ensure that the skills and knowledge of individuals are developed so that they can perform their roles effectively.

- *Integrated Software Management:*

  The purpose is to ensure that the software engineering and management activities are integrated into a coherent, defined software process for the project. This is tailored from the organization's standard software process

- *SW Product Engineering:*

  The purpose is to ensure that the process defined at the project level is consistently performed. This KPA describes the technical activities of the project, e.g., all SDLC phases like requirements analysis, design etc

- *Intergroup Coordination:*

  The purpose is to establish a means for the software engineering group to actively participate with the other engineering groups so the project performs more effectively.

- *Peer Reviews:*

  The purpose is to ensure that defects from the software are removed early, and efficiently. Peer reviews here does not only mean the technique of "peer reviews" as is commonly understood but the process of all verification reviews.

3.5.4 Level 4 KPAs

The KPAs at this level are:

- *Quantitative Process Management:*

The purpose is to ensure that the process performance is controlled quantitatively. The performance is measured from the actual results achieved when a particular process was followed.

- *Software quality management:*

  The purpose is to ensure that the products are quantitatively understood and specific quality goals are achieved.

  Both the KPAs above also imply an ability to predict quantitative quality goals for both product and processes.

3.5.5 Level 5 KPAs

The KPAs at this level are:

- *Defect Prevention:*

  The purpose is to identify the causes of defects and prevent them from recurring. Software processes are changed, if need be.

- *Technology Change Management:*

  The purpose is to identify beneficial new technologies, e.g., tools, processes etc., and transfer them into the organization in an orderly manner.

- *Process Change Management:*

  The purpose is to continuously improve the software processes used in the organization with the intent of meeting the needs of the customer more effectively.

3.6 Common Features

As mentioned earlier, each KPA consists of Key Practices, which for the sake of convenience have been organized into groups called "common features". The Common Features indicate two key aspects of a KPA - institutionalization and implementation of a KPA. Together, these indicate whether a KPA is effective, repeatable and lasting.

The five common features are described below. The common feature "Activities Performed" is the only group that describe *implementation* of a KPA, while the others describe *institutionalization*. Within the latter, the first two, - Commitment to Perform and Ability to Perform (Sec 3.8 and 3.9), describe practices that must be in place *ex ante* - before the implementation can take place while the last two- Measurement and Analysis (Sec 3.11) and Verifying Implementation (Sec 3.12), are *ex post* - after the implementation has taken place.

The Commitment to Perform and Ability to Perform common features are called Enablers, since these must pre-exist for the practices given in Activities Performed to be executed, while

Measurement and Analysis and Verifying Implementation are called Evaluators, since these evaluate the extent to which the practices given in Activities Performed are carried out. The relationship between the common features can be depicted as given in Fig 3.2 below.

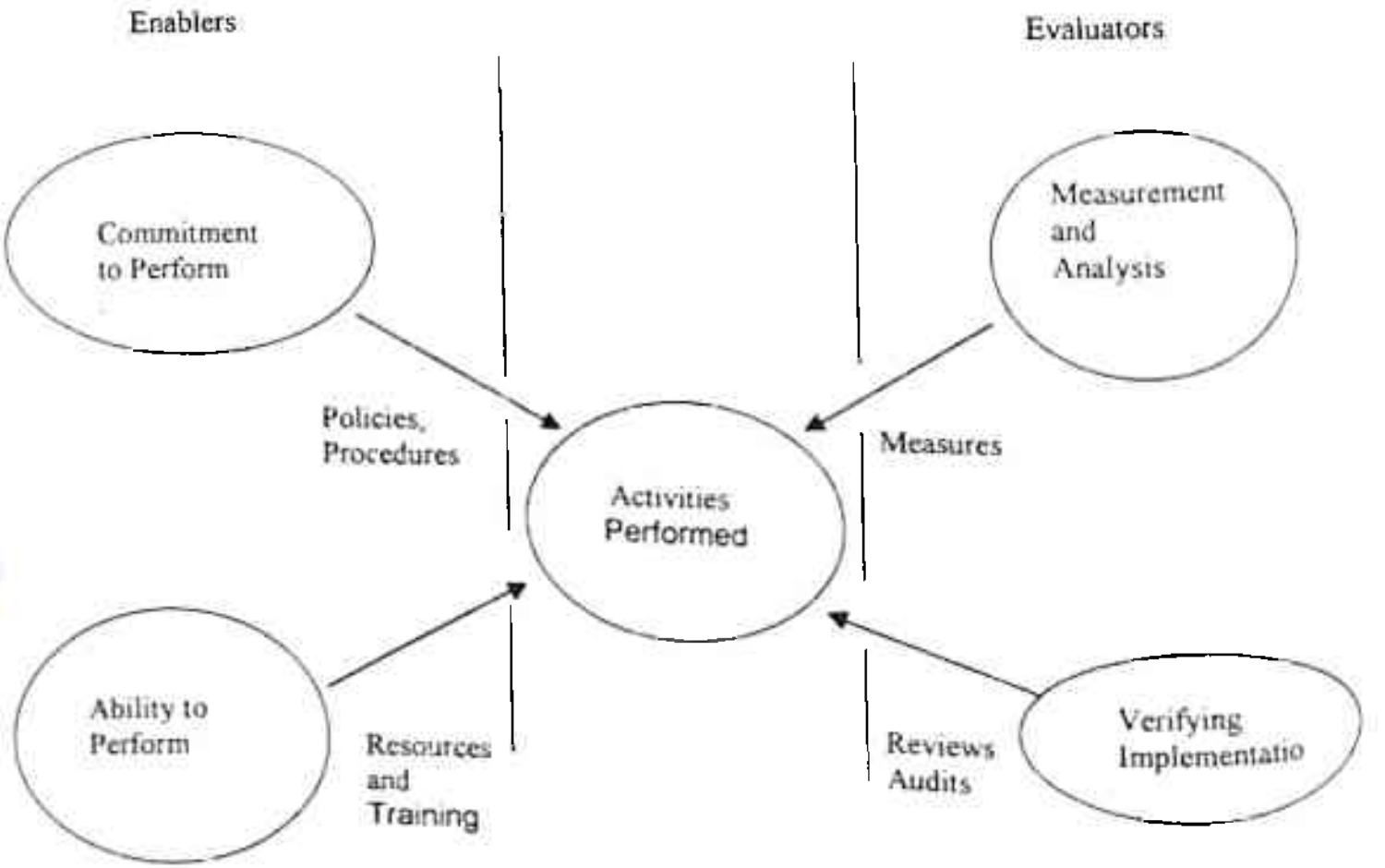


Fig 3.2

Fig. 3.2 depicts the role that the Common Features fulfill with respect to each other.

3.6.1 Commitment to Perform

This common feature describes the actions the organization must take to ensure that the process is established and will endure. This is typically done through written policies and management commitment and ownership for the KPA.

As said earlier, this common feature, together with others, addresses institutionalization of the KPA ex ante.

3.6.2 Ability to Perform

This common feature describes the pre- conditions that must exist to be able to implement the process effectively. Typically, this involves providing resources, organization and training to implement the process.

As said earlier, this common feature, together with others, addresses institutionalization of the KPA ex ante.

3.6.3 Activities Performed

All the procedures necessary to implement a KPA are described in this common feature. This generally involves establishing plans and procedures, performing the work, tracking it and taking corrective action, as necessary.

This is the only common feature which addresses implementation of the KPA.

3.6.4 Measurement and Analysis

This common feature describes the need to measure the process and analyze the measurements. This typically involves examples of the measures that can be captured during the process and analyzed to identify areas of improvement. These then determine the status and effectiveness of the practices under Activities Performed that have been implemented.

As said earlier, this common feature, together with others, addresses institutionalization of the KPA ex post.

3.6.5 Verifying Implementation

The practices in this group describe the steps required to ensure that activities are performed in compliance with the established processes. This typically involves reviews and audits.

As said earlier, this common feature, together with others, addresses institutionalization of the KPA ex post.

3.7 Key Practices

The final and major component of the CMM are the Key Practices. As the name implies, these are the activities required to be performed to ensure either institutionalization or implementation of each of the KPAs within each maturity level. Since the way the activities are carried out may

differ from organization to organization, the SEI has only defined *what* needs to be done and not *how* it has to be done. These provide the description of all common features. The Key practices provide a succinct explanation of each common feature Each common feature within a KPA may have several key practices, each of which has a specific number. For example, the Commitment common feature in Software Project Planning has – practices numbered as CO.1, CO.2 etc., while the Activities Performed in this KPA has --- key practices, numbered as AC.1, AC.2, AC.3 etc.

The Key practices are written in the CMM in bold letters These are mandatory to be followed. There are also a large number of sub key practices which are provided by way of explanation and illustration and are thus not mandatory.

The significant practices for each KPA at every level has been explained in the following section. These have been rephrased in language more pertinent to the typical software organization in India

3.7.1 Level 2 – Requirements Management

- The needs of the user (allocated requirements) are reviewed before the start of the project.
- These needs serve as the basis for software plans and the work products
- Changes to these needs are reviewed before being incorporated into the project.

3.7.2 Level 2 – Software Project Planning

- Project planning is done in the early stages of the project
- The software life cycle is identified or defined
- There is a document procedure for developing the plan and this procedure is used.
- The plan is documented and contains the following
  - Software work products
  - Estimates for size of work products
  - Estimates for project effort and cost
  - Estimates for project computer resources
  - Software development schedule
  - Risk involved in the project
- All the above are estimated according to documented procedures.

- Planning data is recorded

3.7.3 Level 2 – Software Project Tracking and Oversight

This looks at project monitoring and control throughout the project. The key practices for this are:

- The project plan mentioned earlier is used for tracking the project activities.
- This plan is revised according to documented procedure.
- All the items in the plan for eg., work product, size, effort, cost, schedule, risk etc., are tracked and appropriate action taken if necessary.
- The project team conducts periodic internal reviews.
- Formal reviews with the end user and senior management are held.
- Issues that affect other groups are tracked during the project.

3.7.4 Level 2 – Sub contract Management

Since the objective here is to ensure that the organization is able to select and manage effectively the vendors to whom it may assign certain parts of the project, the focus here is to exercise effective control and appropriate milestones over the vendors performance etc. The practices are:

- The work to be sub-contracted is defined and planned.
- There is a procedure for the selection of the vendor and this procedure is followed.
- The work is managed according to a contractual agreement.
- The software development plan made by the vendor is approved by the prime contractor.
- This plan is used for tracking the project.
- Periodic reviews are held with the sub-contractor. These may be held at the management level, technical level, quality assurance group level and the configuration management group level.
- The prime contractor conducts acceptance testing.
- The sub-contractor's performance is evaluated on a periodic basis.

3.7.5 Level 2 – Software Quality Assurance

The SQA group is involved at the project level in auditing the software products and activities. They get involved in the review of the plans to ensure that they meet the project needs and that management gets a visibility on to whether the software project is adhering to its established plans, standards and procedures. The important practices in this KPA are:

- There is a SQA plan and the SQA activities are performed in accordance with this plan
- The SQA group participates in the preparation and review of the project plan, standards and procedures.
- The SQA group reviews the project activities to ensure that activities are done according to the plan
- The SQA group audits the work products.

Please note that the term 'audit' has been used in CMM for work products while the term 'review' has been used for the project activities The idea here is that audits are done on a sampling basis while the reviews are done for all the activities

- The SQA group periodically reports the results to the project team as well as to senior management and if required also to the SQA personnel of the customer

3.7.6 Level 2 – Software Configuration Management

The practices here are :

- There is a CM plan for each project
- The software baselines are stored in a specific library
- The software work products that are to be placed under CM are known and are identified in the CM plan
- Change management is exercised during the project by means of change request, base line control etc.
- Status accounting is exercised.
- Configuration audits are done
- Products are created according to a control release procedure.

3.7.7 Level 3 – Organization Process Focus

It is in this KPA that CMM first talks about establishing an organizational responsibility for process activities and therefore, has the organization move to viewing the process from an organization wide view In this KPA, the emphasis is on performing process, development and improvement activities in a planned and organized manner The important activities are

- There are frequent process assessments
- There is a plan for process development and improvement activities
- All activities for defining an improvement process are co-ordinated at an organization level. This is done by the SEPG

- The software process data base of the organization is used.
- Training on the processes is co-ordinated at the organization level.
- New tools processes and methods are evaluated and if appropriate, transferred to other parts of the organization.
- Dissemination of information on the organization process, development and improvement is done across the organization.

Please note that it is in this KPA that CMM first talks about an organization wide process view and the use of a process data base.

3.7.8 Level 3 – Organization Process Definition

In this KPA, the activities required to develop processes to be used across the organization are discussed. The relevant practices are :

- ***The Organization Standard Software Process (OSSP) is developed and maintained according to a document procedure.***
- ***There are organization standards for documenting these processes.***
- ***Software process data base as well as a process library is maintained.***
- ***Please note that a process data base is the one where the metrics data is all*** stored.

3.7.9 Level 3 – Training Program

This is the KPA where CMM discusses the training activities in the organization. There is a training group set up which performs these activities. Specific activities are :

- Training is planned both at the project level and the organization level.
- Training is performed in accordance with the organization plan.
- Training courses are developed and maintained according to organization standards.
- Training records are maintained.

3.7.10 Level 3 – Integrated Software Management

This is a KPA that primarily looks at project planning in tracking issues but by the use of the organization's standard processes defined in OPD earlier. The activities are very similar to that in project planning and tracking except the following editions :

- Project has defined software processes which are tailored from the OSSP.
- This DSP forms the basis of the project plan and subsequent monitoring control as well.

- The process data base is used for project planning and estimating. This means that the past data is used as a basis for estimation.

- The other parts are similar to that given in project planning and project tracking at KPAs Level 2 except that in this KPA the words used are "managed" instead of "plan" and "tracked".

3.7.11 Level 3 – Software Product Engineering

This is a KPA that essentially describes the engineering function inside the project. Thus the phases of the project namely, system analysis, system design, coding and testing are described in this KPA. All these activities are done according to the projects DSP. Testing may be at various levels which include unit testing, integration testing, system testing and acceptance testing. The two important activities which we believe are the important value additions in this KPA are

- Defects data are captured and analyzed. This therefore, becomes an activity which is very metrics intensive.

- Consistency is maintained across all the software work products so that the used needs (allocate requirements), software requirements, software design, code and test plans are consistent with each other. This is best achieved by traceability metrics.

3.7.12 Level 3 – Inter-Group Co-ordination

This is a KPA that looks at how the various groups interact with each other. In a typical CMM organization, there would be various engineering groups all involved in developing various parts of the project for eg., hardware engineering group, software engineering group, site preparation etc. In most of the software organizations which are involved in developing software alone, these groups may not be pertinent, however, groups like facilities management, recruitment etc., all of whose work has a significant impact on the quality of work done by the project team. The practices focuses on the fact that the project team and the other affected groups should frequently discuss with each other and the commitments from one to the other are known and are documented. Also if inter group issues are not solvable, there should be a issues handling process.

3.7.13 Level 3 – Peer Reviews

It is only in this KPA that CMM has started to discuss the need and conduct of reviews as an effective quality control technique so that defects can be identified and removed early in the life cycle. Although the CMM has talked about peer reviews, it is not essential that the organization restricts itself to peer reviews alone. This has been made clear by subsequent articles by Mark Paulk and others who have defended the use of peer reviews and pointed out that reviews done by peers tend to be much more effective than those done by other people. This is especially true if the organization culture is such that there is a lack of free exchange of ideas and defects identification unless the producers' peers are the only one present. However, many organizations may find that the only ones competent to conduct the reviews are the producers' seniors. In such a scenario, it would be okay for the reviews to be conducted by persons who are not peers. Therefore, we suggest that this KPA be viewed not as much as a "peer review" but a pure and

simple "reviews" KPA. Reviews may be held by any technique for eg., Fagan Inspection, Structure Walkthru etc., as long as the following formality is adhered to :

- Reviews are always planned.
- The findings are logged.
- Findings are closed.

3.7.14 Level 4 – Quantitative Process Management (QPM)

In this KPA, the emphasis is on controlling the organization's previous projects and activities. The past performance of the projects in the organization are captured through metrics data and stored in the process data base as mentioned in Level 3. Based on that, an understanding of the process capability is obtained. Process capability describes the range, expected outcomes from following a software process for eg., the most likely outcomes that are expected from the next software project the organization undertakes. These are documented as we shall see later in Chapter 7 in Capability Baseline Reports. These process capability data are in turn used in the software project to set their performance goals and hence to monitor their performance against these goals. Chapter 7 – Metrics describes the Capability Baseline and other issues in more detail. The activities in this are :

- The software project plan defines how the quantitative process management can be done. In this plan, the projects' goals are also defined in quantitative terms. Goals shall relate to the software products, quality, project productivity and other performance like effort variance, schedule variance etc.
- These QPM activities are performed in accordance with the QPM plan.
- The project DSP also defines the strategy for the data collection and the analysis that would be done on the data.
- If the project goes out of quantitative control, it is brought under control according to documented procedure.
- QPM reports documenting the results of QPM activities are prepared and distributed. The process capability baseline for the OSSP are established.

3.7.15 Level 4 – Software Quality Management

In this KPA, quantitative goals for the software products are defined and plans to achieve these goals are documented. Practices in this KPA are built on the practices of the ISM of the integrated software management and software engineering at Level 3 and the QPM – QPA at Level 4. The activities are :

- The project has a software quality plan which has the basis for SQM activities in the project.

- Goals for the product are defined quantitatively. These goals may be linked to defect density, meantime between failures, defect age. Please see Chapter 7 of this thesis for more details.

- Actual data emanating from quality control activities like testing and review are captured and analyzed to ensure that the products' goals are met

- In case the project is done by a sub-contractor., there are appropriate quality goals for that as well

3.7.16 Level 5 – Defect Prevention

In this KPA, defects are analyzed to identify the root causes so that preventive defects are not repeated in the future Trend analysis is a useful method of identifying root causes These provide insights into how the projects DSP behaves and can be improved to prevent defects from recurring. The important activities are

- The software projects develop and maintain a defect prevention plan. At the beginning of a task the project team needs to prepare for the activities of the task and examine any related defect prevention activities.

- Meetings are held to identify the root causes. Findings of this defect prevention activities are shared between teams and if need be the OSSP and the DSP are revised.

3.7.17 Level 5 – Technology Change Management

In this KPA, a specific group is established which works with the software projects to introduce new technologies and manage changes to existing technologies The organization pro activity makes itself aware of new technologies and selects appropriate technologies to improve the quality of its software and the productivity of its projects These technologies are introduced first on a pilot basis and if the results are satisfactory, these are transferred across the organization. The important activities are

- There is a technology change management plan at the organization level

- The technology group pro actively and systematically analyzes the OSSP to identify the areas that could benefit from the new technology

- Technologies are evaluated and acquired according to documented procedure

- Technologies introduced on a pilot scale

- If pilot efforts are satisfactory then these technologies are incorporated into the OSSP and the DSP

3.7.18 Level 5 – Process Change Management

This final KPA involves defining process improvement goals and proactively and systematically introduce changes to the OSSP on a continuous basis. When these changes are introduced,

appropriate training is imparted as in the TCM-KPA in section 3.7.17 above. These are introduced on a pilot scale and then introduced throughout the organization. The important activities are :

- Process improvement activities are co-ordinated by the process group in the organization. This may be the SEPG as defined at Level 3 - OPF – KPA.
- Process improvement activities are based on an organization wide plan.
- There is a procedure for handling process improvement proposals.
- Specific process improvement teams may be set up across the organization for specified process areas.
- These process improvements are installed on a pilot basis first. If results are satisfactory then changes are made to both the OSSP and the DSP.

Summary

In the preceding sections, we have attempted to provide a detailed exposition of the practices of all the requirements that a software organization needs to fulfil at each level. Having understood these requirements from the CMM view and also having understood the requirements from the ISO standpoint, we shall now study in the following chapters the implementation approach for an organization to move from Level 1 to Level4.

PART II

A METHODOLOGY TO ACHIEVE THE MANAGED AND OPTIMIZING LEVELS IN CMM

Chapter 4 : TRADITIONAL APPROACH TO CMM LEVEL 4

Chapter 5 : MODEL OF THE INTEGRATED APPROACH, USING ISO 9001

Chapter 6 : IMPLEMENTATION METHODOLOGY

Chapter 7 : METRICS IN A MATURE CMM ORGANIZATION

- NEED FOR METRICS
- HISTORY OF METRICS
- CMM REQUIREMENTS
- A SET OF RECOMMENDED METRICS
  - CORE
  - TERTIARY

CHAPTER 4

TRADITIONAL APPROACH TO CMM LEVEL 4

4.0

In this chapter, the traditional approach to implementing CMM Level 4 and Level 5 in an organization is discussed. By the "traditional" approach, we do not mean that the CMM has specifically laid down this approach; in fact, the CMM (like the ISO 9001) is a collection of process requirements and does not advocate any implementation approach at all. Yet, and this is another difference between CMM and ISO, the way that the CMM is structured points to an underlying implementation approach. This approach is predicated on the concept of increasing levels of maturity that an organization attains and, thus, takes "one step at a time".

This approach has inherent limitations which stand in the way of speedy and smooth implementation, as we shall see below. These limitations have been described in the following sections. Section 4.1 provides an overview of the traditional CMM approach. Section 4.2 describes the roadblocks which organizations face when implementing CMM by the traditional route.

4.1 Overview Of Traditional CMM Approach

The Capability Maturity Model provides a progressive implementation path for an organization at the Initial Level and moving to higher levels of maturity. This calls for an organization to move in specific gradations from Level 1 to Level 2, then Level 3, Level 4 and Level 5.

This is depicted as follows :

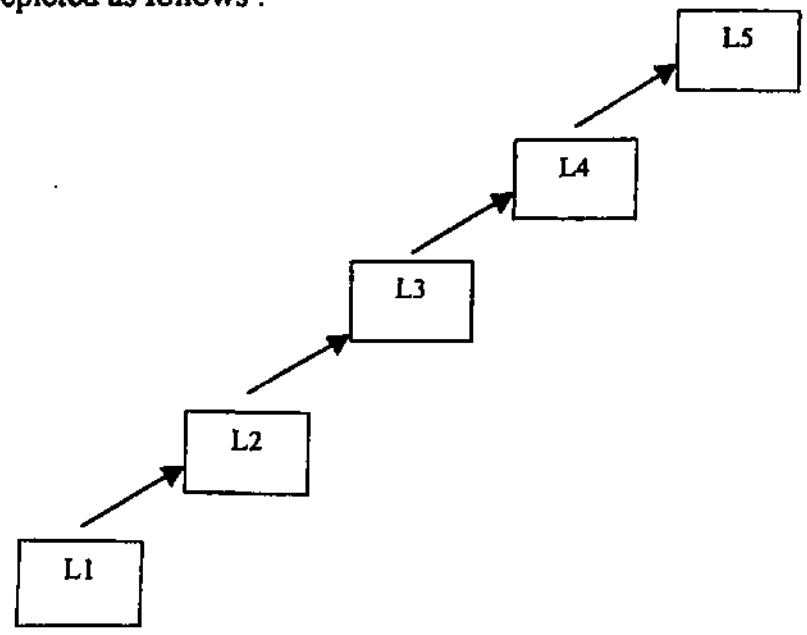


Fig 4.1

4.1.1 Moving from Level 1 to Level 2

As we saw earlier in Chapter III, organizations at the Initial Level – Level 1 do not have any processes in place. To move to the Repeatable Level – Level 2, certain management processes at the project level need to be put in place. The project management processes were taken up first and described at Level 2 in the CMM because of the realization that, before tackling any other processes, it is essential that fundamental project management processes be put in place so that at least an element of control starts to be exercised. This is all the more relevant, considering the type of organization and the nature of projects typically executed by such organizations that the SEI had in mind while developing the CMM. (See Annexure 1 for a discussion on the CMM view of an organization).

These are reflected in the Key Process Areas at Level 2. To reiterate, the Key Process Areas are:

- Requirements Management
- Software Project Planning
- Software Project tracking and oversight
- Configuration Management
- Software Subcontract Management
- Software Quality Assurance

Each of these KPAs require certain key practices to be in place. These have been discussed in Chapter III.

However, the salient implementation points are:

- User needs (called "allocated requirements" in CMM) and changes thereto, are known, documented and used as the basis of all work in the project. Thus, a system of documenting requirements and managing changes to these needs to be set up.
- Projects are planned and all subsequent activities on the project are monitored on the basis of these project plans. Thus, a system of project planning and monitoring and control should be in place.
- Appropriate Configuration management and quality assurance practices are followed in the project. These practices should be set up.
- In case work is subcontracted to an external organization, adequate controls are imposed on the progress of the work done by the sub contractor.

As we can see, the emphasis is on management practices at the project level. Various projects may have differing practices as long as the requirements of the KPAs are met.

4.1.2 Moving from Level 2 to Level 3

Subsequently, after a period of stabilization at Level 2, the organization could start to move towards defining processes at the organization level so that there is a conscious move towards standardizing the processes across all projects. A group like the Software Engineering Process Group (SEPG) is set up to co-ordinate process development across the organization. Although there is a standardization of processes, projects may choose to follow their own processes (called Defined SW process) by following tailoring guidelines. The KPAs at this level are:

- Organization Process Focus
- Organization Process Definition
- Training Program
- Integrated Software Management
- Software Product Engineering
- Intergroup Coordination
- Peer Reviews

Each of these KPAs require certain key practices to be in place. These have been discussed in Chapter III. However, the salient implementation points are:

- Set up a SEPG
- Define organization wide processes (called Organization Standard Software Process – OSSP)
- Establish a process data base
- Develop tailoring guidelines
- Projects use tailoring guidelines to define their own processes (called Defined Software Process – DSP)
- Provide training
- Define the engineering life cycle (Software Development Life Cycle)
- Set up the system of conducting reviews
- Ensure that inter group coordination issues are adequately handled in the projects.

4.1.3 Moving from Level 3 to Level 4

Once processes and metrics have been defined and started being used as explained in the earlier sections, the organization is now in possession of a large amount of quantitative data. This data is

now analyzed and capability baselines set up. These baselines are used to predict and monitor process performance and product quality. Control limits and target values are set up and the project uses this for monitoring its performance vis a vis these limits.

The KPAs at this level are:

- Quantitative Process Management
- Software Quality Management

Chapter 5 describes the implementation steps at this level.

4.1.4 Moving from Level 4 to Level 5

Once an organization has established process measurements and quality plans, it can use these capabilities to make process improvements. The experiences gained from projects is used to make process improvements to the processes. The extensive data on the software process is used to evaluate process effectiveness and make regular adjustments. This provides a foundation for continuing process improvement and orderly and planned productivity improvement. The KPAs at this level are:

- Defect Prevention
- Technology Change Management
- Process Change Management

Chapter 5 provides implementation guidelines to implement this level.

4.2 Limitations in implementing Level 2 by traditional approach

An organisation attempting to move from an Initial Level (Level1) to Repeatable Level (Level 2) will face several roadblocks. In getting around the roadblocks, the organisation may set up certain temporary functions which may be redundant when the organisation moves in to Defined Level Level 3. Removing these functions or making alternate use of these may not be easy at that time.

These roadblocks or implementation bottlenecks are

4.2.1 Organizational policies

CMM has, in all KPAs, required the documenting of organizational policies which by and large address the activities needed to be performed for the KPA. These policies are different from the "Quality policy" in the ISO world which are brief succinct statements expressing the top management's vision and intent. "Policies" in the CMM world are almost mini-processes in that they describe the activities that need to be performed for each KPA. Hence, there would be a policies manual in the organisation which, as we said above, would be like a summarized Processes Manual for the organisation.

The roadblock that would be faced is – ***who writes these policies at the organization level?***

There are two options.

Option 1 :

Since this is a Commitment Feature Key practice, leadership of the organization may write all these policies. Having the leadership (senior management) write this, especially in a small medium software organization would impose an unacceptable burden on the time of the CEO or other senior management.

Option 2 :

The other way to do this would probably be a central group co-ordinating the development of this policies manual.

Note that, at this point of time, neither does this central group exist nor has the CMM provided any insights into the setting up of this group at Level 2. This central group then starts acquiring the contours of the SEPG, a requirement that CMM has discussed only at the Defined Level Level 3. Note that, at this point of time, this central group does not exist.

4.2.2 Documented Procedures

The CMM has defined certain Key Practices in the Activities Performed, common feature which are to be done 'according to a documented procedure' (The SEI CMM Lead Assessors guide calls this '*a doc proc*'). There are 24 such documented procedures required. These are :

<u>SW Project Planning</u> :

1. AC 4 – External Project Commitments are reviewed with senior management *a doc proc*
2. AC 5 – Project plan is developed *a doc proc*
3. AC 9 – Estimates of size are derived *a doc proc*
4. AC 10 – Estimates of effort and cost are derived *a doc proc*
5. AC 11 – Estimates of critical dependencies are derived *a doc proc*
6. AC 12 – Estimates of Software schedule are derived *a doc proc*

<u>SW Project Tracking and Oversight</u>

7. AC 2 – Plan is revised *a doc proc*
8. AC 3 – Commitments external to organisation are reviewed with senior management *a doc proc*
9. AC 13 – Milestone reviews are conducted *a doc proc*

SW Subcontract Management

10. AC 1 – Work to be subcontracted, defined and planned *a doc proc*

11. AC 2 – Subcontractor selected *a doc proc*

12. AC 6 – Changes to work are resolved *a doc proc*

13. AC 9 – Milestone reviews are conducted *a doc proc*

14. AC 10 – Prime contractor's SQA monitors QA activities *a doc proc*

15. AC 11 – Prime contractor's CM group monitors CM activities *a doc proc*

16. AC 12 – Acceptance testing is conducted *a doc proc*

SQA

17. AC 1 – SQA plan is prepared for the project *a doc proc*

18. AC 7 – Deviations in SW activities and Work products are documented and handled *a doc proc*

SCM

19 AC 1 – CM plan is prepared for each project *a doc proc*

20. AC 5 – Change requests are tracked *a doc proc*

21. AC 6 – Changes to baselines are controlled *a doc proc*

22. AC 7 – Products from baseline library are created and release controlled *a doc proc*

23. AC 8 – Status is recorded *a doc proc*

24. AC 9 – Baseline audits are conducted *a doc proc*

The roadblock – ***Who writes these procedures?***

Since these are not 'Commitment to Perform' key practices, obviously the leadership would not be involved in writing these. The choice then is between a central group writing these procedures or the project team (probably, the SQA group of the project) doing so

In companies executing large software projects with consequently large project teams (at least 50 or more), it may make sense for the procedures to be written up by the SQA team (actually, it is only in such large teams that the SQA team may be full time, anyway). In smaller projects, however, the central group should be entrusted with the work of defining the procedures. The comment made by me earlier applies in this case too, viz., at Level 2, the GMM has not discussed the need for setting up this central group (like a SEPG at Level 3.)

4.2.3 Training

The CMM has focussed on the need to provide training in all the KPAs – the key practices in the Common Feature – "Ability to Perform" reflect this. This has rightly been done since an effective development of processes requires all concerned people to have received the required training. In fact, CMM has used two terms – 'training' and 'orientation'. Training is a full fledged, in depth learning imparted to the concerned individuals, while orientation implies only a top level, overview being imparted – generally on the concepts, need and salient features of the process.

In many instances, CMM has required that the persons doing the work receive training while persons affected by the work (those not actually doing the particular process, but using the results of the process) receive orientation on the process. An example of this is found in the Software Quality Assurance KPA where Ability 3 requires the members of the SQA group to be trained on the SQA activities while the project team members receive orientation on the role, responsibilities, authority and value of the SQA group so that they can better utilize the services of this group.

The roadblock in this is - ***"Who provides, or at least, co-ordinates the training?"***

Please note that the training function has been described only at the Defined Level 3. Unless the organization has this function in place, the training needs can only be fulfilled either by the central group that wrote the processes, as described earlier, or the project takes on the responsibility of ensuring that this is done either by the SQA group or other project members. As we saw earlier, unless the project is a very large one, project teams will not be able to spare resources to provide this training. The project team needs to depend on a central training function to ensure that this is done – an aspect that CMM has only focussed on at Level 3.

4.2.4 Ownership of Project level processes

We now come to another aspect of implementation which becomes a roadblock not for implementing Level 2 but when moving from Level 2 to Level 3.

This happens because of what we can call " the emotional ownership of processes". Since processes may differ between projects in a Level 2 organization [CMM1, Page 18, Section 2.1.2) and these processes would have been developed within the projects, either by the help of the SQA group or without, project managers and project teams would develop strong emotional bonds to the processes they follow. This emotional ownership of the processes is obviously very good at Level 2 since these lead to effective process deployment and usage. The roadblock comes when moving from Level 2 to Level 3.

At Level 3, when there is an attempt to develop Organization Standard Software Processes (OSSPs), the emotional ownership, of the project teams, of their respective processes prevents them from being open to adapting a process which are different from theirs. While developing an OSSP, the SEPG would obviously survey the existing processes in areas like project planning and project tracking and recommend a " best practice", a process which would apply to the

whole organization by taking the elements which have been found to be best suited to the needs of the organization. However, at the time, the project teams, having become accustomed to the processes in their individual projects and because of the emotional ownership factor, are extremely, and naturally, reluctant to change. This resistance becomes a roadblock in the way of developing and using OSSP's in the organization.

In the few instances where the roadblock was overcome quickly, We noticed that this was done by allowing each and every project to tailor the OSSPs so much that the project's Defined Software Processes (reference OPD KPA and ISM KPA) bore little resemblance to each other, even in areas like project planning and project tracking, as embodied in the Integrated SW Management KPA.

Thus, this roadblock has significant impact when an organization moves forward from Level 2 to Level 3 implementation.

4.2.5 Deployment of the SQA Function

This factor is not as much of a roadblock as an issue on which there is a fair amount of confusion on how best to implement it.

As we saw earlier in Chapter 1, it is generally recognized that the Quality Assurance function is one that focuses on the processes deployed in an organization, thus preventing defects from being injected into the product. The CMM in defining the activities performed in the SQA KPA has discussed the need for process review by this group to ensure compliance as well as the need for conducting product audits. It is the latter issue that has been confusing for many companies, i.e., if the Quality Assurance group gets involved in work product audits, is it not then getting involved in technical reviews, and thus Quality Control ? If it is doing so, then presumably the SQA group should have the technical expertise to conduct such product QC activities. Insights into these aspects are not given in the CMM.

In the absence of these insights, we find that software organizations implement the SQA function in a variety of ways, some of which are described later in Chapter 6 of this thesis.

CHAPTER 5

MODEL OF THE INTEGRATED APPROACH, USING ISO 9001

5.0 Introduction

The difficulties faced by several companies in achieving high levels of maturity in CMM (Level 4 and above) by following the traditional approach outlined in Chapter 4 led us to examine if an alternate approach was possible which would circumvent and thereby avoid the roadblocks we discussed earlier. This led to the development of what we call the Integrated approach to implementing CMM.

A model of the Integrated Approach is given in Section 5.1. The steps involved in transitioning from a Level 1 organization to ISO 9001 are given in Section 5.2 while the steps recommended for an ISO 9001 organization to move to CMM Level 4 are explained in detail in Section 5.3. Section 5.4 lays down the steps required to move from Level 4 to Level 5.

5.1 Need for the Integrated Approach

An analysis of the organizations that have been assessed for various CMM levels in India and around the world was the subject of a presentation made to SPIN, Chennai in Oct 1999 [SPIN-99] by the author and is relevant for describing the need for an integrated approach.

According to the list of CMM assessed companies published by the SEI in Oct 1999 [SEI1], the distribution of Indian companies and US based companies at various levels is as follows:

	Level 5	Level 4	Level 3	Level 2
US cos.	7	8	36	16
Indian cos	6	12	4	0
Others	1	0	2	2
Total	14	20	42	18

This shows that there is an interesting phenomenon happening in India now viz. there is a preponderance of Indian companies at higher maturity levels than at lower levels. For example, of all the companies at Level 4 and 5, more than half the companies in the world are from India. Further, more than 80 % of Indian companies that have gone in for CMM assessments are at Level 4 or Level 5 while in the US, only 20% of the CMM assessed companies are at Level 4 or higher. See Figs 5.1 and 5.2.

Indian Cos. - % distribution across levels

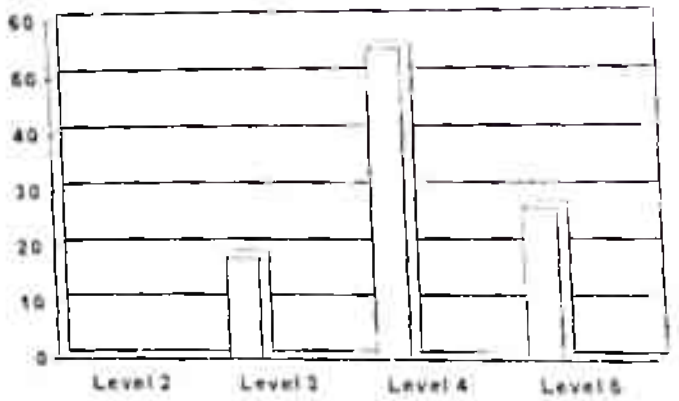


Fig. 5.1

US + Other Cos. - % distribution across levels

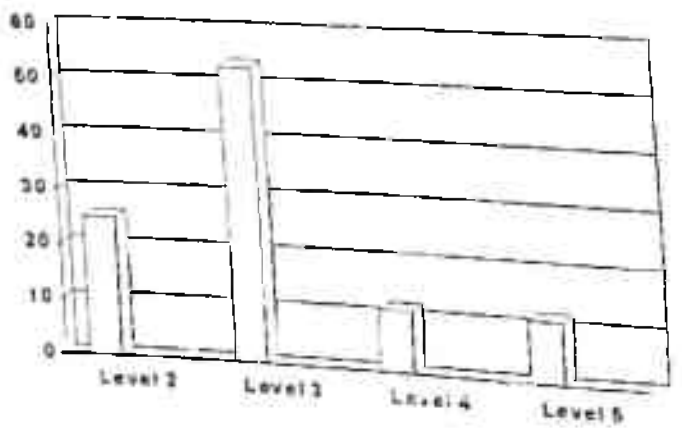


Fig. 5.2

5.1.1 Posing A Question

Seeing the above data, the question that comes to mind is "***Why is this so? Are we witnessing this distribution only because most Indian companies do not consider it worthwhile to go in for CMM Level 2 and 3 and instead shoot for CMM Level 4 and 5 directly or are there indeed other reasons which might be worthwhile to investigate?***"

We believe there are five factors which could provide answers to this question:

1. Demand Pull Factors: This can be classified into -

- Competitive marketing factors : Since Indian software organizations operate in a highly competitive environment, a quality certificate provides a vital edge – thus marketing pressures are very strong
- Genuine management realization re process based quality: Management commitment in most Indian cos. is extremely high. This may be because most Indian SW export work is based on outsourcing – thus
  - emphasis needs to be on documentation
  - emphasis needs to be on processes

As Mark Paulk put it in his paper (PAU4) "Quality is crucial for repeat business" in India; I believe that this statement alone sums up the demand pull factors.

2. Supply Push Factors: There are also a number of factors that one should consider which we have called the supply side factors -- these serve as push factors for the quality initiative. These are:

- Education : The average SW person in India is highly educated with most being Engineers or post graduates in Science. Therefore, these people understand the need for a systematic way of doing things to achieve sustainable quality (PAULK99).
- Cultural factors: Although the average Indian tends to be highly individualistic in his social behavior (The constant jumping of a queue by most of us is probably due to this individualistic streak – the urge to do something different especially when the costs of doing so are not high makes us almost instinctively look for ways to "get around" the laid down rules), this behavioral trait is the opposite at our work place. At the work place, *we tend not to rock the boat and the attitude becomes "Let us do it if it is no big deal"*. This leads to the average Indian SW professional becoming a conformist at work which then leads to increased compliance to laid down processes.

3. Assessment Factors: This is one factor which should be a matter of concern for the Indian SW industry. Since the CMM assessment is an internal assessment process, the assessment team

members may either choose to interpret the CMM in a manner different from other organizations or not be completely honest with themselves when determining the weak areas in process implementation in the company Mark Paulk did a study of the CMM implementation situation in India and commented that "It is likely that some organizations in both India and the US have taken an overly liberal interpretation of levels 4 and 5 in the SW CMM" (PAULK99). Unless something is done about this, there is a real danger that Indian SW companies may start to lose credibility on the CMM assessment front

4. Choice Of Route: I believe, however, that the most important factor is that the approach that they have taken is *"first implement ISO, then CMM"*. This is borne out by the following statistics from the NASSCOM list of quality certified companies – Oct 1999

- Total no. of ISO companies: 109
- No. of CMM companies: 24
- No. of companies who did ISO first, then CMM : 20

[NASSCOM1])

Thus, according to NASSCOM's figures, 83% of the companies who have been CMM assessed obtained ISO 9001 first, then went on to attain CMM Level 4 and 5. From personal knowledge, I know of at least 15 other software companies which were not in the NASSCOM list but have actually obtained CMM All these companies obtained ISO 9001 first. This is depicted in Fig 5.3

5.1.2 Answer To The Question:

The answer to the question that we posed ourselves could now be stated as follows

- **While it is true that organizations in India set their sights on achieving Level 4 or Level 5 because of marketing reasons, it is also true that there are several other reasons which make it possible for them to realize their objectives. A very important reason amongst these is the route chosen by these organizations to move along the quality path which was – First ISO, then CMM.**

Route taken by CMM cos. in India

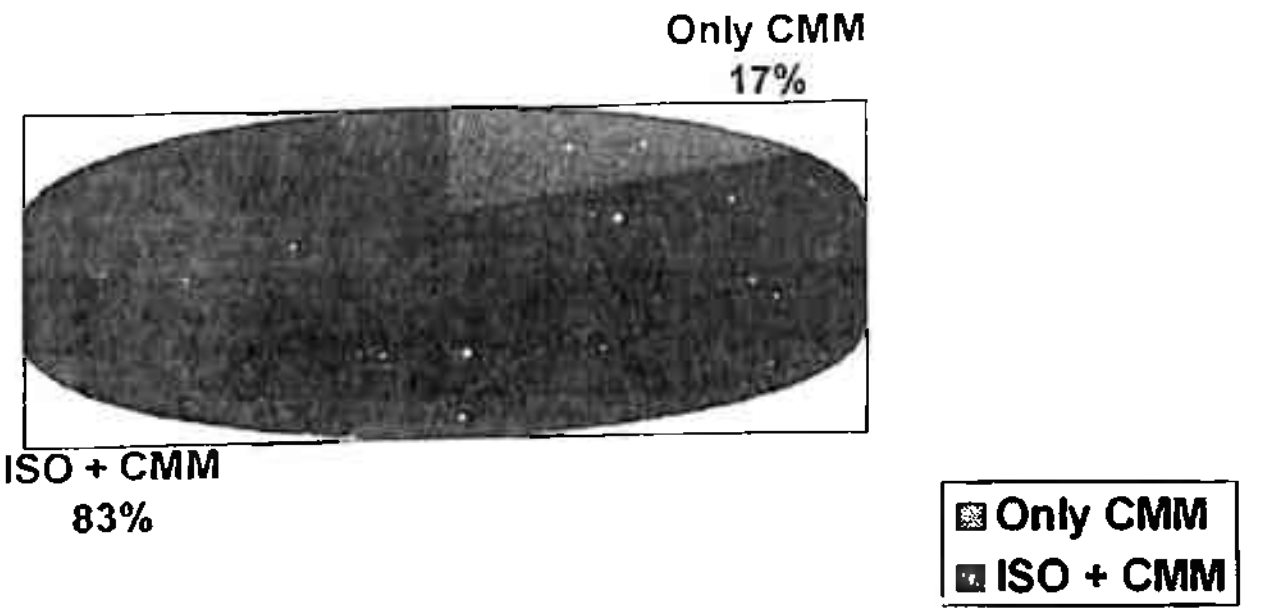


Fig 5.3

5.2 : Modeling the Integrated Approach to achieving CMM Level 4 and Level 5

This approach assumes that an organization is at the Initial Level (Level 1) and plots a path for it to go on to Level 4 and Level 5 in a timely and cost effective manner. Since an organization at Level 1 is characterized by a complete absence of processes, the immediate challenge is to define and deploy processes organization wide. Rather than look at the CMM route of Level 2 and then Level 3, ***it is postulated that it is best to implement ISO 9001 first and then move on to implementing CMM Level 4 and Level 5 requirements.***

The stimulus for choosing this approach came from work done on comparison of the ISO 9001 and the CMM. Notable among these was a paper published by Mark Paulk [PAU5] which compared the CMM and the ISO 9001. Paulk concluded that:

1. "An ISO organization would satisfy most of the Level 2 and many of the Level 3 goals"
2. "Since not all CMM requirements at Level 2 are met by ISO 9001, an organization at Level 1 could also get ISO 9001"
3. "Even a Level 3 organization would need to ensure that it adequately addressed ... clause 4.15 of ISO 9001. With this caveat, obtaining certification should be relatively straightforward for a Level 2 or higher organization"
4. **"There is a sufficient degree of overlap between the two models and an organization may consider doing both"**

Caveat: Although the conclusions drawn by Paulk are significant, particularly the conclusion No. 4 which we have used greatly in our thesis, we believe that the conclusion No 2 was probably not wisely worded and may be viewed to be unnecessarily facetious, especially when his conclusion No. 3 could also be reworded by an ISO champion to reflect similar thoughts. For example, one could always say – "Even a CMM Level 3 organization would not meet the requirements of ISO 9001". The point is that these are two different models and there would necessarily be changes required when one moves from one model to the other.

I have had personal discussions with many practitioners who have picked on these words out of context to play up the merits of CMM over ISO. However, Paulk later on in the article does admit that his may be a biased view.

Based on the conclusion No 4, we also started to examine the possibility of an integrated approach combining both ISO and CMM. This stemmed from the fact that organizations generally reported long lead times in attaining CMM Level 2 maturity (See Section 5.3.1 below) while the data from ISO 900; organizations appeared to suggest that time frames are much less when implementing ISO 9001.

As explained earlier, the traditional approach given in the CMM is to move progressively from Level 1 to Level 2, then Level 3, Level 4 and Level 5. This is depicted in Fig. 5.4.

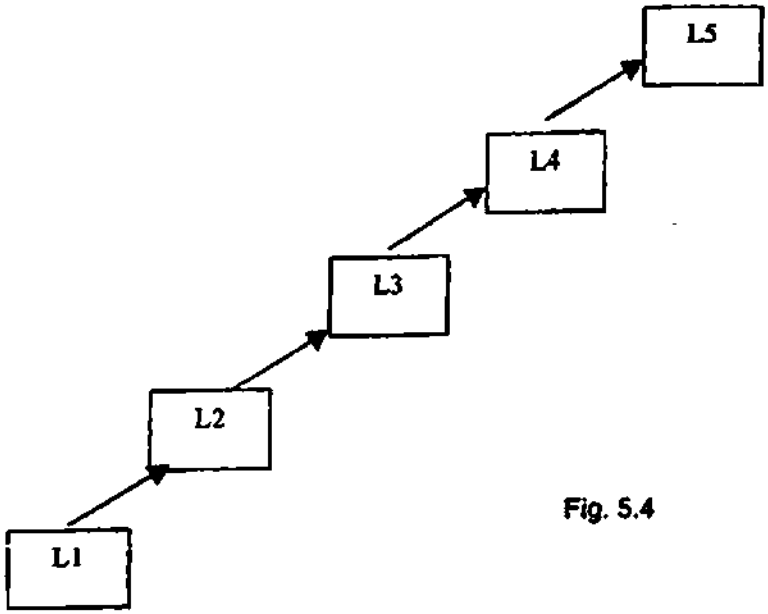


Fig. 5.4

As we have discussed in Chapter 4, software companies are faced with certain roadblocks when using this approach to CMM implementation. This is especially true for companies that do not fit the typical organizational profile that CMM assumes. (Please see Annexure I).

The alternate Integrated approach that we recommend has been proven to be an effective approach in the sense that it takes much less time and costs for an organization to move up the maturity curve than by the traditional route. This is achieved without sacrificing the quality of processes used and therefore is an approach that many organizations in India are beginning to follow. We call this the Integrated approach, since it makes use of the ISO 9001 standard while moving to CMM Level 4 and then Level 5.

The Integrated approach may be modeled as under :

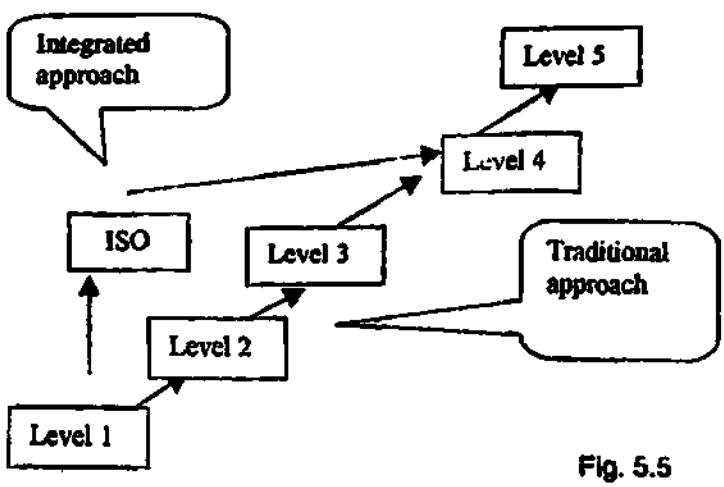


Fig. 5.5

In this approach, organizations first implement processes by choosing the ISO 9001 framework Having implemented ISO 9001, the organization then moves on to the CMM framework and is able to plug the gaps that were required in Level 2 and Level 3 fairly quickly. Once the processes are in place, it is only a matter of time when the organization has enough richness of data to acquire Managed Level Maturity (Level 4). Having acquired Level 4 maturity, the organization follows the SEI recommended path to CMM Level 5.

The broad level tasks in the Integrated approach which an organization at the Initial Level would need to do are:

a) Implement ISO 9001 : As we have discussed elsewhere in this thesis, our experience tells us that organizations should not take more than 12-15 months time to get ISO 9001 certification. A detailed implementation strategy for ISO 9001 is given in Chapter 6, Section 6.2

b) Perform Gap Analysis for CMM Level 4 requirements: This is done to identify both process and metrics gaps. Thus the two gap analysis is done in parallel. Details of this gap analysis is given in Chapter 6, Sec 6.3.

c) Plug gaps: Again, both process gaps and metrics gaps need to be bridged. This is done by revising the documented processes and identifying metrics to be implemented across the organization. Details are given in Chapter 6, Sec 6.4

d) Deploy processes and stabilize: The processes and metrics are now deployed after adequate training to all concerned. After some period, the process usage and metrics implementation are stabilized throughout the organization. If the gaps identified vis a vis Level 4 have been properly filled and implementation is consistent with these requirements, the organization should be at CMM Level 4 by now. Details are given in Chapter 6, Section 6.5

e) Improve processes continuously: Now that metrics and processes are in use throughout the organization, there is a proactive drive towards continuous process improvement. This leads to Level 5 capability

These tasks are depicted in Fig 5.6 below.

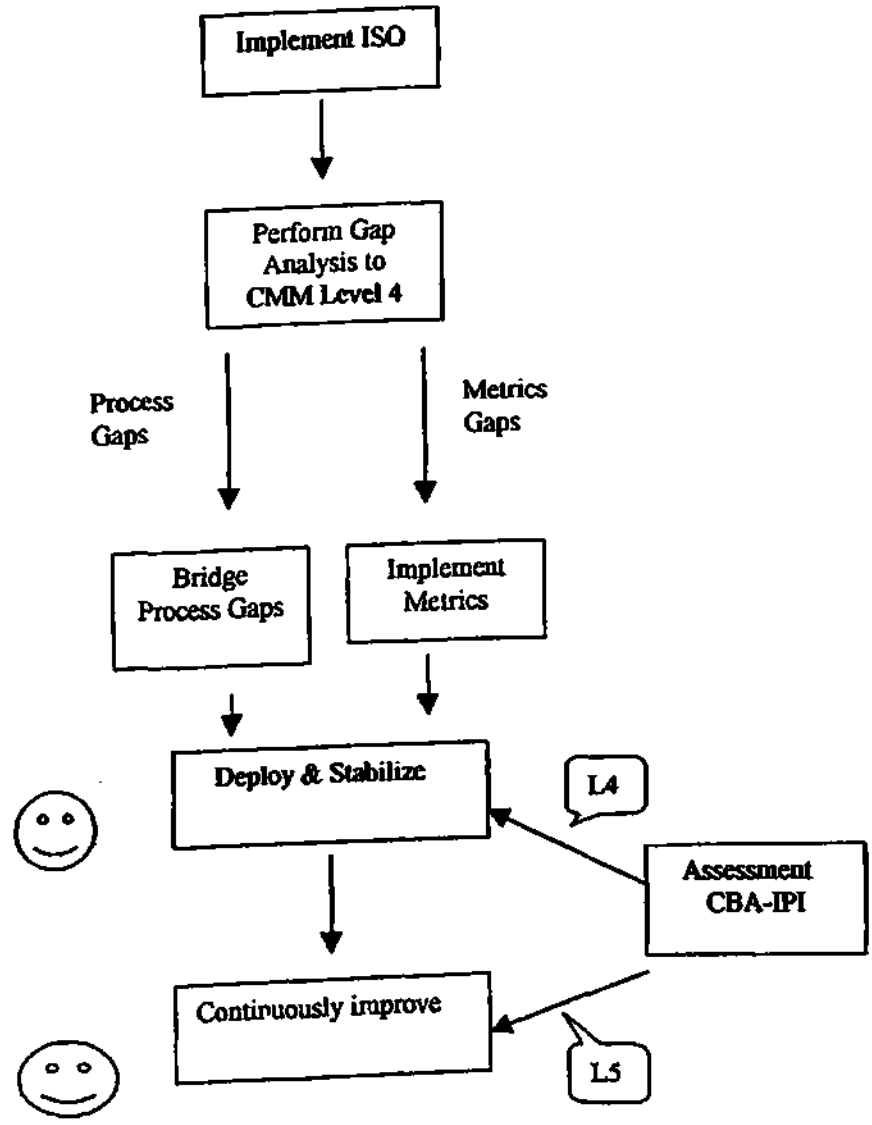


Fig 5.6

5.3 Advantages Of The Integrated Approach

We shall discuss the advantages of the integrated approach on two fronts (i) it takes much less time to reach Level 4 by using the Integrated approach and (ii) the strengths of ISO are captured while implementing CMM

5.3.1 Reduced Time Frames For Implementation

The major advantage in this approach is that the roadblocks that we identified earlier are not encountered by following this route. This brings about a degree of process culture and stability very quickly in the organization, something that would not have been possible by the traditional route of CMM implementation.

Having achieved ISO 9001, the organization would find it easy to move on to the CMM framework. Certain gaps at Level 2 and many at Level 3 would obviously exist (especially with regard to metrics) but the organization , having got accustomed to a process culture during ISO 9001, would find it rather easy to implement these. Moving on then from a regime of process stability, many of which enable metrics collection in a continuous manner, to an environment where metrics are analysed, capability baselines and quality goals set up and then used to quantitatively control the project in terms of both process performance and product quality is a smooth transition.

We have seen that organizations which chose the Integrated approach are able to reach CMM Level 4 maturity in 3 years time (starting from a Level 1 capability). Some have reached Level 4 in 2.5 years time as well, starting from scratch. This contrasts with the experiences of several other companies which have reported much longer time frames by going the traditional route. **Typically, for an organization to reach a Level 2 maturity from Level 1 would require around 2 years and another two years to reach Level 3**. Published literature giving specific time taken to achieve these maturity levels was rather sketchy – however, Motorola's Transmission Products Group (MOT2), Grumman Data [NID-95] and Schlumberger [WOHL-94] reported their experiences which appeared to confirm the above.

It is important to note that this approach has been validated in several companies, experiences of which have been recorded in subsequent chapters.

5.3.2 Using Good ISO Processes Not Covered In CMM

The Integrated approach may appear to be counter intuitive at first since certain ISO specific processes may need to be jettisoned once an organization moves to CMM. However, practical experience from several companies in India shows that this rarely happens. We have found that none of the processes written with ISO 9001 in mind are found unnecessary when moving on to CMM. In fact, there are many ISO practices that are not addressed by CMM explicitly but which would be good for the organization to adopt from the business point of view. Some of these practices are:

- Procurement: Clause 4.6, ISO 9001 – CMM has discussed the need for sub contractor management and Mark Paulk [Ref PAU5] felt that this is equivalent to the requirements of ISO 9001. However, we contest this conclusion, since the Procurement clause in ISO encompasses a much greater gamut of activities than the sub contractor management KPA does. Sub contractor Management is applicable to situations where a portion of the software work is given out to other vendors while the Procurement clause in ISO is applicable for all procurement activities in the organization. Thus it aims at streamlining all practices relating to the acquisition of materials and services including subcontracted work.

- This is borne out by the example of all CMM organizations that we have studied (Ref Chapter 8 of this thesis). None of the 8 organizations (in fact, many more that we have had occasion to provide consulting services to, but have not listed in Chapter 8), had the sub contractor management KPA assessed during their CMM assessment and reported that this KPA was "not applicable". However, all these companies were ISO certified during which the Procurement function was indeed audited.

- Internal audits, Clause 4.17 of ISO 9001: We believe that this clause is one of the great strengths of ISO 9001. Although CMM has also described the need for periodic assessments in the Organization Process Focus KPA, we find that ISO organizations get internal audits at least once in 3 months time while CMM organizations (which do not have ISO) would do repeat assessments only once in 12 – 18 months (experience from industry shows that even this is optimistic, with most organizations not doing any re-assessment at all).

- The reasons for this are that the ISO registration audit procedures require that re-registration audits be carried out once every 3 years and surveillance audits every 6 months [TIC-92 - TICK IT Lead Auditors' guide]. Also the audit procedures are such that the audits can be completed in 2-3 days time [TIC-96 – Lead Auditors' Training material]. This leads to internal audits generally being done at least once every 3 months in most ISO organizations and once every 6 months in the worst case scenario. CMM, on the other hand, has not mandated any periodicity for the process assessments (to quote "The software process is assessed periodically, and action plans are developed to address the assessment findings" – Ref CMM1; OPF, Activity 1). In the sub practice to this key practice, the CMM has said that "Assessments are typically conducted every 1-1/2 to 3 years time". Also, the assessment procedures are such that significant logistical and assessment team member effort is required for each CMM Based Assessment –Internal Process Improvement [CMM2 - official training material for Introduction to CMM] [CMM3 - CBA-IPI Method Description – Assessment Team Member's guide]. Thus, organizations find it extremely difficult to repeat the assessment process often.

- In the absence of frequent internal assessments in an organization, process compliance and continuing improvements could suffer, since there would not be any other pressure apart from "management commitment" and a self motivation amongst all organization employees to continue to adhere to the processes.

- Facilities management – Clause 4.9 (g) of ISO 9001: Again, CMM has not specifically discussed the facilities management issue. (Many CMM organizations consider facilities management under the Inter Group Coordination KPA). ISO organizations generally put in good practices relating to Facilities Management, Systems administration, server back ups, disaster recovery etc. at the organization level . This is notwithstanding the fact that project managers, in their PM Plans or in the CM Plans would have described the back up/ restore procedures to be adopted in the project.

Thus not only do we find that none of the ISO practices are made redundant when moving on to CMM, we also find that there are several good practices which should be retained and add value to an organization adopting the Integrated approach.

To sum up this chapter , the Integrated approach is recommended for organizations to move to CMM Level 4 and higher. This approach of ISO first and then CMM is recommended even, if for any reason, the organization is not interested in ISO and has its long term sights set on achieving CMM Level 4 or Level 5. Not only does the organization save both effort and time, it also imbibes certain strengths of ISO which are lacking in CMM.

The next chapter provides details on the implementation strategy i.e. how exactly should an organization go about implementing ISO 9001 and thereafter the CMM.

CHAPTER 6

IMPLEMENTATION METHODOLOGY

6.0 Overview : In this chapter, we describe in detail all the steps involved in adopting the Integrated approach in moving up the process maturity chain. As was discussed in Chapter 5, the first step would be to implement ISO 9001. Once this is achieved, the organization would move towards CMM Level 4 and beyond. This chapter provides all the implementation steps required to move an organization first to ISO 9001 and then CMM. Before that, however, we believe that one important prerequisite should be discussed. Section 6.1 discusses the need for Management commitment in this light. Section 6.2 provides the implementation steps for ISO 9001 while 6.3 provides a CMM implementation path.

6.1 PRE REQUISITE : Management Commitment

In the adhoc state of affairs in a Level 1 organization, a management commitment first needs to set in. This commitment comes from the realization of senior management that this state of affairs needs to change at the earliest. It is important to remember that management here means the very top management in an organization. Deming, in fact, accorded the top most importance to this by making it the first principle among his 14 principles (DEM-86).

The management commitment needs to extend to the point that the top management firmly believes that "come what may, we shall achieve our goal," i.e., improve quality by bringing about systemic improvements within the organization. We are stressing this here because we have seen that, in those organizations where management commitment is less than complete, when they embark on defining and deploying processes, it is because of marketing pressures and not due to an intrinsic desire to improve quality and the results from their efforts are uniformly disappointing. Some of them may even have achieved ISO 9001 but the results in terms of quality improvements are negligible.

This management commitment manifests itself in the decision to go in for process based quality, and as a first goal, adopt the ISO 9001 framework in doing so.

Very often, specialized help in the form of an external consultant is brought in like with all consultancy assignments, an organization that does not have knowledge of how to implement a Quality Management System benefits from specialized external help. A consultant helps to guide the organization through its journey and avoid common pitfalls especially those leading to excessively bureaucratic systems. Of course, the consultant should have in-depth knowledge of the software industry.

6.2 Achieving Iso 9001 : An Implementation Methodology

We now discuss the methodology that an organization at Initial Level (Level 1) needs to adopt to be able to move to ISO 9001.

6.2.1 Appoint Management Representative

The first step that senior management takes is to appoint a management representative(MR). This person has the following profile :

Essential :

- Senior level person, with direct reporting authority to the top management of the company,
- Has a strong understanding of software project processes,
- Commands substantial peer respect,
- Has deep commitment to process based quality,
- Is strong in human relations, especially in persuasion skills and tactful handling.

Desirable :

- Has management and technical experience in software projects.

If we have endowed the MR with an idealistic (and difficult to get) set of characteristics, it is intentional. We believe the MR's choice is critical for a successful implementation of a Quality system

The MR is very often the Quality Assurance Manager and this is a good thing to do. Only in case when there is no senior person in the quality department (and unfortunately, this is very often the case) do we often see a MR who is generally a senior project manager or a business unit head with the Quality Assurance executives reporting to him

6.2.2 Phase I : Launch ISO 9001 initiative

- 1 day Quality and ISO Appreciation Training :
  - The ISO 9001 initiative is launched in the company by first conducting a Quality and ISO 9001 "appreciation" training for all middle and senior management of the organization. This is a one day seminar conducted usually by the Management Representative or an external specialist (the consultant). Before starting this seminar, it is good for the CEO to formally launch the ISO initiative by addressing all participants and reiterating the management commitment and sharing his vision of the organization in terms of quality. We have seen that the effect of the CEO's address is greatly enhanced if he were to explain the reasons for the organization to go in for ISO 9001 and to emphasise that a

genuine desire to improve quality rather than certification as an end in itself is the driving force in the organization.

- Evaluate existing situation and develop Implementation plan :

A study is then conducted over the organization to understand the practices that are followed in the organization and the processes that exist in a documented form if any. Generally, one would find that although processes may not exist in a documented form, there would be several guidelines, standards (e.g., programming standards, screen standards, documentation standards etc.) and a few formats. Our experience also shows that certain procedures in the areas of marketing, invoicing, finance and administrative, HR and customer support do exist. However, project related processes are generally absent at this stage.

This evaluation should take no more than a day and should be based on discussions with a few project managers and the MR.

Based on this evaluation, an ISO 9001 implementation plan should be prepared. This identifies the processes to be written (described in the next section), who would and by when. This road map also lays out the schedule for all quality assurance activities during the period leading to the ISO 9001 certification.

A sample of a Gap Analysis report and the Implementation Road Map is given in Annexure 2.

- Orientation for Process Writers :

The process writers identified in the implementation plan are given an orientation on process writing and process contents. A template for process writing helps. It is a good practice to have process writer write a 'quick and dirty' process in the presence of the work shop facilitation.

This phase of 'Launch ISO 9001' should take no more than a week to complete.

6.2.3 Phase II : Define and Document Processes

The process writers now get to work and start to define the processes assigned to them. It is good to divide this process definition phase with different sub phases as well based on priorities. We generally divide the processes into three groups, based on the priority of implementation. The most important to do first are the project processes which are in Group I. The Group II and III processes could be done after a few weeks.

Group I : These are the core project processes. The earlier these are written, the earlier would the projects be able to implement these. These are : Project Management including Project Planning, and Project Monitoring and Control (may also be called Project Tracking and Oversight)

- Configuration Management
- Software Development Life Cycles
- Reviews and Inspections
- SW Testing

- SW Maintenance (if the organization has maintenance projects as well)

Please note that some of the processes include a few others, e.g., Project Planning includes Quality Planning, SDLC includes installation and delivery, etc. Similarly, SW Testing may be merged with the SDLC or with the Review Manual (and the integrated manual called the Quality Control or the Software Verification Validation Manual).

Group II : Support processes are included in this group, as well as some of the project processes. These are :

- Quality Assurance Process – This includes Internal Audits, corrective and preventive action and management reviews
- Contract Review
- Procurement
- Training
- Facilities Management
- Customer support (especially for a software product company)
- Quality policy from the CEO

Group III :

- Quality Manual
- Metrication Process

The reason for including the Quality Manual in Group III is that from the point of view of implementation, this does not represent any significant process deployment challenges Including the Metrication process in this group is a marked departure from a CMM implementation where the Metrication process would be about the earliest documents that would be in place.

We are aware, however, that many organizations choose to prepare a Quality Manual first and then use this to define all the processes required For understanding why we believe that the Quality Manual can wait till the end, it would be good to look at the proposed quality system documentation structure which is given below in Fig 6 1

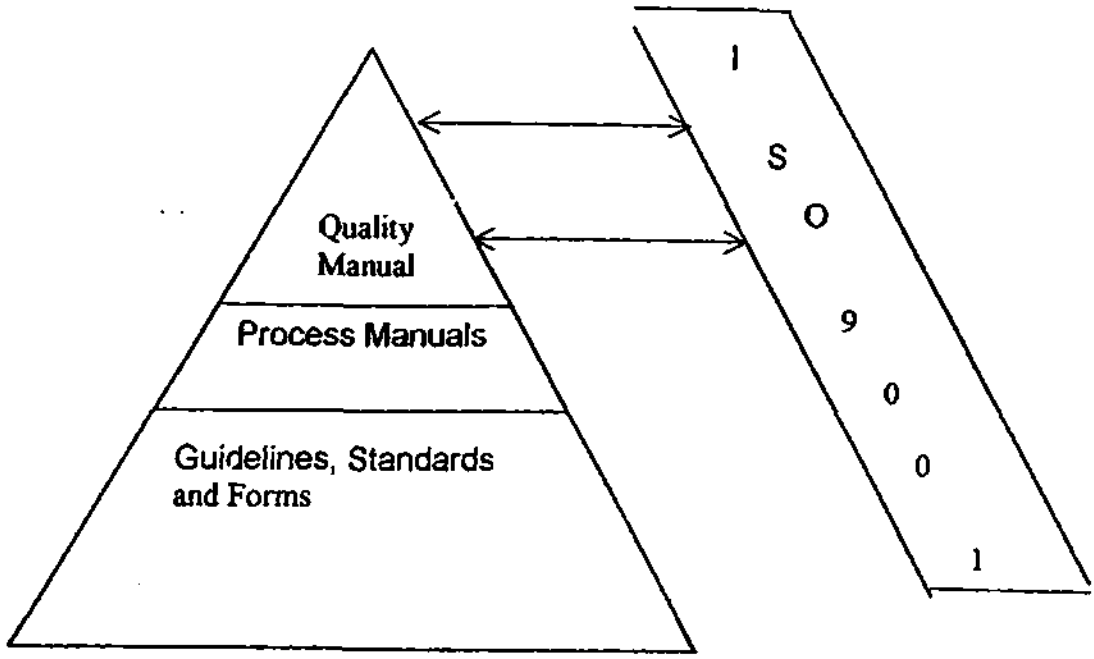


Fig. 6.1

6.2.4 Documentation Structure of the Quality Management System

The documentation structure is composed of three layers :

The Quality Manual is at the top layer. This can be considered to be both a policy document in the sense that it sets down the quality policy of the company and provides the policy framework for all processes that the organization follows. In providing the policy framework, it draws heavily upon ISO 9001. The Quality Manual is a reference document in the sense that it maps on to the ISO 9001 as well as provide references to the procedures that are documented in the Process Manuals in the second layer. The Quality Manual is generally written in an auditor friendly manner (it is the only document in the entire QMS that is so. The process manuals and other documents need to be practitioner friendly). Thus, it generally follows the structure of ISO 9001and describes how the organization fulfills all the requirements of ISO 9001. Since most of these requirements would be fulfilled by the processes at layer 2, the Quality Manual provides references to specific process manuals as well.

The relationship has been depicted as in Fig. 6.2:

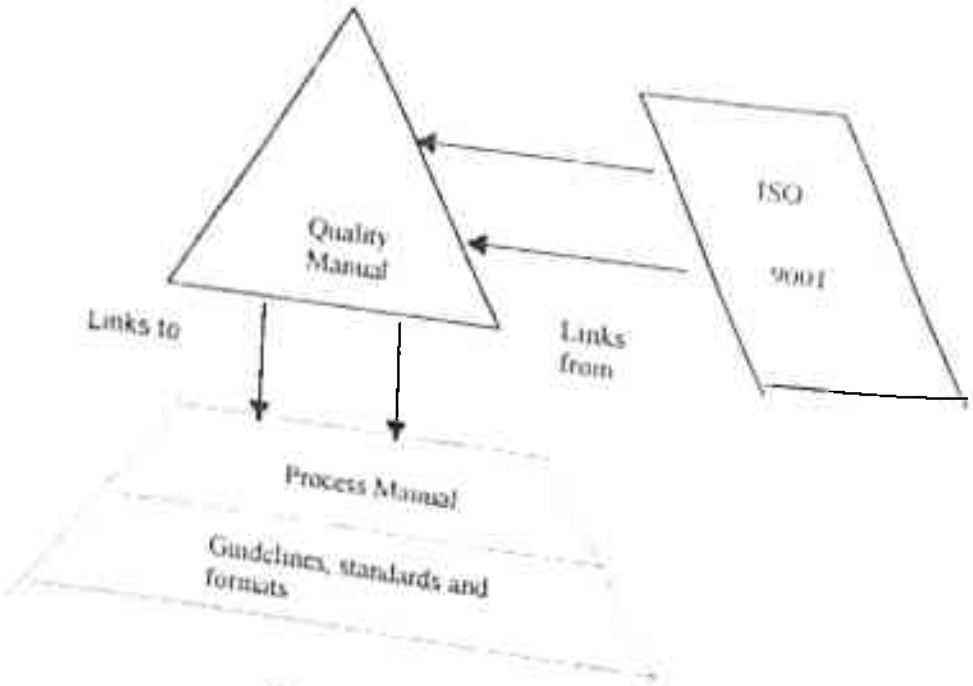


Fig 6.2

A few sample pages of a Quality Manual is given in Annexure 3 to illustrate the point that we have made here As can be seen, the Quality Manual serves mainly as a reference document, and thus it may be prepared towards the end of the documentation exercise

In Layer 2 are the Process Manuals These document the processes that will be followed in the organization and hence, are the 'heart' of the QMS These provide in detail the 'how tos' to enable the practitioners to execute the tasks defined to meet the requirements of ISO 9001and the QM Manual These are also called as Procedure Manuals or System Manuals in some software organizations in India These process manuals are based on reference from the Quality Manual and, in turn, provide links to Layer 3 i e., Guidelines, Standards & Formats This is diagrammatically depicted in Fig 6.3 below

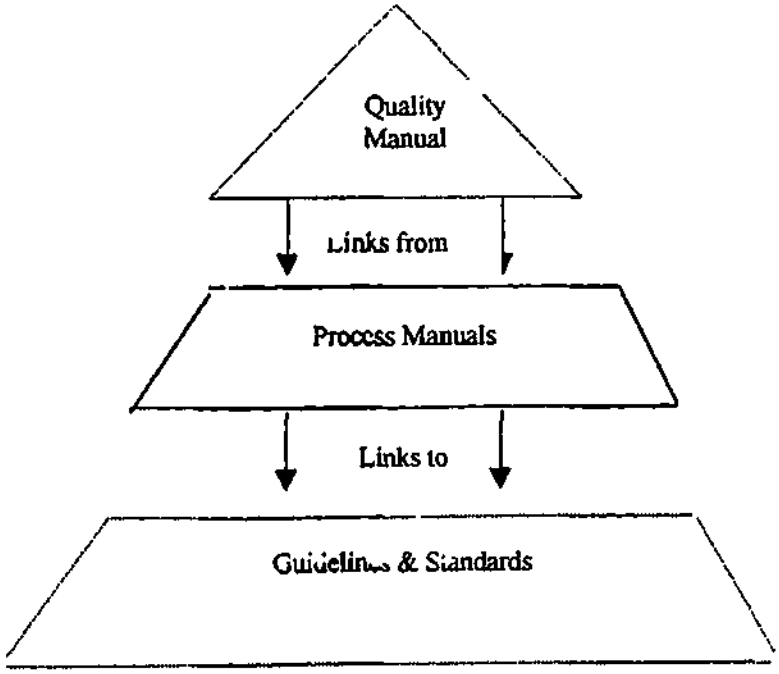


Fig. 6.3

Each of the processes identified above is generally documented in a process manual. However, a few companies, we studied had the practice of preparing process manuals for many sub processes as well. For example there were process manuals for Requirements Analysis System Design, Coding and Unit Testing etc., separately in a few companies while in many others, there was a composite Software Development Life Cycle manual which had the various phases as chapters within it.

Guidelines and Standards

Layer 3 of the documentation structure is composed of guidelines and standards. These are in the nature of recommendations and detailed suggestions on work to be done with the objective of helping the organization to implement the processes identified in Layer 2. These may include check lists, programming standards, document standards, templates as well as guidelines which the specific project may choose to use. Examples are :

- Review checklist for SRS
- Checklist for Y2K testing
- Function Point Counting Guidelines by IFPUG Method
- Function Point Counting Guidelines by Mark II Method
- Programming standards for JAVA

- *Screen layout standards*
- Documentation standards (some of these standards may be made mandatory examples for process documents)
- Project Plan template

6.2.5 Documentation Model

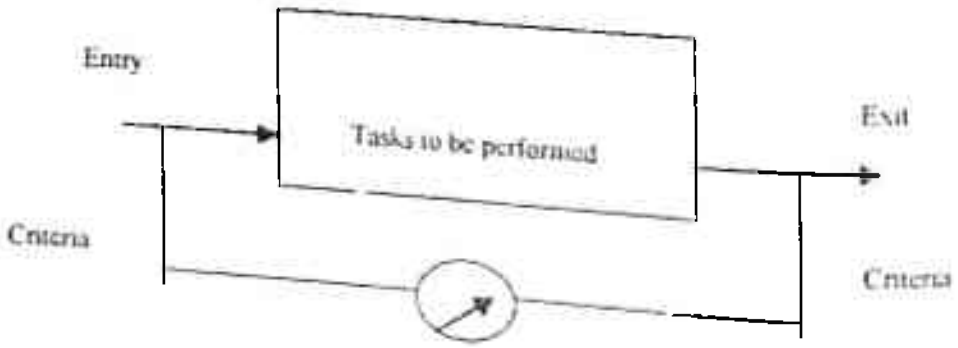
We now discuss the manner in which documentation may be done for the QMS. Two models may be followed – the ETVX model or the generalized model.

6.2.5.1 ETVX Model

The documentation is generally done by using the ETVX model. ETVX stands for :

- ENTRY CRITERIA
- TASKS
- VALIDATION
- EXIT CRITERIA

See Fig. 6.4



Validation

Fig. 6.4

The process model first defines the entry criteria that need to be fulfilled before beginning to execute the process. The entry criteria, therefore, addresses the twin questions of "When do we start?" and "What must exist before we can start?"

Examples of entry criteria are :

- For the Systems Requirements Analysis process, the entry criteria would be –
  - User requirements in the form of a statement of work, a proposal, a contract, a series of e-mails, minutes of meetings, or any other form are available.
  - The project plan which is an output of the Project Initiation phase is available.
- For the System Testing process, the entry criteria would be :
  - The System Test Plan is available
  - The software to be tested is available in an integrated form and all prior quality control activities have been performed satisfactorily

The tasks to be performed are defined next. These describe all the activities that are carried out in this process. In this sense, just like process manuals form the heart of the QMS, the 'tasks to be performed' are the essence of the Process Manual. This section is also called as 'Procedures to be followed', 'Activities to be done' etc. The tasks performed therefore addresses the question of "What do we do in the process?"

Examples of tasks performed are :

- For the Reviews Fagan Inspection process, the tasks performed would be :
  - -The Moderator calls a preparatory meeting at least a week before the Inspection Meeting in which all inspectors, the producer and the moderator are present.
  - The Moderator chairs this meeting and assigns the following roles :
    - > Reader
    - > Recorder
    - > Inspector

He / She also explains the Inspection process to all participants and responsibilities for each role.

- The Reader and the Inspectors then study the object under review and prepare review comments.
- During the Inspection Meeting, which is held according to the schedule laid down in the project plan, the reader does the following –etc.

The third element of the ETVX model is the Validation Criteria. This answers the question – "How do we know if the Process has been done well?" It, therefore, defines the verification and validation used in the process to ensure that the tasks listed have been carried out in accordance to requirements. Examples of this are :

- For the Project Planning process, the validation done is
  - The project plan is reviewed at least by the Project Director and, if required, the Business Unit Head and the Service Delivery Manager.

The fourth element of the ETVX Model is the Exit Criteria which define criteria based on which the process execution may stop. This, therefore, answers the question "When do we stop?" Examples of Exit Criteria are :

- For the Systems Requirements Analysis, the Exit Criteria would be :
  - The System Requirement Specification (SRS) are reviewed, review comments closed and are put under Configuration Management.
- For the System Testing process, the exit criteria would be
  - The System test results are logged and have been reviewed. Review comments, if any, are closed
  - The software is approved for release and has been put under Configuration Management.

6.2.5.2 General Document Model

In general, software organizations had the following sections in their process documents :

- Objective / Purpose of the Process
- Overview of the Process
- Scope
- Definition / Glossary of terms used
- Entry Criteria
- Inputs
- Tasks Performed
- Outputs
- Validation

- Exit Criteria
- Quality Records
- ISO 9001 Reference

One Software organization had an interesting variant and had the following sections :

- What does this process do, in general?
- When do we start this process?
- What do we do?
- How do we know it is done well?
- When do we stop?
- What are the records we maintain?
- ISO 9001 Reference

6.2.6 Review Processes And Release After Approval

Once the process manuals have been written, these should be reviewed for compliance to ISO 9001 requirements as well as for effectiveness. We find, from our experience, that processes are very often written in an idealistic and ambitious manner without regard to whether it will be possible to fulfil these or not. Similarly formats and templates are often defined to such a degree of detail that the processes become unnecessarily bureaucratic. Review of processes should focus on these aspects as well.

After the review comments have been incorporated or otherwise closed, the process documents are approved for release and then put under configuration management..

The processes should be released in batches, as and when they are ready. We find that a useful rule to remember is "Do not wait for perfection". We have seen a few organizations where the cycle of process definition, reviews and improvement was repeated so many times that new, unexpected obstacles cropped up and the organizations got bogged down completely and could not get to release the process manuals till an extraordinary length of time had passed. In many cases, they were not able to release the processes at all. A few of these obstacles are:

- Loss of motivation of the authors : When the cycle of reviews and fine tuning goes on for too long, the author loses his drive and creative urge.
- Hardening of positions on all sides : When processes are initially defined and documented, the organization generally has an open atmosphere with the process writers being open to all suggestions. As reviews drag on interminably, people start taking rigid stands and this becomes difficult to break later on.

- Loss of morale in the organization : Together with the process writers' loss of motivation, the process implementers, i.e., the project teams, the support function etc., also find their enthusiasm going down. Keeping up the morale in the organization is important and we find that this becomes difficult if process definition is dragged on too long

- Loss of commitment from top management : Top management's expectations, having being belied in the sense of delays having accrued, lead to perceptible loss of commitment.

We have seen other problems happen, e.g., the Management Representative or the Quality Manager, because of all the above, start to seek greener pastures elsewhere which again has an impact on all the above.

We therefore, believe that this phase is critical and the 'hump' must be overcome in a determined and quick manner. We believe that this phase should take no more than 3 months, while smaller organizations should aim to have this done in 2 months time

Reviews are extremely important but you should have no more than 2 cycles of reviews (for the same process document). We have seen organizations where the reviewer takes the stand of "You first write, only then I will give you my views." Further, we find reviewers giving review comments only in patches. e.g., "Here are the review comments for Chapter I You fix these and only then will I review Chapter II." This approach leads to the number of cycles of reviews increasing.

6.2.7 : Process Implementation and Internal Audits

The processes, once released, are implemented across the organization. This should be accompanied by relevant training provided to all users

After around 6 weeks of the start of the process implementation, the audit cycle should begin

ISO 9001 : 4.17 provides for Internal Audits to be done on a continuing basis in the organization and we believe that this has been a major benefit of ISO implementation. CMM does require periodic assessments, however, a period of 18 months is considered okay in CMM. In the ISO world, internal audits are generally done at 6 weeks to 12 weeks intervals and this keeps the level of process compliance fairly high in the organization

An Internal Auditor's training should be done before the first internal audit begins.

The Audit schedule would generally be as follows :

- Audit No. 1 – 6 weeks after Process Implementation begins
- Audit No. 2 – 8 weeks after Audit No 1
- Audit No 3 – 8 weeks after Audit No 2
- Pre-assessment by certification agency – 3 weeks after Audit No. 3

- Audit No. 4 – 4 weeks after Pre-assessment or 2 weeks before Registration Audit, whichever is later

- Registration Audit – 2 weeks after Audit No. 4

The Internal audits are carried out by teams of trained auditors, generally led by a Lead Auditor. A lead auditor is one who has undergone final lead audit training and has attained certification by passing the requisite examinations. These audits are planned for through an audit schedule made for the year and an audit program which is prepared individually for each audit. A sample audit program is given in Annexure 4.

During the audit meeting, the audit team evaluates if the documented Quality Management System is being complied within practice. It also looks for process improvements all the while. Generally the former is logged in the form of Non Compliance Reports (NC) while the latter is logged in the form of Observations. Sample formats are given in Annexure 5.

At the end of the audit cycle, an audit report is prepared which summarizes the NCs and observations logged and provides an insight to management about the functioning of the QMS. A sample of an audit report is given in Annexure 6.

6.2.8 : External Audits By Registration Agency

The Registration Agency (also called certification agency) performs audits on the Quality system in accordance with auditor guidelines laid down by ISO. These audits are in the form of :

- Pre registration assessment

- Registration audit – usually 4-6 weeks after Pre assessment

- Surveillance audit, usually done every 6 months after the registration audit

- Re – registration audit is done every 3 years

The pre registration assessment is done to confirm if the organization is in a state of preparedness to go in for registration audit. The documented QMS is first reviewed to ensure that ISO 9001 requirements are met. A few sample projects are then audited to ensure that practices are in accordance with the documented QMS.

The ISO 9001 certification is awarded to the organization following the successful completion of the registration audit.

The registration audit generally follows the activities listed in the Audit Program given in Annexure 4 . Following the Opening Meeting, the auditors conduct a document review and then proceed to audit a sample of the project and support functions. The duration of the audits and the sample size depends on various facts like the number of employees, number of projects, scope of certification, nature of business etc. After the audits are completed, the audit team prepares its audit report, together with any non compliance that may have been observed. These are then presented during the closing meeting. The results of the registration audit is, therefore, converged

during the closing meeting itself – hence the organization gets to know if it has successfully met the requirements of ISO 9001 or not.

Surveillance audits are carried out by the registration agency every 6 months to ensure continued compliance of the Quality system. Changes to the Quality system are reviewed and a few projects audited. The sample is, of course, much smaller than that in the registration audit. Again, an opening meeting and a closing meeting are held to discuss the findings.

As mentioned above, an organization should be able to achieve ISO 9001 certification within 12 months from start.

6.3 : Moving on to CMM – Level 4:

The activities involved in moving on to CMM were briefly described in Chapter 5. The diagrammatic representation given in Fig 5.6 is repeated below.

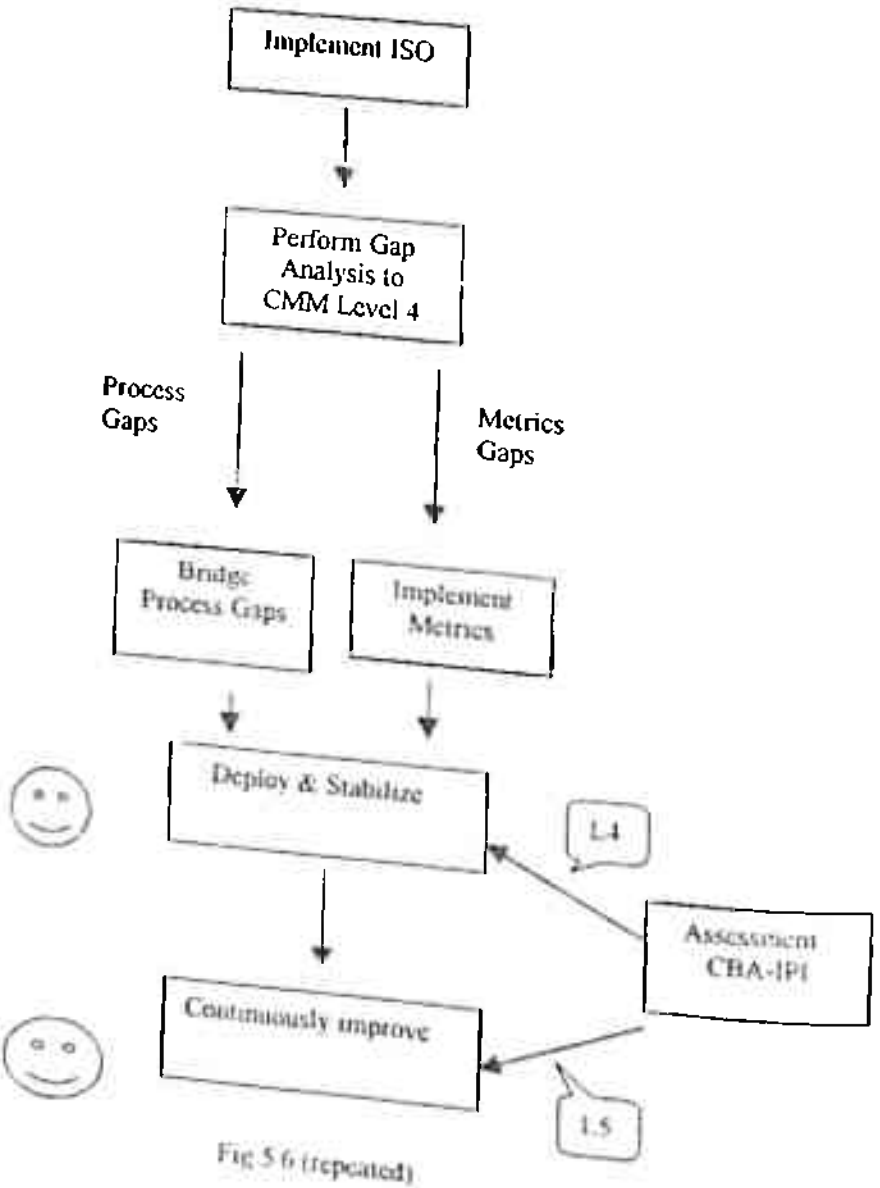


Fig 5.6 (repeated)

6.3.1 Perform Gap Analysis to CMM Level 4 and Level 5 requirements:

A gap analysis is conducted to identify the gaps in the deployed quality system vis a vis requirements of CMM Level 4 and Level 5. This analysis is conducted along two streams :

6.3.1.1 Process gap analysis:

Many organizations conduct what they call "abridged assessments" and generate an interim profile of the company. This method depends heavily on the CBA-IPI method and similar tasks as in the CBA-IPI are carried out, albeit on a smaller scale. A full discussion on the CBA-IPI method is given in Annexure 8. This includes administration of a maturity questionnaire as well. A few sample pages of the maturity questionnaire is given in Annexure 9.

However, we have found during our consultancy work with KPMG [KPMG-99] that an effective method of doing the gap analysis is by means of an extensive document review and focussed interviews with the Project Managers and the Quality Assurance Group.Organization that is already at ISO 9001. It also puts much less strain on organizational resources and logistics than the abridged assessment method. We also find that the administration of the maturity questionnaire, as given by SEI, does not provide much insight since the likelihood of getting wrong or incomplete information is very high at this stage. This stems primarily from the fact that the maturity questionnaire respondents do not understand the language used in CMM well enough to provide the correct answers (the maturity questionnaire uses terms exactly as given in the CMM and the organization generally would not have mapped the CMM terms to its own language at this stage; also, the questionnaire respondents would not have been trained on the CMM at this early stage)

Based on the interviews and document review, the gaps vis a vis Level 4 and Level 5 are identified. We have seen that ISO organizations generally have the following gaps:

a) In the Requirements Management KPA, there are generally no gaps. The statement of work or the proposal or any other document purporting to be the basis on which work would be done is, in the words of the CMM, "managed and controlled". However, we recommend that since ISO organizations have a strong CM process already in place, they should place the proposal under configuration management as well.

   A strong area of ISO organizations is that they carry out contract reviews. This brings out a lot of discipline in the Requirements Management area.

b) In the Project Planning KPA, estimates for size are generally not available. This stems from the fact that most estimation is based on the task based or the Work Breakdown Structure estimating method rather than the indirect method of using size and productivity norms to calculate effort.

c) In the Project Tracking and Oversight KPA, some organizations do not have a defined method of team meetings or some other form of status reporting within the project. This is generally because the project teams are small (less than 5 members) and information on who is doing what is known to the project manager informally.

d) The QA function (we will call it QAG for easy reference here) in most ISO organizations focuses on processes and not on product quality. It is thus more or less like the SEPG envisaged in the CMM. The differences between a typical SEPG in a CMM organization and the QAG is that the SEPG has many more part time members from the projects and support functions while the QAG is generally composed of full time quality professionals. The QAG coordinates process audits, as envisaged in the OPF KPA at Level 3 but generally does not get involved in product audits.

The project teams do have reviews and independent testing but as we said earlier in Chapter 4, the SQA requirement of CMM is not filled exactly in the way the CMM key practices read. Thus, during the gap analysis, a lot of mapping has to be done to determine how the SQA practices are being followed.

e) In the Configuration Management KPA, by and large, there are no gaps, except in key practices like the need for a Software Configuration Control Board and configuration status reporting.

The SCCB is not explicitly formed in most ISO organizations, partly because the projects themselves are not too big and partly because ISO 9001 did not require such a board to be formed. It should be noted that in most ISO organization, the function of the SCCB is not carried out by any alternate practice.

The configuration status reporting in ISO organizations is generally achieved by an alternate practice where the configuration status accounting and reporting are combined by means of a master document list or a configuration control register. Most CM tools also provide a status report on request.

f) In the Organization Process Focus and the Organization Process Definition KPAs at Level 3, there is generally a gap in the establishment and usage of a process data base. The QMS is, of course available to the ISO organization but other process assets like the metrics data base, project plans etc. are not available as a library or a data base at the organizational level.

The other gap in these KPAs is generally that tailoring guidelines are not explicitly available. ISO organizations tend to create different organization standard software processes (OSSPs) for different needs – thus, tailoring guidelines are not created

g) In Training KPA, there are generally no gaps

h) In Integrated Software Management, the gaps are generally in the risk management area. ISO organizations would have identified the risk factors but would probably not have handled the mitigating of the risks adequately.

i) The requirements of the Product Engineering KPA are generally met except for the Activity # 10 i.e Consistency is maintained across work products (CMM3). ISO organizations do ensure that this consistency is checked for during reviews of the documents but have no other method to ensure this. We therefore generally log this as a weak area of implementation.

j) Peer reviews KPA is generally strong. The method of doing reviews varies from structured walkthrough to Fagan inspection and may not always be reviews strictly between peers.

k) Inter group coordination is not practiced in ISO organizations in a formal manner. We know of some CMM assessors who take the view that this KPA is not applicable since there are no other groups like hardware design, firmware design etc. whose work affects the product. However, we take the view that groups like Systems Administration (facilities management), Human resources etc. do work which has an impact on the project. Thus these should also be considered in this KPA. Generally, ISO organizations do not have a formal system which calls for commitments to be made and agreed upon, as the CMM has required (CMM3 – Inter Group Coordination).

l) In the Level 4 KPAs – the Quantitative Process Management and the Software Quality Management there is often a large gap. ISO software organizations have a very sketchy quantitative implementation.

6.3.1.2 Metrics Gap Analysis

Although ISO 4.20 requires the use of statistical measures, we find that most ISO organizations have a very perfunctory usage of metrics. They would generally have the following metrics:

a) Effort variance, computed at the end of the project

b) Schedule variance, computed at the end of the project

Some organizations, in addition, do compute measures like productivity and defect density etc. but the problem generally is in the fact that the use of size measures is neither consistent nor well defined.

In most organizations, there is a large gap in terms of metrics implementation in most organizations.

As a deliverable of the gap analysis phase, the gap analysis report not only identifies the gaps but also the processes and metrics required to bridge these gaps.

The gap analysis phase should be completed within a week. We generally budget for 2 days each for the process and the metrics gap analysis.

6.3.2 Bridge the Process Gaps

This phase consists of the following :

- Define additional processes. Generally, new processes would need to be written for Level 5 KPAs
- Modify existing processes, as identified during Gap analysis
- Deploy processes
  - Release

- Provide training on new and modified processes
- Facilitate use of processes by project teams / functional teams

The gaps in processes are bridged according to the suggestions given in Section 6.3.1 above. We believe that the suggestions given therein should enable the organization to bridge all the process gaps.

A good practice that we find in several organizations is the use of a Traceability Matrix. This has been recommended in the DoD Military standards 2167A and 498 (MIL1 and MIL2) and we find that this brings in a lot of value addition to the reviewer, the project manager and the SQA to ensure that all requirements of the customer have been incorporated in the various stages of the project. (See Annexure 10 for a sample Traceability Matrix).

The process gaps are first bridged in the documented procedures and then deployed, after necessary training. Facilitation is done by SQA and the SEPG for a while. Internal audits, as is normal practice in an ISO organization, continues to be done so that process compliance is ensured.

The tasks of process modification and deployment should be completed within three months of the gap analysis being done.

6.3.3 Implement Metrics

Parallel to the above, the organization starts to implement metrics, based on the gaps identified in the Metrics Gap analysis. It is generally found that the gaps in Metrics implementation are fairly large at this point of time, since an organization at ISO 9001 typically has only rudimentary metrics in place. Hence, rather than call this task a 'Bridge Metrics gaps' we have chosen to call it 'Implement Metrics' since the organization needs to understand that metrics implementation would be required to begin almost from scratch now. Although this may seem like a lot of work to do, we find that because the ISO 9001 organization has strong process strengths, the metrics roll out gets done fairly quickly – generally within 4 months time. The tasks here are :

- Define Metrics and document in the form of a Metrics Plan or Process. The definition of each measure should be explicit so that there is no room for varying interpretations.
- Set up a data collection mechanism. Automated systems are preferred since this reduces the work load on the project teams.
- Design and develop a software process data base. The data collection mechanism directly updates the software process DB
- Deploy Metrics by adequate training and facilitation

6.3.4 Implement And Stabilize

Once the processes and the metrics collection programs have been deployed as given above, the organization now enters a phase of consolidation. Processes are now used and stability sets in. Data collected is analyzed and baselines established. The tasks are

- Process implementation
  - Use processes that have been defined
  - Continue to do internal audits as was required under the ISO system.
- Collect data
  - Having set up the processes for collection of quantitative data, data is now captured and stored till a rich number of data points are available. It is difficult to say how many data points are required to enable setting up of capability baselines, and we have discussed this point in Part III of this thesis. Briefly, however, around 20 data points should exist before any meaningful analysis can be done [DAN-92]. The organization should plan for around 5-6 months for this richness of data to be achieved.
- Analyze Metrics
  - Derive control limits
  - Set up Capability baselines
  - Set up quantitative quality goals.

Details of this analysis are given in Chapter 7.

At least 3 cycles of metrics analysis, each cycle providing a set of capability baselines, is done. By the end of this, the organization should have the level of maturity required at Level 4 and should be in good shape for the final assessment to begin.

6.3 Achieving Level 5

The assessment done for Level 4 capabilities should be able to provide valuable insights into the gaps at Level 5. However, since the CBA-IPI would have been focussed at Level 4, another round of gap analysis is recommended where the gaps at Level 5 are identified.

6.3.1 Perform Gap Analysis

The gaps that we find have been of the following nature:

a) At Level 5, in the Defect Prevention KPA, gaps exist - a formal system of ensuring defects prevention generally does not exist at the project level. The internal audits done in an ISO organization do provide insights to the Defect prevention process in case the NCs found during the audits relate to product defects; however, since none of these practices are based on quantitative measures, the gap for this KPA can be considered to be large.

b) In the Technology Change management KPA, some practices may exist with regard to tools and other technological innovations. A R&D group may exist which continuously looks at technological innovations and provides inputs to senior management so that the technological

direction can be charted out. There may also be a systematic evaluation of tools being done. However, none of these are generally formalized in the form of a written process. Also, since none of these practices are based on quantitative measures, the gap for this KPA can be considered to be large.

c) Certain practices exist for the Process Change Management KPA in an ISO organization. A system for proposing changes to the process framework may exist and changes made in a controlled manner in an ISO organization - however, since none of these practices are based on quantitative measures, the gap for this KPA can be considered to be large.

6.3.2 Perform Metrics Gap Analysis

Since there are no processes implemented at this level, the metrics for Level 5 are also absent.

6.4.3 Bridge process gaps

The additional processes that an organization should implement to achieve Level 5 capabilities are as follows:

6.4.3.1 Defect Prevention KPA

The CMM requires that projects implement Defect prevention activities at end of every significant milestone which may be completion of tasks or phases. It suggests that a Defect Prevention (DP) group be formed for each project.

Depending on the size of the project, we find that organizations form a DP group at the organization level which then performs DP activities for each project. This DP group composes of members of the SEPG and the project personnel. Often, the SQA personnel are part of this group.

The DP group works according to a DP plan and meets regularly at the end of significant tasks (generally it is at phase end). Quantitative data is analyzed and suggestions for preventing defects are evaluated. Action on preventing such defects are then taken.

6.4.3.2 Technology Change Management KPA

A technology group is formed with the objective of spearheading the technological directions of the company. This group may be composed of some full time R&D technologists as well as some part time members representing various types of projects and technologies. A systematic scanning of the directions that technology is moving to is done by interacting with the academic world, literature survey of relevant technical journals, attending conferences etc. Emerging technologies are continually identified and analyzed. At the same time, the marketing inputs are taken from various sources and the commercial feasibility of new technologies evaluated.

Once an idea is found to be worth exploring further, Technology focus groups may be formed which does a complete analysis of the technology and publishes white papers for the senior management to decide upon.

Similarly, various tools group are set up to evaluate and take decisions on tools that would be useful for the software project teams.

An important aspect of the TCM KPA is the need for piloting tools and technologies first before implementing organization wide. Pilot projects are chosen based on factors like – representative of the work generally done in the organization, commitment on the part of the project personnel to adopt new technologies, skills level in the project team etc. Based on the pilot findings, the Technology focus group decides to implement the technology or the tool across the organization. Before doing so, it ensures that the roll out activities are planned for. This will include training, availability of user manuals, documenting of experiences gathered from the pilots etc.

6.4.3.3 Process Change Management (PCM) KPA

Although the CMM requires the establishment of an organization wide PCM group, the PCM activities can be adequately performed by the SEPG itself. Thus we find that, in many organizations, there is no separate PCM group and the SEPG is entrusted with this responsibility. Again, an ISO or a CMM Level 4 organization would probably have this already.

The inputs for process improvements may be any one or more of the following:

- Process improvement suggestions from any employee of the organization
- Findings of ISO internal audits / ISO certification audits / ISO surveillance audits / CBA-IPI assessments
- SEPG
- Customer feedback
- Metrics analysis
- Defect prevention activities
- Inputs from the technology focus groups

Please note that this is only an indicative list. Inputs may come from other sources as well e.g. senior management, market intelligence regarding practices in competing organizations, technology, tool and process vendors etc.

CMM requires that the processes be piloted first and then implemented across the organization. We believe that this is a very good practice since it would minimize the impact of an inappropriate process and should be done for all new processes sought to be implemented in the organization. A word of caution, however- do not carry it too far. We have seen organizations where a pilot is done for each and every small change to the processes e.g. a cosmetic change in a format. (*Such organizations do so in the belief that since the CMM has specifically required this practice, it has to be done in exactly the same manner. It should be always kept in mind that the CMM should be viewed as a framework for sensible process implementation and that the effectiveness of the processes is of overriding importance).* This leads to unnecessary delay in bringing about process improvements. The SEPG or the PCM group should view the question of pilots as basically a "judgement call" and act accordingly.

The results of pilot implementation should be analyzed. If the results show that the modified or the new process has been successful, then it should be deployed organization wide. Like in the earlier KPAs, implementation organization wide should be preceded by adequate training, rollout planning, documentation etc.

6.4.4 Bridge Metrics Gaps

Implementing metrics as given in Chapter 7 would bridge the gaps for the Level 5 KPAs. At least two more rounds of baselining should be done so that the organization achieves much more maturity than it had at Level 4. It should be remembered that an organization at Level 5 has not only implemented all Level 5 KPAs but has attained substantially more maturity and experiences in all KPAs at the earlier levels. Thus, capability baselines established and used at Level 4 show that there are improvements in all goals especially those relating to productivity, defect density, effort variance and schedule variance.

Metrics coming in from the implementation of the Level 5 KPAs are also included in the baselining exercises.

As we said above, at least 2 more cycles of metrics analysis should be done after achieving Level 4. By the end of this, the organization should have the level of maturity required at Level 5 and should be in good shape for the final assessment to begin.

The time taken for achieving Level 5 from Level 4 would generally be 12 months, assuming that the gap analysis for Level 5 began right after the Level 4 assessment was over.

6.5 Indicative Time Frames

The Integrated approach has been described in detail in this chapter. The major tasks and the time frames have been discussed at various points in this chapter. A summary of the tasks and the time frames are

S no	Task	Duration	Time frame
1.	Implement ISO 9001	12 months	Mth. 12
2.	Perform Gap analysis for CMM (Note: We have provided for a two month break in between. This is often required for the QAG)	1 week	Mth 14
3.	Bridge process gaps	3 months	Mth 17
4.	Implement metrics Note: This is a parallel task	4 months	Mth 18

5.	Stabilize process implementation	9 months	Mth 25
6.	Analyze metrics and baseline capabilities Note: This has three cycles of baselining and is a parallel task	9 months	Mth 25
7.	Phase I of CBA – IPI	10 days	Mth 26
8.	Prepare Exploratory questions for Ph 2	5 weeks	Mth 28
S no	**Task**	**Duration**	**Time frame**
9.	On site period of CBA-IPI	8 days	Mth 29
10.	Gap analysis for Level 5	5 days	Mth 30
11.	Bridge process gaps for Level 5	3 months	Mth 33
12.	Implement metrics Note: This is a parallel task	2 months	Mth 32
13.	Stabilize processes and implementation	6 months	Mth 39
14.	Analyze metrics and baseline capabilities Note: This has two more cycles of baselining and is a parallel task	6 months	Mth 39
15.	Phase I of CBA – IPI	10 days	Mth 40
16.	Prepare Exploratory questions for Ph 2	5 weeks	Mth 42
17.	On site period of CBA-IPI	8 days	Mth 43

We thus find that an organization can reach CMM Level 5 capability in about forty three months (approximately three and a half years') and Level 4 within two and half years from starting out at the Initial level. One of our clients was recently assessed at Level 5 and several others were assessed at Level 4 following the methodology given in this chapter. The implementation time frames given above reflect the experience of these clients.

Chapter 8 cites the experience of these companies where this approach has been implemented. Actual time frames in which these companies obtained CMM Level 4 and Level 5 have also been given in that chapter.

CHAPTER 7

METRICS IN A MATURE CMM ORGANIZATION

7.0 Need for Metrics

We have seen earlier in Chapter 3 that the role and importance of quantitative measures in management has been strongly emphasized in the CMM, especially at higher maturity levels. Effective management requires the extensive use of measures – in fact, Drucker equated management with quantitative control. This applies to all management functions. The sales manager knows and tracks his numbers in terms of products sold both by number and value. He also has the breakup available in terms of sales by region, by salesmen, by dealers etc. Similarly, the materials manager has quantitative data on the inventories received, issued and in hand. Likewise the production manager, who monitors the production in his factory by the extensive use of numbers. Unfortunately, this is often not true of the software project manager. Ask him fundamental questions like – "How much did you produce / how soon did you produce / how well did you produce?" and he will, at best, in answer to the first question, be able to tell you how much time he has spent on the project – "Mine was a 15 month project etc." (a measure of input instead of the output). It is therefore, important for the software industry to start to use quantitative measures so that management can be based on objectivity rather than subjectivity or 'gut' feel.

7.1 History of Metrics

The last fifteen years have, however, seen a tremendous increase in the deployment of metrics throughout the world. Actually, measurement research started in the late 60s and early 70s when Lines of Code and bugs counting were done for a large number of projects and models for predicting the quality of software were developed by engineers like Dr Maurice Halstead (the term that he defined included program length, program volume etc.). In 1979, Alan Albrecht published his work on Function Point Analysis (FP) in the IBM Systems Journal. Although similar and in some ways more technically complete size counts like Tom De Marco's Bang Metric [MAR-82] were also in use. Albrecht's FP method came to be widely used and adopted with the formation of the IFPUG (International FP Users' Group) in 1984. Caper Jones

[CAP-91] wrote a book "Applied SW measurements [CAP-91] which did much to spread the knowledge of Function points. FP Counting guidelines were released first in 1984, then in 1994 and the latest one now in 1999 [IFPUG-99]

Also, in the mid 80s, Hewlett Packard embarked upon a concerted measurement drive through the efforts of Robert Grady, Deborah Caswell and others. These were reported in the book "Implementing a Company wide Measurement program" [GRA-86]. This book was instrumental in showing to the world that metrics implementation was effective, provided meaningful results and, as long as certain key principles were kept in mind, was not as difficult as many had initially

thought. The late 80s and early 90s were also the years when CMM and ISO started to draw attention and the important role that metrics played in high maturity organizations was recognized. Since the beginning of the 90s, therefore, interest in the area of quantitative control has been very high, more so with organizations reporting significant successes in their metrication efforts.

7.2 Metrics In CMM

Having provided this backdrop, let us understand what the CMM requirements are in terms of software measurements. CMM discusses these requirements at two levels

- Common Feature – Measurements and Analysis in each KPA (discussed earlier in Chapter 3) has one or more key practices which require the use of measurements to monitor the extent to which the practices given in the Activities Performed Common Feature of the KPA have been performed. This has been expanded upon in Sec 7.3.1
- Specific Practices in the Activities Performed Common Feature have required the use of quantitative measures. This is explained further in Sec 7.3

7.2.1 Common Feature – Measurement and Analysis

We have understood, in Chapter 3, the purpose of the Common Features and their relationship with each other. We learnt that the "Commitment to Perform" and "Ability to Perform" are "enablers" while the "Measurement and Analysis" and the "Verifying Implementation" common features are "evaluators". All these address institutionalization while the "Activities performed" common feature addresses the implementation issue. Let us now understand in detail what the CMM requires from the "Measurement and Analysis" Common Feature

The Measurement and Analysis Common Feature for all KPAs at Level 2 has only one key practice which generally reads as follows (we shall refer to this as the standard measurement practice hereafter)

"Measurements are made and used to determine the status of the _____activities."

The blank is generally filled up with the nature of the KPA activities eg. In the Project Planning KPA, the words are – ""Measurements are made and used to determine the status of the project software planning activities." etc

At Level 3, all the KPAs have at least one key practice similar to that given above. However, some of the practices go beyond determining status of the process implementation

- The quality of the training program (Training Program KPA)
- The effectiveness of management (Integrated SW Management)
- The functionality and quality of software products (SW Product Engineering)

[pp 56, CMM...]

At Level 4 and Level 5 all the KPAs have only the standard measurement practice.

Thus, apart from the Training Program KPA, the Integrated SW Management KPA and the SW Product Engineering KPA, all other KPAs have the standard measurement practice alone. Let us understand this standard measurement key practice, the wording of which is given above. Although an initial reading of this practice seems to suggest that the measurements should focus on determining the extent of progress made in carrying out the activities and thus should look at a planned vs. actual scenario, the "Guidelines for improving the Software Process" [CMM...] provides the clarification that the measures should look at the results obtained in the particular KPA, which then tell us how well the activities performed in the KPA are being done. Measures based on this are identified in Sec. 7.3.3 below.

7.2.2. Metrics Intensive KPAs

There are some KPAs where metrics have been defined extensively in the Activities Performed Common Feature itself. These are :

a) SW Product Engineering at Level 3 : Since this is a KPA that discusses the development and maintenance life cycle (the 'engineering' of the product), CMM provides several insights into the nature of metrics to be captured during the life cycle. Examples of these are defect density, defect age, defect removal efficiency etc.

b) Integrated SW Management at Level 3 : This, being a KPA addressing Project Management issues (an amalgam of Project Planning, Project Tracking and the use of tailoring guidelines to define project specific processes from the organization standard software processed), there are a few quantitative measures which are given here as well. Examples are – estimates of size, effort and cost, risk measures etc. It should be noted that these have also been described in the Project Planning and Project tracking and Oversight KPAs at Level 2 as well.

c) Peer Reviews at Level 3 : - Activity 3 of this KPA reads –"Data on the conduct and results of the peer reviews are recorded". TR 25 also gives examples of such measures which include preparation time, types and number of defects found and fixed etc.

d) Training at Level 3 : - In this KPA, measures have not been discussed in the Activities Performed Common Feature but in the Measurement and Analysis common feature. This has a non standard measurement key practice which reads "Measurements are made and used to determine the quality of the training program". Examples of such measures have been given which include actual attendance, number of training waivers approved over time, feedback from students, results of post training tests etc.

e) Quantitative Process Management at Level 4 – This KPA has dealt extensively with the usage of quantitative measures to manage the project better as well as to bring all processes under quantitative control. Thus, this KPA has discussed the use of control limits and setting up capability baselines. Further insights into this is provided in a SEI report on goal driven measurements [SEI CMM HB003 – CMM...] This KPA has also stipulated that measures like Cost of Quality etc., size, effort and schedule variances should be tracked, so that predictability of processes come.

f) SW Quality Management at Level 4 – This KPA deals with the quality of software and being able to compare this quantitatively with relevant quality goals. Thus, this KPA also focuses extensively on the usage of such quantitative measures that describe various quality attributes of the product eg., functionality, reliability, maintainability etc

7.3 Mapping Metrics to CMM KPAs

Based on all the above and our interaction with various companies, we have provided a set of metrics below which would satisfy all the requirements of CMM KPAs. Please note that this is a superset in that it encompasses all likely requirements. In Section 7.4, we shall distil this set into a recommended subset that companies could use readily

7.3.1 Level 2

Level	KPAs	Key Practices for Common Feature
		Measurement and Analysis
2	Requirements Management	Determine status of activities for managing the allocated requirements
		Eg. status of each reqmt.
		Change activity for reqmts
		: Cum no. of changes to reqmts., total No. of changes proposed, open, approved, incorporated in baseline

Level	KPAs	Key Practices for - Common Feature:
		surement and Analysis
2	SW Project Planning	Determine status of SW planning
		Eg. comparison of milestones for the *actual proj. plg. activities vs. planned*
		: actual effort / cost vs. planned : effort variance – initial estimates vs revised estimates : Schedule variance – initial estimates vs revised estimates : Size variance – initial estimates vs revised estimates

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
2	SW Proj. Tracking & Oversight	Status of SW tracking & oversight activities
		Effort / cost spent in doing tracking
		: Change activity for SW Plan
		Effort variance – initial estimates vs. actuals
		Effort variance–revised estimates vs actuals
		Schedule variance–initial estimates vs actuals
		Schedule variance – revised estimates vs actuals
		Size variance – initial estimates vs actuals
		Size variance – revised estimates vs actuals
		: Changes to SW cost estimates
		Changes to critical computer resource estimates
		: Changes to schedules

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
2	SW subcontract mgt.	Measures to determine status of activities for managing the software subcontract e.g.
		. Actual costs of managing subcontract vs. planned
		.. Actual delivery dates by subcontractor vs. planned
		. Actual delivery dates to subcontractor vs. planned
		. Milestone completion variance
		. Actual testing done vs. planned
		. No. of criteria satisfied vs. planned defect to size ratio vs expected
		. Performance rating

Level	KPA	Key Practices for Common Features
		Measurement and Analysis
2	SW Qty Assurance	Determine cost and schedule status of SQA activities e.g.: - completion of SQA milestones : actual vs. planned - effort spent in SQA: actual vs. planned - no. of product audits : actual vs. planned - no. of activity reviews : actual vs. planned - no. of defects : actual vs. expected, if appropriate - no. of reviews held with customer : actual vs. planned

	KPAs	Key Practices/Common Features	Measurement and Analysis
2	SW Config mgt.	Determine status of SCM activities e.g..	
		- no. of CIs identified	
		- no. of work products identified	
		- no. of change requests processed per unit time	
		- no. of change requests per product	
		- no. of problem reports processed per unit time	
		- no. of problem reports per product	
		- completion of milestones - actual vs. planned	
		- effort in SCM - actual vs. planned	

7.3.2 Level 3 :

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
3	Organization Process Focus	Measurements made to determine status of org's process development and improvement activities e g..
		- work completed - actual vs planned
		- effort spent - actual vs. planned
		- training imparted - actual vs planned
		- Comparison of results of process assessments vs. earlier assessments
		Note: SW process DB should contain process and product measures - this is a commitment feature for next KPA

Level	KPAs	Key Practices for – Common Feature: Measurement and Analysis
3	Organization Process Definition	Measurements are made and used to determine **status of org.'s process definition activities e.g..** - work completed – actual vs. planned - effort spent - actual vs. planned - Contents of process DB may be: : estimates of SW size, effort : actual data of above : productivity data : quality measurements : peer review coverage / eff. : test coverage / efficiency : SW reliability measures : no. and severity of defects in SW reqmts : no. and severity of defects in SW design doc. : no. and severity of defects in SW code

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
3	Training Program	Measurements are made & used to determine status of trg program activities e.g.. : actual attendance vs. expected at each course : implementation of trg plan - actual vs. scheduled : no. of trg. waivers over time : no. of times trg dates were shifted Measurements are made to determine quality of trg program e.g.: : results of post trg tests : review of student feedback : feedback from SW managers

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
3	Integrated SW Mgt.	Measurements are made to determine effectiveness of the integrated SW mgt. Activities e.g · effort spent to manage project - actual vs. planned . frequency, causes & magnitude of replanning effort . for each identified risk, the realized adverse impact vs. estimated adverse impact no. & magnitude of unanticipated major adverse impacts to SW project, tracked over time : Risk forecasting ability index

Level	KPAs	Key Practices for Common Feature: Measurement and Analysis
3	SW Product Engineering	Measurements are made and used to determine the functionality and quality of SW products e.g. - defect category and severity - units containing defect - units affected by defect - activity where defect was introduced - review or test cases that identified the defect - no. of defects, by type and by severity, cumulative and by stage. - allocated reqmts. (equiv. to a "statement of needs" in a non DoD env.) summarized by category (quality attributes like security, performance etc.) and traced to SW reqmts and system test cases. Measurements are made to determine status of SW product engg. activities e.g. - status of each allocated reqmt. throughout the life of project - problem reports by severity and length of time they are open - change activity for allocated reqmts. (changes in customer needs) - effort to analyze proposed changes - average / cumulative - no. of changes incorporated into baseline by category - size and cost to implement and test changes made, including initial estimate, actual size and cost.

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
3	Intergroup Coordination	Measurements are made and used to determine status of intergroup coordination activities e g..
		- actual effort spent by SW engg group for support to other groups
		- actual effort spent by other groups for support to SW engg group
		- completion of specific tasks by SW engg group to support other groups
		- completion of specific tasks by other groups to support SW engg group.

Level	KPAs	Key Practices for – Common Features – Measurement and Analysis
3	Peer reviews	Measurements are made and used to determine status of peer review activities e.g.. - no. of reviews - actual vs. planned - effort spent - actual vs. planned - no. of work products reviewed - actual vs. planned - no. of times reviews delayed - elapse time of reviews – actual vs. planned

7.3.3 Level 4:

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
4	Quantative Process Management - Project's defined SW process is under quantitative control (which implies any quantitative or statistical based technique appropriate to analyze a SW process) IMP.- QPM policy for projects specifically states that sensitive data relating to individual's performance is protected and access controlled. - Org's std SW process is analyzed and a baseline created.	Measurements are made to determine the status of activities for QPM e.g.: - cost over time for QPM activities - actual vs. planned - completion of schedule milestones for QPM activities - actual vs. planned Examples of measurement data captured are: : estimates of SW size, effort : actual data of above : productivity data : quality measurements (no. of QCs done - actual / planned) : peer review coverage / eff. . test coverage / efficiency : SW reliability measures : no. and severity of defects in SW reqmts ; no. and severity of defects in SW design doc. : no. and severity of defects in SW code . no. and rate of closure of action items. IMP Measures are taken from the entire SW life cycle

Level : KPAs	Key Practices for - Common Feature: Measurement and Analysis
4 Software Quality Management - Measurable goals for SW product quality are set and actual progress toward achieving these are measured	Measurements are made and used to determine the status of the SW QM activities e.g.: : cost of poor quality : cost of achieving the quality goals Quality characteristics that may be measured include functionality, reliability, usability. and maintainability. For each characteristic numeric values are defined as goals e.g.. Reliability - MTBF specified in reqmts and that is planned to be achieved Maintainability - Mean time to repair Functionality - the % of overall reqmts. that will be met Goals related to SDLC stages are: - defects related to each stage will be reduced from the previous product release by a pre defined percentage - a predetermined % of predicted defects will be found by the end of the test cycle - a target maximum defect age - - a target max. defect density

Level	KPAs	Key Practices for - Common Feature: Measurement and analysis
5	Defect Prevention	Measurements are made and used to determine the status of the Defect Prevention activities e.g.: : cost of DP activities : effort involved in DP activities : profiles measuring the number of action items proposed, open and completed : number of defects injected in each stage, cumulatively and over various releases of similar products : number of defects : cost of defect correction (including identification) vs. cost of not correcting these defects

Level	KPAs	Key Practices for Common Features: Measurement and Analysis
5	Technology Change Management	Measurements are made and used to determine the status of the Technology Change Management activities e.g.: : cost of TCM activities : effort involved in TCM activities : profiles measuring the number of technology changes proposed, open and completed : the effect of implementing the technology change, compared to the goals

Level	KPAs	Key Practices for - Common Feature:
		Measurement and Analysis
5	Process Change Management	Measurements are made and used to determine the status of the Process Change Management activities e.g.: : cost of PCM activities : effort involved in PCM activities : profiles measuring the number of action items proposed, open and completed, sorted by key process area, each project, group and departments etc : response time for handling process improvement proposals : effect of implementing process improvement proposals : overall performance of the organization's and project's processes, including effectiveness, quality and productivity compared to their defined goals : overall productivity and software quality trends for each project . measures relating to customer satisfaction
		- Ref. CMM – 94 and CMM-93-2

7.4 A set of recommended Metrics to attain CMM Level 4 & 5 maturity

Although we have, in the earlier section, analyzed the requirements for metrics from the CMM point of view, it is important to bear in mind that CMM has, time and again, stressed the need to ultimately choose metrics that are appropriate to the needs of the organization. If the metrics chosen do not satisfy the managerial needs of the organization, then the very purpose of instituting quantitative measures would be defeated. Thus, while the metrics identified below may be an useful guideline, the organization should identify whatever is appropriate to its needs and move forward accordingly. In light of this, we recommend that the metrics set be divided into two :

- Core Metrics
- Tertiary[1] metrics

The Core Metrics address the fundamental management concerns of the organization, in terms of effort, schedule and quality of production while the Tertiary Metrics address the requirements of other processes which the Core Metrics may not have addressed. The Core Metrics set may hence be viewed as a set that the organization cannot do without and therefore, should be mandatory. The set of Tertiary Metrics that we have identified may be tailored according to the business needs of the organization. This is not to suggest that the Core Metrics are not tuned to the organization's business needs but as we shall see, an organization would generally find that it cannot do without the Core Metrics anyway.

It should be kept in mind that this runs counter to the philosophy of the CMM, which has refrained from recommending an overall set of metrics that an organization can use. This is because the CMM has consciously stayed away from becoming a prescriptive model and believed that recommending an overall set of metrics would put the company into a "straight jacketed" frame of thinking. On the other hand, we believe that software organizations are presently groping for answers and insights into what metrics to adopt which would help them satisfy the requirements of CMM Level 4 & 5. Thus, a recommended set of metrics, we believe, would benefit the software industry greatly.

The two sets of metrics – Core and Tertiary are explained below:

7.4.1 Core Metrics

The concept of Core Metrics has been explained above. These metrics are explained below :

7.4.1.1 Schedule variance – Original

Definition : This is defined as :

[1] The term "tertiary" has been used in the sense it is used to describe the educational system – primary education, secondary education and tertiary education. Tertiary metrics, therefore, implies a much more advanced set of metrics than the core metrics

Actual Duration of the project – Original estimated duration x100%
Original estimated duration

Source of data :

- Project Plan for the estimated duration
- Project Status reports for the actual duration
- Project closure reports for the actual duration

Analysis : This metric is useful for the Project Manager to track any variance against the original estimates. It also sheds light on the accuracy of initial estimates. Hence, one organization in India also calls it "estimation accuracy metric".

The organization may set up organization goals with appropriate control limits. Management according to its needs may define the control limits. Typically, organizations set up control limits as +/- 10 % with the target being 0%.

Please note that the definition, as given above, implies that schedule variance can only be done at the end of the project. However the project manager would need to track this metric during the course of the project. The variance should then be computed on the basis of the actual and planned duration of the activities till date.

7.4.1.2 Schedule variance – Revised

Definition: This is defined as :

Actual Duration of the project – Last estimated duration x100%
Last estimated duration

Source of data :

- Project Plan for the estimated duration
- Project Status reports for the actual duration
- Project closure reports for the actual duration

Analysis : This metric is extremely useful for the Project Manager to track the progress of the project. The last revised estimate is taken as the basis here instead of the original estimate which was taken earlier. This metric would be reported in the periodic status reports for review by senior management.

The organization may set up organization goals with appropriate control limits. The control limits may be defined by management according to its needs Typically, organizations set up control limits as +/- 5 % with the target being 0%. This implies that management, in these organizations, is sending out the signal that the variance with the revised estimates should not be

high (a max. of 5%) while in the case of variance against the original estimate, a variance of 10 % would be tolerated.

Please note that , as stated earlier in 7.4.1.1, the definition implies that schedule variance can only be done at the end of the project. However the project manager would need to track this metric during the course of the project. The variance should then be computed on the basis of the actual and planned duration of the activities till date.

7.4.1.3 **Effort variance – Original**

Definition : This is defined as :

$$\frac{\text{Actual Effort} - \text{Original estimated effort}}{\text{Original estimated effort}} \times 100\%$$

Effort may be measured in person days or person months, according to organization practice.

Source of data :

- Project Plan or proposal or contract for the original estimates
- Time sheets or activity recording sheets for the actual efforts
- Project Status reports for the actual efforts
- Project closure reports for the actual efforts

Analysis : This metric is useful for the Project Manager to track any variance against the original estimates. It also sheds light on the accuracy of initial estimates. Hence, one organization in India also calls it "effort estimation accuracy metric".

The organization may set up organization goals with appropriate control limits. The control limits may be defined by management according to its needs. Typically, organizations set up control limits as +/- 10 % with the target being 0%.

Please note that the definition, as given above, does not mean that this variance can only be computed at the end of the project. The project manager would need to track this metric during the course of the project. The variance should then be computed on the basis of the actual and planned effort of the activities till date.

7.4.1.4 ***Effort variance – Revised***

Definition : This is defined as :

$$\frac{\text{Actual Effort} - \text{Revised estimated effort}}{\text{Revised estimated effort}} \times 100\%$$

Effort may be measured in person days or person months, according to organization practice:

Source of data :

- Project Plan for the revised estimates
- Time sheets or activity recording sheets for the actual efforts
- Project Status reports for the actual efforts (these reports may also contain the revised estimates)
- Project closure reports for the actual efforts (these reports may also contain the revised estimates)

Analysis : This metric is extremely useful for the Project Manager to track the effort spent and the extent of variance from the latest planned, if any. The last revised estimate is taken as the basis here instead of the original estimate which was taken earlier. This metric would be reported in the periodic status reports for review by senior management.

The organization may set up organization goals with appropriate control limits. The control limits may be defined by management according to its needs. Typically, organizations set up control limits as +/- 5 % with the target being 0%. This implies that management, in these organizations, is sending out the signal that the variance with the revised estimates should not be high (a max. of 5%) while in the case of variance against the original estimate, a variance of 10 % would be tolerated.

Further, some organizations set up much tighter limits for schedule variance than for effort variance, thus conveying the thinking that while the organization is willing to tolerate effort variance (to an extent), schedule variance must not be there in the project

Please note that the definition, as given above, does not mean that this variance can only be computed at the end of the project. However the project manager would need to track this metric during the course of the project. The variance should then be computed on the basis of the actual and planned effort of the activities till date.

Caveat: Implementing Time sheets

One of the most contentious issues that organizations are faced with, while implementing a metrics program, is the issue of implementing a time sheet system to capture the actual effort spent in the project. We have seen in the above four metrics (and many others that we will see later) that tracking data on effort spent is not only extremely important for project monitoring and control but also for estimating for new projects

Time sheets are most useful as a method of capturing this data since the data can then be captured at source i.e. filled in by the doers themselves. If this were not there, the project manager would have a difficult time in computing the effort spent in a particular month and the nature of efforts spent e.g. how much was spent on requirements analysis, how much on system

design, on testing etc. A well-designed time sheet system, with adequate activity codes, makes the job of collecting effort data much simpler. A list of activity codes is given in Annexure 7.

The problem in implementation arises because most IT professionals start to feel threatened by a time sheet system since they feel that they are now being held accountable for every single hour they spend on the job. This runs counter to the spirit of "free thought and creativity" that is one of the strengths of the IT industry.

We believe that this stems from the fear that the use of time sheets may be misused by management to either point fingers or to demand explanations for too less time or too much time spent on a particular activity. Instead, if the message goes out strongly that time sheet data shall only be used to track project progress and to serve as a basis for future estimation, the time sheet system gets to be accepted very quickly. We have seen an organization in Bangalore where the CEO had sent out an explicit assurance to this effect to all his employees before implementing a time sheet system. Several other organizations expressly prohibit their HR department from having a look at the time sheet data. Others give read permission only to the Project Manager and not to anybody else. Whenever senior management needs to look at the data, they only get aggregated information without the names of employees. Maybe this is symbolism, but we believe that this symbolism is extremely important for a smooth implementation of the time sheet system.

7.4.1.5 Productivity:

Definition: This may be defined as

= Size / Effort.

Thus productivity is measured as Kilo Lines of Code per person day or Function points per person day etc.

To compute this, we need both Size and effort data.

7.4.1.5.1 Size Measures:

Size of the software being produced / ported / tested needs to be measured so that productivity can be computed. Also quality metrics can be effectively compared across similar projects only if size measures are available. However, the size will depend on the type of project being executed. The measure chosen will depend on the type of system. The principles of "Tall Tent Pole Phenomena" (Fred Brooks – BRO-75) and that of "Principal Indicator" (Tom De Marco – MAR-82) viz. "Identify the one characteristic that may be most indicative of the size" should be kept in mind while deciding on the size measures.

Size measures may be Function points or Lines of Code or Feature points or any other that is appropriate to the needs of the organization. We have, during our work with several organizations, helped to define size models for various types of projects and environments e.g. for QO projects, testing projects, systems software projects etc.

7.4.1.5.2 Effort :

Effort may be calculated from the time sheets directly. The total effort is required for computing productivity; however, the breakup of the effort into various activities is required for determining effort required for each KPA – from Level 2 to Level 5.

7.4.1.6 Core Quality Measures:

Quality of the product produced is measured from the defects which are detected by both Testing and review activities. The core measures that an organization should have in this area are:

7.4.1.6.1 Defect density

This metric reflects the "health" of the product created in the sense that a high number of defects shows that, quality wise, a bad product has and leads to a quantitative prediction of product quality.

Definition : This is defined as :

$$DD = \frac{\textit{Total number of defects}}{\textit{Size}}$$

Source of data : Defect data would come in from the "test logs" and "review findings reports". These may be called differently in different organizations but these are essentially the defect logs from review and testing activities.

Analysis : Based on this, organizational norms can be set up. These norms are specific to a class of projects. The defect density of a product can then be compared to other similar products and management decisions can be taken in case the quality is very different from the organizational norms.

This metric is in line with requirements of the Software Quality Management KPA at Level 4 of the CMM.

7.4.1.6.2 Weighted Defect density

This metric takes into account the fact that the severity of defects may not be always the same. Thus some defects may have severe impact while many others may only have a trivial impact. Treating all defects equally and measuring on this basis may lead to distorted pictures emerging from metrics analysis.

The first step thus is to assign a severity level to all defects. Generally severity levels are at three levels -

- Major
- Moderate
- Minor

IBM's severity codes are as follows:

- Total failure / System Crash
- Major Function Failure
- Minor Function Failure
- Superficial

Weights are assigned to each severity level e.g.

Major defects may have a weight of 5, moderate 3 and minor 1. However, from the practical point of view, we find that organizations are reluctant to use weights which appear to magnify their defect density levels. Hence, they use weights like

- Major – 2
- Moderate – 1
- Minor – 0.5

Definition : This metric may be defined as :

Weighted Defect density = (Number of major defects * WMJ + No. of moderate defects * WMD + No. of minor defects * WMN) / Size

Where WMJ = Weight for major defects

WMD = Weight for moderate defects

and WMN = Weight for minor defects

Source of data : The data for this would come in from the same sources as for Defect density i.e. "test logs" and "review findings reports". However, the test logs and the review findings report formats may need to be modified to ensure that severity levels can be assigned to each defect by the tester or reviewer.

Analysis : The analysis is similar to that of defect density. Organizational norms can be set up and the quality of the product may be compared against these.

7.4.2. Tertiary Measures

Having defined certain core measures, it would now be appropriate to examine other measures which would provide additional insights to processes being followed within the organization. Many of these metrics provide insights into the quality control processes used in the company while others measure various key process areas as required by CMM.

7.4.2.1 Defect Age

This is an extremely useful metric for measuring the effectiveness of the quality control processes being used. It essentially measures the length of time a defect lay inside a system without being detected. Thus, the time from which a defect was introduced to the time that it was detected is measured.

Definition: The defect age can be defined in either of two ways:

a) *Defect Age (Time method)*

$$= \frac{\Sigma(\text{Time detected} - \text{Time Introduced})}{\#\ \text{of defects}}$$

This will give the average elapse time for which the defect lay in the system without being detected for a specific project. However, the elapse time method is not very useful to compare across projects. The wide variation in duration that one project may have from the other will mean that a defect age of, say, 3 months for a small project with a total elapse time of 4 months may be alarming, while the same number may not be a cause for concern for a 36 month project

This makes us consider an alternate method i.e. computing Defect Age by the Phase Numbers method

b) Defect Age (Phase method) : In this method, phase numbers are assigned to each phase e.g.

- *Project Initiation – Phase 1*
- *Requirements Analysis – Phase 2*
- *Software design – Phase 3 etc.*

This metric is defined as:

$$\text{Defect Age} = \frac{\Sigma(\text{Phase detected} - \text{Phase Introduced})^2}{\#\ \text{of defects}}$$

Based on information on the phase in which the defect was detected and the phase in which it was introduced, the defect age is calculated

Source of data: The phase detected and the phase introduced should be logged in the defect log sheets. The phase detected is the phase in which the relevant quality control activity was done. The comparatively difficult data to fill in is the phase introduced. We recommend that this should be filled in based on the subjective opinion of the reviewer or the tester. You would never be able to know if the data pertaining to the phase introduced was exactly correct; however what

is important is that the opinion of the reviewer or tester will be correct in at least 90 % of the cases.

Analysis: In the ideal scenario the defect age should be zero, since strong quality control processes (reviews or testing) should be able to detect the defect in the same phase in which it is introduced.

This metric sheds useful light on the effectiveness of the quality control processes used in the project. If the defect age is high, then it would mean that the quality control at each phase is weak and has allowed the defects to leak from one phase to the other. Hence this is also called the Defect Leakage Metric.

7.4.2.2 Defect Removal Efficiency (DRE)

This measure was first used by Grady [GRAD-86] at HP, USA. This is also a measure of the effectiveness of the quality control processes in the project. However, unlike Defect age which provides an insight into the various QC processes used, this metric measures the effectiveness of the aggregate of QC in the project.

Definition: This is defined as:

$$DRE = \frac{\text{\# of defects before shipment}}{\text{Total \# of defects (before and after shipment)}} \times 100\%$$

Source of data: No new sources of data need be there for this. The numbers would be available from the defect logs used in the project. The problem would however be in determining what the total number of defects should be, since defects could continue to be found even a long time after shipment. We recommend that organizations fix a time frame uptil which they would wait , the assumption being that all defects found within that period would be all that would ever be found.

Thus *total # of defects may be defined as = Defects found before shipment plus those found within a year after shipment.*

Most organizations in India are not able to get even this data since most projects that they execute from India are either development projects or maintenance projects but not both (For the above data, the project should have been involved in both development and maintenance of the system, otherwise it would not be possible to get this data). We therefore recommend that they assume that:

Total # of defects = Defects found till acceptance testing

Defects found before shipment = Defects found before acceptance testing

Analysis: The DRE figure should be as close to 100% as possible. Grady found, in his research, that good organizations in the world have DRE > 90% (GRADY-86). A high DRE figure shows that the quality control processes used in the project were effective in removing most of the defects before shipping the product to the client. A low DRE figure shows that many defects were found after shipment.

Based on analysis of past data, capability baselines and control limits may be set up so that projects could compare their performance against these.

7.2.4.3 Test Effectiveness Ratio (TER):

This is also known as Test Coverage Ratios. There are three types of TERs (NCC ..) that may be calculated:

Definition:

$$TER\ 1 = \frac{\#\ of\ LOC\ tested}{Total\ \#\ of\ LOC}$$

$$TER\ 2 = \frac{\#\ of\ branches\ tested}{Total\ \#\ of\ branches\ in\ a\ program}$$

$$TER\ 3 = \frac{\#\ of\ paths\ tested}{Total\ \#\ of\ paths\ in\ a\ program}$$

Source of data: For capturing this data, tools need to be used. Without tools, it would be very difficult to compute this metric. Most test tools provide data on TER1 and TER2; however only a few like Logiscope etc. provide TER3 data (NCC..).

Analysis: These metrics are generally relevant for determining if the testing done at a program level (white box testing) has been adequate or not.

Goals can be set for each of the TER metrics – an example of such goals would be:

- 100 % for TER 1 and TER 2 during white box testing
- 70 % for TER 3 during black box testing

Although intuitively it would seem that goals for TER 3 should also be 100 %, organizations would find it very hard to achieve since the number of combinations of paths would be very large. Hence during black box testing (system testing, acceptance testing etc.) they would be satisfied if at least 70 % of the paths have been exercised at least once.

7.4.2.4 Review Coverage Ratio

This is a set of measures that determine the extent (coverage, not depth of review) to which the various review artifacts have been reviewed. The relevant review artifacts may be Requirements specifications, Design specifications, code etc.

Definition: The various definitions are:

$$\textit{Requirements Review Coverage ratio} = \frac{\textit{\# of requirements reviewed}}{\textit{Total \# of requirements}}$$

$$\textit{Design Review Coverage ratio} = \frac{\textit{\# of design specifications reviewed}}{\textit{Total \# of design specifications}}$$

Source of data: This data would be available from the review sheets. The reviewer would need to fill up this data. The total number of specifications may also be obtained from the Traceability Matrix, if available.

Analysis: The goals for Requirements review Coverage and Design review Coverage should be nothing less than 100 % . The goals for code reviews may be set at lower numbers and may be based on control limits obtained from past data.

7.4.2.5 Defect Distribution

This set of measures provides a view of the distribution of defects across the various phases in the project.

Definition: Various definitions would apply for various phases as given below:

$$\textit{Requirement defects ratio} = \frac{\textit{\# of defects found in requirements phase}}{\textit{Total \# of defects}}$$

$$\textit{Design defects ratio} = \frac{\textit{\# of defects found in design phase}}{\textit{Total \# of defects}}$$

Source of data: This data would be available from the defect logs

Analysis: Based on this set of measures, a defect profile could be drawn up. An expected number of defects for each phase could then be known from the defect profile and the defect density. The project manager could then use this information to compare with the actual defects found in each phase and take management decision on whether further reviews / testing are necessary, rework is necessary or not etc.

It is useful to represent the defect profile in the form of pie charts showing the defect distribution across phases.

The above metrics related to the quality of a product. The following relate to other Key Process Areas in the CMM.

7.4.2.5 Requirements Stability Index

As the name implies, this provides insights into the stability of requirements during the life of the project.

Definition:

$$\textit{Requirements stability Index (RSI)} = \frac{(1 - \#\ \textit{of changes to requirements}\ )}{\textit{Total \# of requirements}} \times 100\%$$

Source of data: This data will be available from change requests the traceability matrix.

Analysis: This metric is very useful for an objective evaluation of changes to scope of work and functional requirements. This metric may be used for extensive root cause analyses of other metrics e.g. it would be logical to find that the effort variance was very high in cases where RSI is very low.

This would be an useful metric to measure the effectiveness of the Requirements Management KPA at Level 2 of the CMM

7.4.2.6 Effort Distribution

Similar to defect distribution, this measures the effort spent in each phase as a percentage of the total effort in the project. There would therefore be various measures within this set.

Definitions:

$$\textit{Requirements analysis effort ratio} = \frac{\textit{Effort spent in Reqmt. Analysis}}{\textit{Total effort for the project}} \times 100\%$$

$$\textit{Design effort ratio} = \frac{\textit{Effort spent in Software design}}{\textit{Total effort for the project}} \times 100\%$$

$$\textit{Project Management effort ratio} = \frac{\textit{Effort spent in Project Management}}{\textit{Total effort for the project}} \times 100\%$$

$$\textit{Review effort ratio} = \frac{\textit{Effort spent in reviews}}{\textit{Total effort for the project}} \times 100\%$$

$$\textit{Configuration Management effort ratio} = \frac{\textit{Effort spent in Config Management}}{\textit{Total effort for the project}} \times 100\%$$

Similarly, a number of other metrics could be defined depending on the activities that one would like to track for a project. The effort spent for each KPA in the CMM would be tracked which will lead to knowing, at any point of time, the effort in these areas. The effort in any one KPA may also be the summation of all effort spent in related activities e.g. the effort spent in doing TCM activities at Level 5 may be the sum of efforts spent in tool evaluation, R&D activities, tool implementation on a pilot basis etc.

Sources of data: All data for these would come in from the time sheets. All that would be required would be an appropriate set of activity codes. A sample list is enclosed as Annexure 7.

Analysis: Similar to defect distribution, an effort profile for the project can be drawn up with the data available for past projects. Thus, one would be able to predict that project management effort accounts for x% (say, 15%) of total effort on the project. Similarly, other predictions can be made. These would be useful for estimating effort on the project, especially if the task based method of estimating is being used.

Apart from effort estimation, the effort distribution is also useful for tracking productivity during the course of the project. Based on productivity and estimated size, the estimated effort for the project is obtained. Thereafter, based on the effort distribution, the effort in each phase can be estimated. This is documented in the project plan. The effort variance metric, explained earlier in this thesis, is then used to monitor progress, thereby giving the project manager if the productivity he is achieving is on track or not.

7.4.2.7 Mean Time to Repair (MTTR)

This is a very useful metric for maintenance projects; in fact, for certain production support type of projects, this may even be construed to be a Core Metric since metrics like effort variance, productivity etc. may not be easy to compute for such projects.

Definition:

$$MTTR = \sum \frac{(Time\ problem\ resolved - Time\ problem\ reported)}{\#\ of\ problem\ reports\ in\ project}$$

Sources of data: Data for this would be available from the tracking sheet used for logging the problems reported by customer.

Analysis: MTTR is useful for objective evaluation of an organization's performance in providing maintenance services. In a way, it is a surrogate measure for productivity for such projects where determining the size of each and every problem report may not be possible. This measure is also called as "Turnaround time".

Based on past performance, target values for MTTR may be obtained with appropriate control limits. These values may then serve as the basis for service level agreements with the customer.

7.4.2.8 *Mean time to baseline (MTTB)*

This metric measures the effectiveness of the Configuration Management Key Process Area.

Definition:

$$MTTB = \frac{\sum (Time\ CI\ baselined - Time\ CI\ approved)}{\#\ of\ CIs\ in\ project}$$

where CI = Configuration Item

Sources of data: This data would be available from the document Master list or the Configuration Control Register or any equivalent form of status accounting in the project

Analysis MTTB provides an insight into how quickly the project is able to move the Configuration Item into the baselined library, once it has been approved for such base-lining The expected MTTB in an effective and simple CM process would be a value very near zero

We had once studied an organization where the MTTB was as much as 15 days. This was a cause of concern since it meant that the organization had probably a very cumbersome configuration management procedure. It turned out to be true – there was only one configuration controller for this 500 employee strong organization. All CI s had to be sent up to this one person who was generally so busy with his other managerial responsibilities (he was a Vice President in this company) that he could do the baselining work only once in a fortnight

Based on past performance, target values for MTTB may be set up with appropriate control limits.

7.4.2.9 *Metrics From the Quality Assurance and SEPG Areas*

Processes like process definitions, internal audits, process improvements etc. may be measured by some or all of the following metrics

a) *Average non conformances per audit* = $\frac{No.\ of\ Non\ conformances}{No.\ of\ audits}$

Like the defect density measure for products, this may also be weighted in terms of major and minor non-conformances. This may also be done KPA wise so that a process health profile may be drawn up (similar to a product profile)

b) *Average NC closure time* = $\frac{\Sigma Time\ taken\ to\ close\ a\ NC}{No.\ of\ NCs}$

This is a measure which is calculated for each internal audit and shows the responsiveness of the auditees in getting the NCs resolved

c) Effort distribution for process related activities: Again, a set of activity codes would suffice to provide these data. Effort spent in process definition, process improvement and internal audit activities could be tracked.

d) Frequency of process improvements: This could be measured by the number of process improvements made per unit time e.g. 5 process improvements per month etc. This would show the extent to which the Quality Management System is "live" within the organization.

e) Frequency of process change requests: This could be measured by the number of process change requests made per unit time e.g. 3 process change requests come in on the average per week etc. This would show the interest of the users in ensuring that their Quality Management System meets their needs. This would serve to meet the measurement needs for the Process Change Management KPA at Level 5

f) Status of process improvement (PI) suggestions e.g. number of PI suggestions open and closed

g) Status of Technology change proposals: A number of measures from the Technology Change Management KPA at Level 5 could be taken e.g. number of TCM proposals open and closed, frequency of TCM proposals, benefit accruing from TCM proposals in pilots / organization wide etc.

h) Status of Defect Prevention proposals: These would be similar to the TCM measures given above, except that these may also be tracked project wise.

7.4.2.10 Metrics from the Training process

The training processes may be measured by the following metrics:

a) *Average training feedback score* $= \frac{\Sigma \text{training feedback scores}}{\text{No. of participants}}$

This would serve as an objective evaluation of the training course. Each training course would then have a metric as defined above. Averaged over a number of training courses, an average of the average training feedback score would be computed and would serve as the capability baseline for the organization.

Target values could then be set up as improvements over past data. Together with appropriate control limits, the training process performance could be very tightly monitored.

The nice thing about this metric is that the training area is very data rich (If each training program has around 20 participants, only 20 programs a year would give around 400 data points to analyze). The data can be partitioned into various types of training e.g. technical training, soft skills training, quality training etc. and different target values set up for each.

a) Average training days per employee per year: *This could be defined as:*

$= \frac{\text{No. of training days in this year} * \text{Total No. of participants}}{\text{No. of employees in organization}}$

The senior management could set up a goal for this metric e.g. 5 days per head per year and the actual performance monitored against this goal.

7.4.2.11 Metrics from the System Administration function

We are assuming here that the System administration function is the one which is responsible for hardware, system software, network maintenance etc. This function may be measured by the following metrics:

a) Mean Time to Repair (MTTR) : This is defined in exactly the same manner as earlier. To repeat,

$$MTTR = \frac{\Sigma (\text{Time call resolved} - \text{Time call made to Sys Admin})}{\#\ \text{of calls made in time period}}$$

The MTTR is calculated for a specified time period, generally a month. The term "call" has been used here instead of "problem report" that we used earlier, since in the System Administration function, these terms are more widely used.

Communication Link up time

$$= \frac{\Sigma \text{No. of hours communication link was up}}{\text{No. of available hours in time period}} \times 100\%$$

b) Server up time

$$= \frac{\Sigma \text{No. of hours server was up}}{\text{No. of available hours in time period}} \times 100\%$$

c) Desktop up time

$$= \frac{\Sigma \text{No. of hours desktop was up}}{\text{No. of available hours in time period}} \times 100\%$$

For all the uptime metrics, the available hours means the number of hours that the equipment should have been up. Therefore this would discount the fact that the desktops need not be available in the night etc.

Based on this, service level agreements could be drawn up between the projects and the System Administration function.

Of course, several other metrics could also be computed from this function relating to activities like back ups, disaster recovery etc.

The above section provides the metrics canvas. Several other metrics may be captured, depending on management priorities, problem perceptions etc. However, we believe that the set given above would suffice to give the organization a solid foundation on which it can move on to achieving CMM Level 4.

7.5 Base-lining process capabilities

Activity 7 of the Quantitative Process Management KPA requires that "the process capability baseline for the organization's standard software process is established and maintained." (CMM Key Practices ver 1.1). The sub key practices provide, inter alia, the following explanations:

- The project's process data is summarized in the performance baseline and this is recorded in the process data base
- The process performance baseline for each project is incorporated into the organization's capability baseline
- Capability baselines are documented
- Capability trends are examined to predict likely problems and likely improvement opportunities

Capability baseline means that the organization's capability is known in quantitative terms, *at a specific point of time*. Similarly performance baselining means that the project's performance is known at any specific point of time.

The distinction is made between performance baseline and capability baseline in that performance is linked to a project while capability is that of an organization. An aggregate of project performances lead to a buildup of an organization's capability. Performance relates to the past while capability relates to the future – the former is ex post while the latter is ex ante.

These baselines are built up by performing periodic analysis on the data. As described earlier, we generally recommend that these baselining exercises be done at least once every 3 months. These are then documented in the form of baseline reports and published organization wide so that all concerned projects could use these for managing their projects and to estimate for new projects. During these baselining exercises, the project data for each metric is analyzed and the following computed:

- Arithmetic mean.
- Control limits

These have been described in greater detail in various sections below. We also see, in Chapter 8, examples of some baselines in some companies we worked with.

7.5.1 Aspects of Process Measurement

While building up process capability baselines, it is useful to understand concepts of

- process stability
- process compliance

- process capability
- process improvements

from the point of view of measurements and statistical analysis. The SEI has explained these through a measurement handbook titled "Practical Software Measurement" (SEI-)

a) Process Stability

This is considered by many to be at the core of process management.

Stable processes lead to predictable results, which in turn is synonymous with "in control" Variations in results (product or service) are studied. The sources of these may be grouped into two :

- Variations due to *common* causes, i e causes that are linked to the processes being followed or other underlying reasons which will keep repeating themselves. These variations can only be removed by improving the process
- Variations due to *special* causes i e causes that are in the nature of chance or any reason which happened due to a special combination of circumstances and is unlikely to repeat itself

To determine if a process is stable, please refer to Section 7.4.2 below

b) Process Compliance

For a process to be stable, it must be operated consistently. If this is not done, the causes for the variation in performance will not be known. Thus process compliance needs to be looked at as well. These are looked at from three aspects:

- Fitness of organization - The extent to which an organization is able and ready to use a particular process. Thus, issues of people awareness, training, tools etc. to execute the processes need to be looked at.
- Use of the defined process - The extent to which the processes are used
- Oversight, benchmarking and assessment of processes - Formal measures eg. CMM Levels may exist to benchmark the maturity of an organization's process

c) Process Capability

This aspect of process measurement examines the question of whether or not the process is meeting its goals. These goals may be business goals, customer defined goals, project goals etc. If the statistical analysis shows that we are consistently doing equal to or better than the targets, we can infer that the processes followed are capable.

An example to illustrate the above is a measure to determine the mean response time to customer calls. If the target is 2.25 hours and statistics show that the mean response time is consistent around 2 hours, it can be taken to reflect the ability of the customer handling process in meeting its goals. Similarly, if the customer has defined that defect density should not exceed 0.75 defects per Function Point, and our data shows that our average Defect Density is 0.70 Defects per FP, we can conclude that our quality assurance and control process is capable of meeting customer needs.

d) Process Improvements and investments

Identifying changes is not enough. These should lead to process improvements. At the same time, the costs associated with these needs to be looked at and compared with the likely benefits. Financial indicators may of course be used but in the software environment, many other non conventional measures like Customer satisfaction, productivity, quality, delivery time etc. may also be looked at.

7.5.2 Use of Control Charts for Establishing Baselines

Control charts are strongly recommended by the SEI for analysis of the metrics data collected.

The concept of control charts was first introduced by Walter Shewhart of Bell Labs in 1924 and further refined in his landmark book – *Economic Control of Quality of Manufactured Product* – 1931 [SHE-31; DAN-92]. These charts are used as a decision making device to determine if the attribute of the product or process being measured is a cause for management intervention or not.

It consists of three horizontal lines – the center line is the average of the data points with the top line representing the *upper control limit (UCL)* and the bottom line representing the *lower control limit (LCL)*. (See Fig 7.2). As long as the points fall within the control limits, we do not question the quality of the product and believe that the process is in control. If a point falls outside the limits we examine the reasons for this variation. If the variation is due to chance alone (or special cause, in Deming's words – DEM-86) we say that the process is still under control. However, if there is an assignable cause (or common cause, as Deming put it – DEM-86), we conclude that the process is out of control. We then decide on the actions required to bring the process back under control.

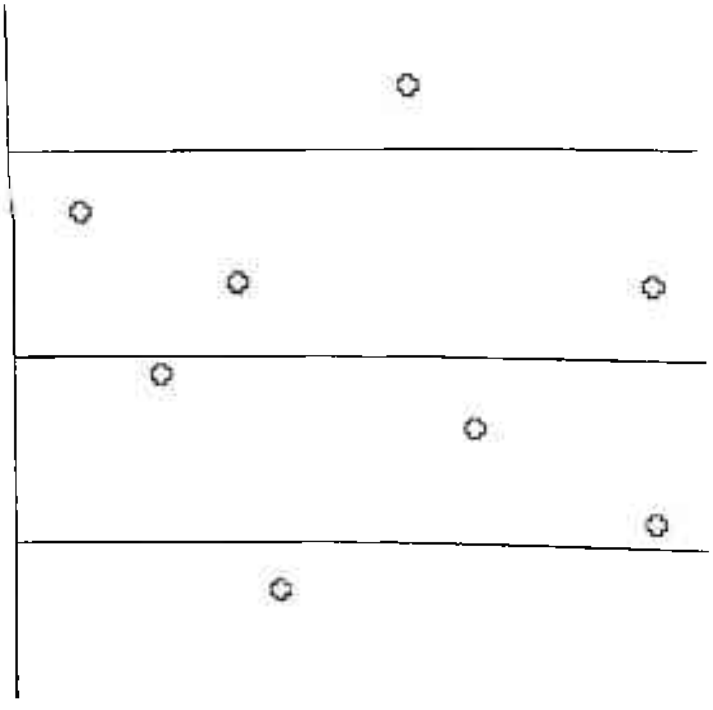


Fig. 7.2

The control chart shown in Fig 7.2 shows two points outside the control limits – one above the UCL and the other below the LCL.

Control charts are used for analyzing:

- Process stability
- Process capability

7.5.2.1 Process Stability

A stable process is one that is in statistical control – the underlying distribution of its measurable characteristics are consistent over time, and the results are predictable

Control limits can be set and if the results fall outside these limits, the process may be said to be out of statistical control or, in other words, unstable These limits are generally called Upper Control Limit and Lower Control Limit.

Several norms exist for determining if the process is unstable Some of these are

Test 1: A single point falls outside the 3-sigma (std. Deviation) limits

Test 2: At least two out of three successive values fall on the same side of, and more than two sigma units away from the mean

Test 3: At least four out of five successive values fall on the same side of, and more than one sigma unit away from, the mean.

Test 4: At least eight successive values fall on the same side of the center line i.e mean.

Thus to determine instability in a process, control limits need to be set and tests such as the ones stated above applied.

7.5.2.2 Process Capability

Once a process is brought under statistical control i.e. process is stable, the capability of the process may be analyzed.

This is done by using the Natural process limits method: The data reported during a period of stability is plotted either as histograms or as control charts and *Natural Process Limits* set. SEI recommends that these be set as + or – 3 sigma around the mean. These are therefore the same as the Upper and Lower Control Limits in a period of stability.

Once these Natural process Limits are set and adhered to by the process, the capability of the process may be measured by determining if these fall within the *Specification Limits* or the limits imposed by the business or customer needs.

If it does, it is safe to assume that all products produced by the stable process will continue to meet the needs of the business or the customer *and it is therefore a capable process.*

When one or both the Natural Process Limits (as explained above) fall outside the business specification limits, the process may be stable but *is obviously not capable.*

7.5.2.3 Deciding on Control Limits

Deciding on the values of the UCL and LCL is an important step in constructing the control charts during the metrics analysis exercise.

Generally, the control limits are based on the value of standard deviation σ. We have seen earlier that the Natural process limits and the ones recommended by SEI are the mean +/- 3σ. At these values, 99.7% of the data points would lie inside the control limits, assuming a normal distribution for the data.

At values of : Mean +/- 2σ, 95 % of the data points would lie inside the control limits while at values of: Mean +/- σ, 68% of the data points would lie inside the control limits.

These statistical rules are used for setting the control limits.

When the value of σ is small, we recommend that the specification limits be kept at Mean +/- 3σ.

As σ becomes higher, we set the specification limits at Mean +/- 2σ, while if the value of σ is very high, we set the limits as Mean +/- σ.

We generally set the following rules:

a) If σ is not greater than 10% of mean, then control limits are Mean +/- 3σ

b) If σ is greater than 10% of mean, but not greater than 25% of mean , then control limits are Mean +/- 2σ

c) If σ is greater than 25% of mean, but not greater than 50% of mean , then control limits are Mean +/- σ

d) If σ is greater than 50% of mean, then control limits are Mean +/- 0.5σ

Having discussed, in this chapter, the metrics that an organization needs to have to be at Level 4 and Level 5 and the means of setting up capability baselines, we shall see, in the next chapter, the practical implementation of these and how these have been implemented in several software organizations across India.

Part III

PRACTICAL IMPLEMENTATION OF THE METHODOLOGY

Chapter 8 : Validating the Approach – Experiences from Industry

Chapter 9 : Future Research Directions and Conclusions

CHAPTER 8

VALIDATING THE APPROACH – EXPERIENCES FROM INDUSTRY

8.0 Introduction

The approach given in Chapters 5 and 6 has been implemented by us in a large number of software organizations in India. In this chapter we have documented the experiences of 10 of these companies. All these companies are primarily engaged in software export in domains ranging from business applications software to systems software to internet and multimedia software development. Some of these companies are product development and maintenance companies as well. The names of the companies whose experiences have been documented are given below :

1) HCL Perot Systems, Delhi and Bangalore
2) Information Technologies India Ltd., Delhi
3) Hexaware, Chennai and Mumbai
4) Patni Computers, Mumbai
5) Tata Interactive Systems, Mumbai
6) HCL Technologies, Noida
7) RS Software, Calcutta
8) BFL Software, Bangalore
9) Oracle Systems, Bangalore
10) EDS India, Delhi and Chennai

The implementation approach followed by these companies have been described in Section 8.1. To the extent that information about their implementation approach has been made public by these companies, we have reported specific implementation approaches followed by each company. All information that is confidential in nature and have not been made public as yet have been reported without attributing to any specific company – thus terms like company A, company B, company C etc. have been used.

8.1 Implementation Approach Followed By Various Companies

The approach that we have recommended in Chapter 5 namely, first ISO then SEI-CMM Level 4 was implemented in the organizations mentioned above. As we shall see, almost all these

organizations first implemented ISO and then went in for CMM. Most of them were able to get ISO in around 12 months time and CMM Level 4 in another 12 months from then. There were indeed some instances where these time frames showed significant variation and we have examined the reasons for these as well. The main reasons for these were either the top of "waiting for perfection" or else a serious lapse in management commitment somewhere along the way. There are also instances of companies which after obtained ISO went into a "wait" mode which meant that they were not making any further progress towards CMM. The experience of two of these companies have been documented in detail while for the others a broad overview along with an analysis of the problems encountered have been given.

8.1.1 Company A

This organization has around 800 employees now. It was started in late 1996 and is a joint venture between a major IT company in Delhi and a large systems integrator in the USA. Its focus is on business application software on both main frames and Client Server platforms. Of late it has transitioned heavily into e-commerce applications.

It started its implementation of the quality system in March 1997 and obtained ISO certification in March 1998. It was assessed for CMM Level 4 in June 1999 and for SEI CMM Level 5 in February 2000. The important milestones on its quality journey were as follows :

- Launch ISO 9001 and Gap Analysis, March 1997.
- Definition of processes, March to June 1997.
- Organization wide training on processes, June to July 1997
- Deployment of QMS, July 1997.
- Internal Audit 1, September 1997.
- Internal Audit 2, November 1997.
- Internal Audit 3, January 1998.
- Pre assessment audit, February 1998.
- Internal Audit 4, March 1998.
- ISO Certification audit, March 1998

Total period for ISO implementation - 12 months.

The important milestones on its journey from ISO to CMM Level 4 were as follows :

- Process Gap Analysis for CMM Level 4, May 1998.
- Metrics Gap Analysis, June 1998.

- Metrics process – definition, June to August 1998.
- Development of size and estimating models, June to October 1998.
- Deployment of an activity recording system, June to July 1998.
- Deployment of a defects capturing system, July to August 1998.
- Development of a Metrics Management system, July to October 1998.
- Baseline Report, First round, December 1998.
- Baseline Report, Second round, February 1999.
- Baseline Report, Third round, May 1999.
- CMM Assessment, Phase I, May 1999.
- CMM Assessment, Phase II, June 1999.

Important milestones on its journey from Level 4 to Level 5 were:

- Gap analysis for Level 5 – July 1999
- Bridge process gaps – Aug 1999
- Baseline report, Fourth round, Nov 1999
- CMM Assessment, Phase I – Jan 2000
- CMM Assessment, Phase II – Feb 2000

Thus, the time frames for this company can be summed up as follows:

- Level 1 to ISO 9001 : 12 months
- ISO 9001 to Level 4 : 13 months
- Level 4 to Level 5 : 8 months

Hence, TOTAL time taken by this company to reach Level 5 from Level 1 was 33 months (while Level 1 to Level 4 was 25 months). These results are much better than that we had proposed in Chapter 6.

8.1.2 Company B:

This organization is part of a large industrial electronics group based in Delhi. It has around 400 employees now and has been engaged in software development for clients in UK, Korea and Hong Kong for the past 8 years. It is now involved in product development for the Internet business as well.

This organization started its journey towards quality fairly early in June 1994 but had not made much progress till as late as December 1996. The reason for this was that they were waiting for perfection to emerge from the quality system. This is a phenomena that we have cautioned against in Chapter 5 and our note of caution was primarily based on the experiences of this company.

We were engaged by this company as an ISO consultant in January 1997 and our first step was to ensure that processes start to get deployed at the earliest. For this organization we believed that too much time had already been lost and that it would be counter productive to try and fine tune the processes even further. We were able to move this company to obtain ISO certification by June 1997. The significant milestones that this company encountered were :

- Start of definition of QMS, June 1994.
- Initial deployment of QMS, October 1996.
- Internal Audit No. 1, December 1996.
- Re deployment of QMS, February 1997.
- Internal Audit No. 2, March 1997.
- Internal Audit No. 3, April 1997.
- Pre assessment, May 1997.
- Internal Audit No. 4, end May 1997.
- Certification audit, June 1997.

After having obtained ISO, Company B made no progress towards moving on to CMM. It was partly due to the management perception that system should stabilize first before moving towards CMM but more importantly there was a change of management which then led to a lowering of management commitment.

Management commitment was again reinforced around May - June 1999 after which the organization has been moving rapidly towards implementing CMM requirements. It should be assessed at CMM Level 4 by May 2000. The milestones from June 1999 till date has been as follows :

- Process Gap Analysis, June 1999.

- Metrics Gap Analysis, June 1999.
- Process documentation, modification and deployment of revised QMS, August 1999.
- Definition of metrics completed by August 1999.
- Size and estimation modeling completed by October 1999.
- Deployment of a time sheet system, August 1999.
- Deployment of a defects tracking system, November 1999.
- Baseline report No. 1, December 1999.
- Baseline Report No. 2, February 2000.

It is expected that this organization will be able to do two more cycles of capability baselining before their assessment in May 2000.

8.1.3 Company C

This organization based in Calcutta was started in March 1995 and focussed on software development for business applications for overseas markets. It had around 75 people by January 1996 when it decided to go in for ISO 9001 as a first step towards eventual CMM implementation. It obtained ISO certification by March 1997 It then decided to move on to CMM very quickly. However, due to a change of management representative as well as the senior management, there was a stoppage of activity on the process side for almost 2½ years. It has now started to get serious about CMM implementation and hopes to be assessed at CMM Level 4 by October 2000.

8.1.4 Company D

This is an interesting case. It had initially started off by planning to go in for the traditional route of CMM implementation and had fixed its goal at implementing CMM Level 3 by December 1997. By December 1998, it had realized that implementing CMM Level 3 would be extremely difficult. The obstacles that they faced were similar to what we explained in Chapter 4. They then revised their approach and decided to move in to ISO first. They obtained ISO in August 1999 and hope to get CMM Level 4 by June 2000.

8.1.5 Company E

This organization is the Indian subsidiary of a very large data base software organization (amongst the top five in the world). There was a specific direction from world Headquarters, given in early 1997, that software development centres around the world should be at Level 3 and above by December 1999. Therefore, there was no marketing reason for this organization to move towards ISO. They tried to implement CMM for about 8 months in 1997, found that they were not making too much progress, then decided to move towards implementing ISO which they did by April 1998. By March 1999, they had been a sessed at CMM Level 4, nine months before the deadline imposed by their world headquarters

8.1.6 Company F

This again is an instance of an organization which is a subsidiary of a very large organization based in the US. Again there was a directive from the world headquarters to be at CMM Level 2 or at ISO 9000 by December 1998. They tried to implement CMM Level 2, gave up after a year and then moved on to implementing ISO which they were able to do by October 1998.

8.2 Metrics in Use in a Few Software Companies

We were also privileged to implement metrication programs in most of the companies mentioned above (in all cases except Company F, where I went in as the certifying auditor, we provided consultancy all the way through till CMM Level 4 and 5). The approach that we used in all these companies was in line with those defined in Chapter 7 namely, we helped them to define core metrics as well as tertiary metrics (they were not always called by these names – some of these companies felt that giving them items like core and tertiary would send a signal to the software development teams that the tertiary metrics are not important).

We have documented, in the following pages, the metrics used by some of these companies. We have also provided an insight into an analysis done by these organizations in arriving at their capability baselines. Samples of reports from their baselines have also been given. Unless otherwise stated, the metrics definitions are consistent with the ones we gave in Chapter 7. Again company codes have been used to protect the confidentiality of information.

8.2.1 Company A: (same as mentioned in Section 8.2 above)

8.2.1.1 The projects were divided into the following categories. These are the buckets of data on which analysis could be done in a consistent manner.

Project Type	Description
Y2K	Following sub-types have been defined based on scope and usage of tools
Y1	Impact assessment + Renovation
Y2M	Impact assessment + Renovation + Unit testing, Manual
Y2T	Impact assessment + Renovation + Unit testing; Tool based
Y3M	Impact assessment, Manual
Y3T	Impact assessment; Tool based
ST	System testing

Client Server	Development projects in C/S environment
Migration	Migration of programs from one hardware and/or software environment to another
Object Oriented	Development projects in OO environment
System Software	Scope is restricted to writing and maintaining scripts
Mainframe Development	Development projects in Mainframe environment

8.2.1.2 The metrics defined[2] in this organization were :

- Schedule variance – only the variance between the actual and the last revised plan was taken. This is therefore, equivalent to the SVB that we defined in Chapter 7
- Effort variance – again same as above
- Defect density.
- Weighted Defect density – The weights used for the severity of the defects were – 7 for fatal, 3 for major and 1 for minor. This thus gave more importance to the most severe defects rather than treating all of them the same way.
- Productivity.
- Review effectiveness.
- Phase wise distribution of efforts.
- Phase wise distribution of defects
- Percentage of efforts spent on project planning compared to the total effort for the project
- Percentage of efforts spent on project tracking compared to the total effort for the project
- Percentage of the efforts spent on configuration management compared to the total effort for the project
- Percentage of efforts spent on software quality compared to the total effort for the project.
- Percentage of efforts spent on inter group co-ordination compared to the total effort for the project.
- Reviews.
- Technical (Project life cycle phases)

[2] The definitions used were generally consistent with those we defined in Chapter 7. We have defined them explicitly only in the instances when they are different from those we provided in Chapter 7.

In addition the following metrics from the following areas were also analyzed :

- Training
- Facilities management
- Customer feedback

The analysis from the training area have been included in the attached Exhibit 1 as well.

8.2.1.3 Analysis of the data to arrive at capability baselines

8.2.1.3.1 Methodology followed in each round of baselining were :

- Collate the metrics data from all on going projects as well as closed projects.
- Compute the mean and standard deviation for each of the metrics identified in 8.3.1.2.
- Establish the baseline and control limits for each project category as follows :
  - Baseline = Mean
  - Control limits = Mean +/- n(S.D.), where n is taken as 3 if S.D. is less than 10% of mean, else n is taken as 1.
- In some cases, senior management may set control limits as targets. This is especially true for effort variance and schedule variance.
- Plot all data points (those excluded also) along with the baseline and control limits, for each of the above metrics in each project category.
- For data points lying outside the control limits, the concerned Project Managers investigate and document the causes of variance.
- For the phase wise distribution, the average numbers are computed which then become the norm used for estimation and tracking purposes.

8.2.1.3.2 Results from Co. A

Baseline and control limits are attached as Exhibit 1. The analysis has been pictorially represented in the form of charts, sample of some of them are also enclosed in Exhibit 1.

8.2.2 Company G

8.2.2.1 The projects were divided into the following categories. Like in the case of Company A, these are the buckets of data on which analysis could be done in a consistent manner.

Project Type	Description
Development	This organization is executing development projects in the *client server* area. All the projects are ***business applications***.
Maintenance	These are round the clock (24x7) production support for ***mainframe applications***. The project team handles change requests as well as bug fixes – thus, both corrective maintenance as well as perfective maintenance is involved.
Testing	A number of testing projects are being executed by this company. The team in India operates as an ***independent test group***, preparing test cases and test scripts, executes tests and logs the test results.
Conversion / Migration	These are projects where there is ***no change in functionality*** while converting or migrating to a different software or hardware environment.

8.2.2.2 The metrics defined[3] in this organization were :

- Project Management:
  - Schedule variance :
    - Actual vs. original estimate
    - Actual vs. revised estimate
  - Effort variance :
    - Actual vs. original estimate
    - Actual vs. revised estimate
  - Size variance :
    - Actual vs. original estimate
    - Actual vs. revised estimate
  - Productivity
  - Effort spent on Project Planning

[3] The definitions used were generally consistent with those we defined in Chapter 7. We have defined them explicitly only in the instances when they are different from those we provided in Chapter 7.

- Effort spent on Project Tracking and oversight
- Average turnaround time per Change Request (for maintenance projects)

- Quality Control
  - Effort spent on Reviews
  - Effort spent on Testing
  - Defect density
  - Defect age
  - Defect rate
  - Defect distribution by phases
- Quality Assurance
  - Effort spent on OPF activities
  - Effort spent on OPD activities
  - Effort spent on SQA activities
  - Effort spent on Process data base activities
  - No. of Non conformances per process
  - Mean time to fix a NC
  - Configuration Management
  - Effort spent on CM activities
  - No. of Configurable Items
- Training and Development
  - Training service level
  - Course quality
  - Faculty effectiveness

8.2.2.3 Analysis Of The Data To Arrive At Capability Baselines.

8.2.2.3.1 Methodology followed in each round of baselining were :

- Collate the metrics data from all on going projects as well as closed projects.

- Compute the mean and standard deviation for each of the metrics identified.
- Establish the baseline and control limits for each project category as follows :
  - Capability Baseline = Mean of past performance

The rules for control limits that this company used were the same as we gave in Chapter 7, viz.

a) If σ is not greater than 10% of mean, then control limits are Mean +/- 3σ

b) If σ is greater than 10% of mean, but not greater than 25% of mean , then control limits are Mean +/- 2σ

c) If σ is greater than 25% of mean, but not greater than 50% of mean , then control limits are Mean +/- σ

d) If σ is greater than 50% of mean, then control limits are Mean +/- 0.5σ

- For schedule and effort variance, the target driven limits set by senior management were as follows:
  - SVA = 0 +/- 10 % .
  - SVB = 0 +/- 3 %
  - EVA = 0 +/- 15 %
  - EVB = 0 +/- 5 %
- Plot all data points along with the baseline and control limits, for each of the above metrics in each project category.
- For data points lying outside the control limits, the concerned Project Managers investigate and document the causes of variance.
- For the phase wise distribution, the average numbers are computed which then become the norm used for estimation and tracking purposes.

8.2.2.3.2 Results from Co. G

Baseline and control limits are attached as Exhibit 2. The analysis has been pictorially represented in the form of charts, sample of some of them are also enclosed in Exhibit 2.

8.2.3 Company B:

8.2.3.1 The projects were divided into the following categories.

These are the buckets of data on which analysis could be done in a consistent manner.

Project Type	Description
Development – Business applications	This company is engaged in the development of client server based business applications
Development– Systems SW	These are development projects in the area of systems software
Development – Lotus Notes	Development projects in Lotus Notes
Maintenance	All projects are in the client server environment
Migration / Conversion	Migration of programs from one hardware and/or software environment to another

8.2.3.2 The metrics defined[4] in this organization are given below.

As can be seen, many of these were the same as in the two earlier companies. Some metrics were redefined, which have been explained below.

- Project Management:
  - Schedule slippage :
    - Actual vs. original estimate
    - Actual vs. revised estimate
  - Effort slippage –
    - Actual vs. original estimate
    - Actual vs. revised estimate
  - Changes to size estimate = Revised estimated size / Initial estimate
  - Productivity
  - Project management effort overrun

    = (Actual PM effort – Planned PM effort) / Planned PM effort
- Defect Metrics:
  - Defect density

[4] The definitions used were generally consistent with those we defined in Chapter 7. We have defined them explicitly only in the instances when they are different from those we provided in Chapter 7.

- Weighted defect density
- Defect age
- Defect removal efficiency *(the cut off time for computing the total number of defects is till the Acceptance testing stage only)*
- Testing effort productivity = $\frac{\text{Total no. of defects found in testing}}{\text{Effort spent for testing}}$
- Review effort productivity = $\frac{\text{Total no. of defects found in reviews}}{\text{Effort spent for reviews}}$

- Project related other metrics:
  - Requirement stability index
  - Requirement coverage metric (Functionality Metric) = $\frac{\text{No. of requirements met}}{\text{No. of requirements}}$
  - Average no. of CIs
  - Mean time to respond to a CR / Query / Problem
  - Mean Time to repair
- Software Quality Assurance
  - Effort spent on SQA activities
  - Effort spent on Process data base activities
  - No. of Non conformances per project
  - Project wise repeated NCs profile

    $= \frac{\text{No. of findings that are repeatedly happening}}{\text{No. of weighted findings in project}}$
- Software Support Metrics
  - Training Execution effectiveness

    $= \frac{\text{No. of training conducted}}{\text{No. of training planned}}$
  - Training effectiveness
  - Mean time to repair

8.2.3.3 Analysis Of The Data To Arrive At Capability Baselines.

8.2.3.3.1 Methodology followed in each round of baselining were :

- Collate the metrics data from all on going projects as well as closed projects.
- Compute the mean and standard deviation for each of the metrics identified.
- Establish the baseline and control limits for each project category as follows :
  - Capability Baseline = Mean of past performance

The rules for control limits that this company used were the same as we gave in Chapter 7, viz.

a) If σ is not greater than 10% of mean, then control limits are Mean +/- 3σ

b) If σ is greater than 10% of mean, but not greater than 25% of mean ,then control limits are Mean +/- 2σ

c) If σ is greater than 25% of mean, but not greater than 50% of mean , then control limits are Mean +/- σ

d) *If σ is greater than 50% of mean, then control limits are* Mean +/- 0.5σ

- For schedule and effort variance, the target driven limits set by senior management were as follows:
  - SVA = 0 +/- 10 % .
  - SVB = 0 +/- 3 %
  - EVA = 0 +/- 15 %
  - EVB = 0 +/- 5 %

In addition the following metrics from the following areas were also analyzed :

- Training
- Facilities management
- Customer feedback

The analysis from the training area have been included in the attached Exhibit 1 as well.

8.3.3.3 ***Analysis of the data to arrive at capability baselines.***

8.3.3.3.1 *Methodology followed in each round of baselining were :*

- Collate the metrics data from all on going projects as well as closed projects.
- Compute the mean and standard deviation for each of the metrics identified in 8.3.1.2.
- Establish the baseline and control limits for each project category as follows :
  - Baseline = Mean
- Control limits = Mean +/- n(S.D.), where n is taken as 3 if S.D. is less than 10% of mean, else n is taken as 1.
- In some cases, senior management may set control limits as targets. This is especially true for effort variance and schedule variance.
- Plot all data points (those excluded also) along with the baseline and control limits, for each of the above metrics in each project category.
- For data points lying outside the control limits, the concerned Project Managers investigate and document the causes of variance.
- For the phase wise distribution, the average numbers are computed which then become the norm used for estimation and tracking purposes.

8.3.3.3.2 Results from Co. B

Baseline and control limits are attached as Exhibit 3. The analysis has been pictorially represented in the form of charts, sample of some of them are also enclosed in Exhibit 3.

CHAPTER 9

FUTURE RESEARCH DIRECTIONS AND CONCLUSIONS

In this thesis we have seen that the approach of first implementing ISO and then moving on to CMM is the more effective approach even from a theoretical viewpoint. We have seen in Chapter 4 that implementing Level 2 by itself has got small to medium sized projects. This approach was appropriate for organizations with very large projects who could then ensure that the facilities required for providing training, quality assurance etc are all available within the project. Implementation of ISO first on the other hand does not suffer from these problems.

This approach is also being backed up by empirical data from Indian industry where we find that organizations which implement ISO first and then move on to CMM are able to do so in much shorter time frames than if they had to traverse the CMM traditional route.

We believe that future areas of research should focus on the development of an integrated model which captures the strong points of CMM as well as ISO.

If we were to analyze further the approach that we have suggested we would come up with the question of "Why choose ISO to solve the implementation bottlenecks that we have identified earlier, instead why not look at developing a model where there is an intermediate level which organizations can hope to achieve quickly and then have them move to CMM Level 4 from there?"

The answer to the above question points to the future research directions that we hope can be undertaken. We think there is need for an integrated model which will have the following building blocks :

a) Foundation Level

b) Level 3 – Defined Level

c) Level 4 – Managed Level

d) Level 5 – Optimizing Level

In this model, the need for Level 2 is then dispensed with and is being replaced by a level called Foundation Level. This level should have the following KPAs :

a) Organization Process Definitions

b) Training

c) Requirements Management

d) Project Planning

e) Project Tracking and Oversight

f) Software Configuration Management

g) Software Quality Assurance

h) Sub-contract Management

Please note that the reasons for moving the OPD KPA to the Foundation Level is that the organization starts to define the processes (by taking an organization wide view) right from the beginning. They could look at the best practices across the projects and define appropriate processes which meet the organizational needs.

Technically speaking, however, the OPF KPA may not even be required since OPD will necessitate the OPF practices to be present. Also the need for a process data base would be modified by stipulating that the process documents itself should be available centrally within the organization – however, the metrics data base should be a practice required only at Level 3.

We have kept the training KPA at the Foundation Level because this function is extremely important to implement all the other KPAs.

It will also mean that the KPAs at Level 3 would be drastically pruned and that the Foundation Level is really an amalgam of the existing Level 2 KPAs and some important elements of Level 3.

The model may then be pictorially represented as follows :

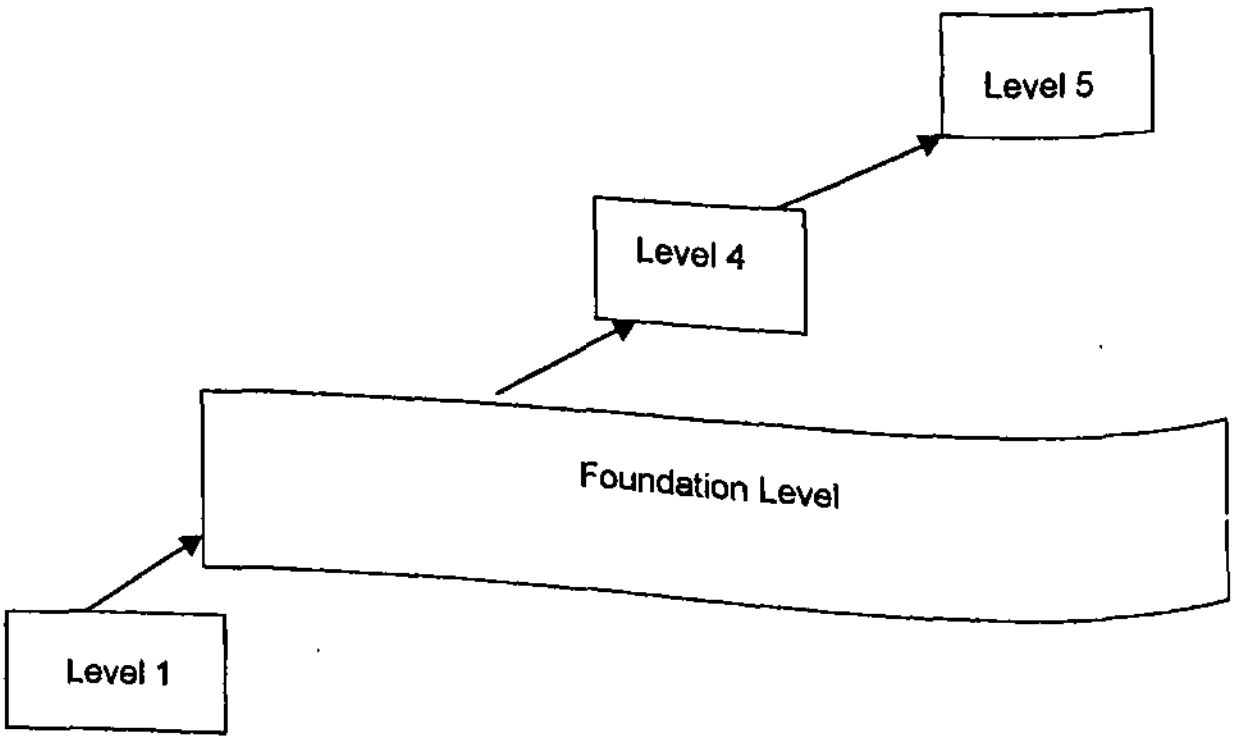


Fig 9.1

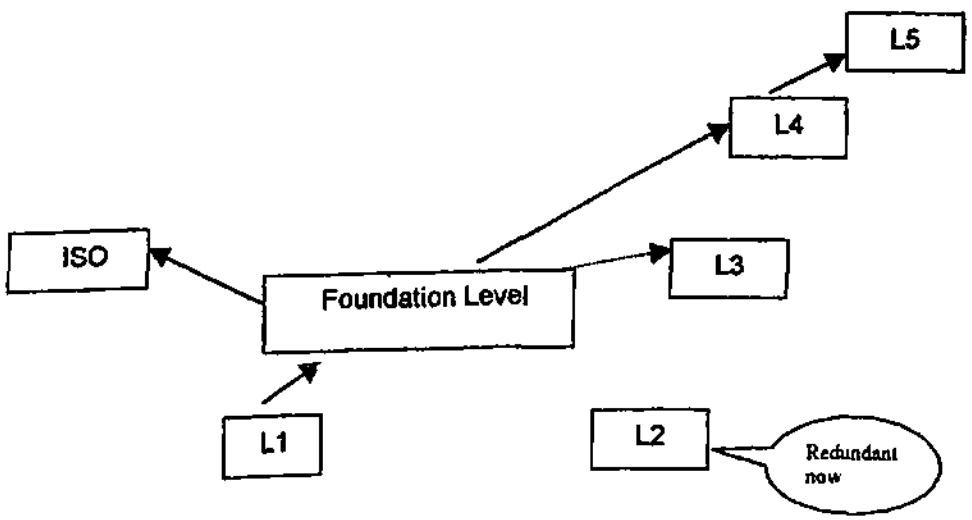
As can be seen from above, an implementation strategy may well be that an organization having reached the Foundation Level moves on directly to the Managed Level – Level 4 instead of waiting for a while at Level 3 and then moving on to Level 4.

We also visualize that the key practices at the Foundation Level would not be the same as given for the respective KPAs in the CMM. Organizations tend to have a lot of difficulty in implementing the practices given in the measurement and analysis common feature. One would visualize that the core metrics that we identified in Chapter 7 be built in as part of the key practices in the project planning, project tracking and SQA KPAs so that organizations can quickly bring about a process culture in all they do.

The practices given in Level 3 would also be modified sine many of them would already have been followed at the Foundation Level. This specifically includes the practices linked to the development of the process data and tailoring guidelines which would then be included in some other KPA (since OPD has been moved to the Foundation Level).

A fallout of this model would be that an organization could be very flexible on its certification approach. It would always implement Foundation Level regardless of the model ultimately chosen. Having achieved Foundation Level, it could then decide to go in for ISO 9001 with minor modification to its processes or choose to go on to CMM directly. This would be useful to consider because bringing about changes to the certification standard and the quality models like ISO and CMM is difficult and time consuming (which is as it should be). Therefore, without contemplating any formal changes to the CMM or the ISO, an organization could always aim to reach the Foundation Level first and then move on to a model of its choice.

This may be pictorially represented as follows :



Option B

Fig 9.2

As can be seen from above, an organization reaches the Foundation Level after which it is a short step away from either ISO 9001 or CMM Level 3. If it wishes it can go in for Level 4 directly instead of going in for Level 3.

CONCLUSIONS

In this thesis, we have seen that the traditional approach of implementing CMM leads to inordinate delays in attaining higher maturity levels. This is borne out by the experiences of a large number of companies all over the world which have reported their experiences and which we have described in this thesis. On the other hand, organizations in India have followed the path of ISO first and then CMM. This had led to much shorter time frames for implementation and has been among the major reasons for the Indian software industry accounting for such a large proportion of the CMM Level 4 and Level 5 organizations in the world.

Annexures 11 and 12 provide the latest list of companies that have been assessed for level 4 and 5 in the world and in India. Annexure 11 is a list brought out by NASSCOM, India giving details of all quality certifications obtained by Indian companies. Annexure 12 is a list brought out by SEI giving the list of all CMM Level 4 and 5 companies as of Feb 7, 2000.

Based on this empirical evidence and critical analysis of the implementation approach in the CMM we have come to the conclusion that ISO first then CMM is the most cost effective and valuable approach. We strongly recommend that even if an organization does not need an ISO it should focus on achieving ISO first and then moving on to CMM.

We have also given in this thesis detail implementation activities that are required to implement ISO and then move on to CMM Level 4 and Level 5. We are confident that an organization would be greatly benefited by this implementation road map. This is all the more so because we find that most of the quality managers are groping around in the dark in the search for pointers to implement the quality practices required of either ISO or CMM.

In Chapter 7, we have provided a list of metrics and in doing so have segregated them into core and tertiary metrics. This stems from our belief that an organization often goes into a confusing medley of measurements to track for getting their business objectives. All that the metrics program then achieves is that although there is a lot of data collected this data is not used effectively since it was never aligned with the core business processes of the organization.

Subsequently, we have provided experiences from the industry. The implementation approach followed by 8 organizations have been described which we hope will be of guidance to quality managers across the world. Out of these 8 organizations we have chosen 3 for whom we have reported the metrics as well as the use to which these are put. We hope that the insights we have given to the baseline reports and the metrics analysis will help the quality managers to achieve similar success.

Annexure 1

PROFILE OF A CMM ORGANIZATION

The typical organization profiled in the CMM is involved in developing large projects consisting of both hardware and software components. The customer gets a complete system from such an organization which meet both his needs. An explanation of the terms used in the CMM, when viewed from this perspective, is given below. These terms help us to understand the nature of organization that the SEI assumed when developing the CMM. It is important to remember that these terms are generally consistent with MiL [MIL-STD] and IEEE [IEEE – 610] standards.

1. System: This is defined as a collection of components organized to accomplish a specific function or set of functions. Thus a system may consist of hardware, software and other components. Thus an on board command and control system in a Naval ship is a system which consists of hardware like radar, A/D converters, display terminals etc. and software which can analyze input data.

2. Allocated requirements: The system defined earlier would have system requirements which are the requirements that the customer has from the "big black box". A system team then decides on the parts of the system requirements to be met by hardware and the parts to be met by software. The system requirements to be met by software are called "allocated requirements".
In a typical software house, the "allocated requirements" are equivalent to the user needs i.e. the inputs to the software project.

3. System Engineering Group and Software Engineering Group: The System Engineering Group is the team responsible for specifying and allocating requirements to hardware and software. This is the team referred to in pt. 2 above. The Software Engineering Group, on the other hand, is the team that is responsible for software development and maintenance. In other words, this is the project team in a software house.

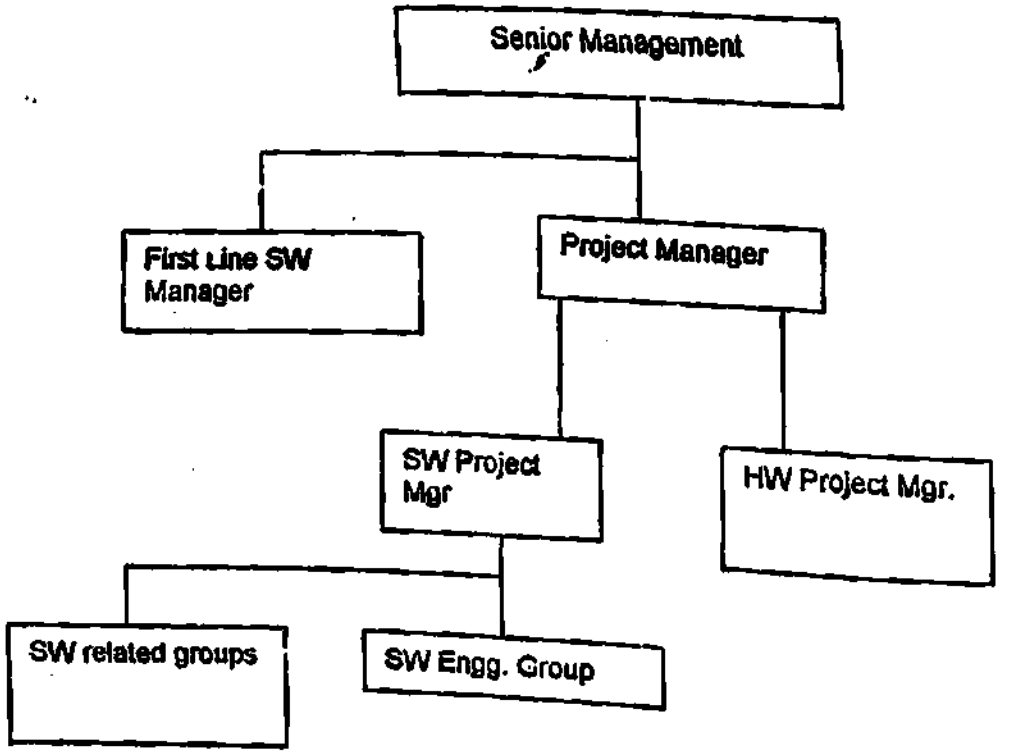
4. Software Engineering Process Group: This is the group that facilitates development, maintenance and improvement of software processes organization wide.

5. Senior manager: This is an organization level manager who is responsible for multiple projects or department or a function. In the CMM, the senior management provide leadership and resources.

6. Project Manager: This person is responsible for project at system level while the project software manager is responsible for software project.

7. First line software manager: This is the person akin to senior management for the software organization. This person has management responsibility for software project teams, support teams, department or the organizational unit

The organizational structure given above can be depicted as below:



1.0 Executive Summary

1.1 Assessment of Current situation

- There are well documented processes for most of the business processes relevant to ISO 9001 and CMM Level 3. However, there are more than one documented processes in existence in the organization and the implementations are not consistent as far as the Calcutta office is concerned. In contrast, the Mumbai office follows well documented procedures in most of the processes.
- Some of the projects work on the basis of industry experience and "best practices" approach. There is little documented process. In some of the UAL projects the documentation standards as specified by the customer are used.
- The motivation and management commitment necessary to achieve ISO 9001 and CMM Level 3 exist in great measure.
- Primary responsibility center for the deployment of a quality system exists.
- Infrastructure and work culture are conducive to process improvement measures.

1.2 Certification / Assessment Milestones

- The core processes to be documented by March 24, 2000.
- The guidelines and standards are to be written by May 31, 2000.
- Internal quality audit would start by April 10, 2000.
- Selection of certifying agency to be done by April 17, 2000.
- Pre-Assessment Audit for ISO 9001 to be done by June 30, 2000.
- Certification Audit for ISO 9001 to be done by July 31, 2000.
- Phase I Assessment for CMM Level 3 to be completed by September 22, 2000.
- Phase II Assessment for CMM Level 3 to be completed by November 20, 2000.

1.3 Key immediate actions

- Prepare Project ISO 9001 & CMM Level 3 Plan.
- Identify QA Manager for Calcutta office.
- Set up Management Review committee. Ensure that management review takes place at least once every fortnight starting March 15, 2000.
- Review documented processes prepared by CyberQ and deploy them as soon as possible.
- Prepare Standards and Guidelines as may be required and desired and deploy them before May 31, 2000.

3.0 Quality System Assessment for ISO 9001

3.1 Basis for Assessment

The CYBERQ consultant assessed the current process documentation and the maturity and consistency of the implemented processes and process awareness by interviewing key persons at and enquiring about current procedures and standards. The current situation was compared against the requirements of ISO 9001.

3.2 ISO 9001 Clause wise assessment

This section contains the assessment of the current situation with respect to ISO 9001. Under each requirement, a "Documentation Rating" as well as an "Implementation Rating" on a 1-5 scale has been given.

Documentation Rating relates to the existence of documented policies, procedures and standards. Implementation Rating relates to the consistency of practiced procedures, documented or undocumented. needs to score at least 3 on all requirements to be ready for ISO 9001 certification.

3.2.1 Management Responsibility (Clause 4.1 of ISO 9001)

Current Situation

- A Quality Policy does not exist yet.
- The Organization structure, role and responsibilities are not clearly documented. However, efforts have been undertaken to define the organization model.
- The process for Management Review (of implementation of Quality System) is not defined yet. No formal process is implemented.
- The Chief Executive Officer of the organization has assumed the role of the Management Representative for Quality. The coordinators for Quality Assurance for Calcutta and the Mumbai offices have been appointed.

Documentation rating 1 on a scale of 1-5

Implementation rating 1.5 on a scale of 1-5

3.2.2 Quality System (Clause 4.2 of ISO 9001)

Current Situation

- Quality Manual has not been created.
- Quality system procedures exist but they have been implemented in bits and parts. Some procedures and guidelines exist for software development life cycle phases. Implementation has been done well in some of the projects, particularly in the projects being carried out in the Mumbai office, and in other projects they are not implemented.
- Quality planning does not exist.
- Internal quality audit has not been done.

Documentation rating 2 on a scale of 1-5

Implementation rating 2.5 on a scale of 1-5

3.2.3 Contract Review (Clause 4.3 of ISO 9001)

Current Situation

- Documented process for proposal making and reviewing contracts exist. Not being done formally, although informal reviews do take place before taking on a project.

Documentation rating 2 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

3.2.4 Design Control (Clause 4.4 of ISO 9001)

Current Situation

- Documented Project Planning process exists, but has not been followed consistently. However, generally good practices are followed.
- Defined processes for requirement analysis and system designs exist. However, they have not been uniformly implemented.
- A defined process for coding exists. Coding standards were written but they are not implemented consistently.
- A process for conducting design verification and validation exists, although it is not implemented consistently.

Documentation rating 3 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

3.2.5 Document and Data Control (Clause 4.5 of ISO 9001)

Current Situation

- Version Control procedures are not documented.
- A process for Configuration Management on documents exists.
- CM Plan is made in some projects but is not being followed consistently.
- Documentation control system is defined but not implemented.

Documentation rating 3 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

3.2.6 Purchasing (Clause 4.6 of ISO 9001)

Current Situation

- Procedures are defined and documented. Implementation is done.
- Approved vendors' list exists.

Documentation rating 4 on a scale of 1-5

Implementation rating 4 on a scale of 1-5

3.2.7 Control of Customer Supplied Product (Clause 4.7 of ISO 9001)

Current Situation

- Procedures exist. The respective project / process group keeps custody of customer supplied product in some cases and keeps track of the same. However, the process is not uniformly implemented.

Documentation rating 3 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

3.2.8 Product Identification and Traceability (Clause 4.8 of ISO 9001)

Current Situation

- Procedures exist. However, though the members keep control effectively through experience and adoption of best practices, the procedures are not consistently implemented.
- CM plan and a configuration register exist in some cases.

Documentation rating 3 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

3.2.9 Process Control (Clause 4.9 of ISO 9001)

Current Situation

- Project / process groups follow good life cycle processes. Documented processes also exist. However, the implementation is not always consistent.
- Criteria for workmanship exists in the form of programming standards, samples of documentation required etc.
- The Facilities Management Group maintains a list of hardware and software and takes care of preventive maintenance. Backups are being maintained.
- A disaster recovery plan exist.

Documentation rating 3 on a scale of 1-5

Implementation rating 3 on a scale of 1-5

3.2.10 Inspection and Testing (Clause 4.10 of ISO 9001)

Current Situation

- Documented procedure for Independent System Testing exists. However, testing practices are not being followed consistently.

Documentation rating 4 on a scale of 1-5

Implementation rating 2 on a scale of 1-5

5.0 Road Map

5.1 Activity Set-1: Top Management Responsibilities

SL. No.	Activity	Responsibilities	CYBERQ Responsibilities	Date of Completion
1	Formally appoint the Management Representative (MR) for Quality	Issue the formal letter and announce	—	January 03, 2000
2	Set up the Management Review Committee for review of implementation of the Quality System	Identify members, set up meeting dates	—	February 28, 2000
3	Appoint QA Manager	Issue the formal letter and announce	—	February 28, 2000
4	Hold Management Review Committee meetings	MR will prepare an agenda and a progress report for this meeting. All members to attend this meeting.	—	Every fortnight from March 15th, 2000

5.2 Activity Set-2: Definition and Implementation of the Quality System

SL. No.	Activity	Responsibilities	CYBERQ Responsibilities	Date of Completion
1	Document Group 1 #	Review, release and implementation	Documentation, review and hand over to	February 29, 2000
2	Document Group 2 #	Review, release and implementaicn	Documentation, review and hand over to	March 24, 2000
3	Document Group 3 #	Documentation, review and release	—	May 31, 2000
4	Deploy Quality system	Implement (use) the documented procedures of the QS	Support, where necessary	March 24, 2000 (Start using each document as soon as it is released.)
5	Provide Training to employees on	Organize periodic training	Conduct the first rounds of	March 31, 2000. To be continued

	the documented Quality System	to cover each employee	training in Calcutta and Mumbai	thereafter by as per need.
6	Provide supporting training, especially internal audits	Organize for supporting training	Provide training as planned	April 20, 2000

The Document Groups have been listed in Appendix A.

5.3 Activity Set-3: Internal Quality System Audit

SL. No.	Activity	Responsibilities	CYBERQ Responsibilities	Date of Start
1	1st Internal Audit of the Quality System	Perform Internal Audit	Perform lead audit	April 10-11, 2000 for Calcutta; April 20, 2000 for Mumbai
2	2nd Internal Audit of the Quality System	Perform Internal Audit	Perform lead audit	May 22-23, 2000 for Calcutta; May 25, 2000 for Mumbai
3	3rd Internal Audit of the Quality System	Perform Internal Audit	Perform lead audit	July 10-11, 2000 for Calcutta; July 12-13, 2000 for Mumbai
4	CMM Facilitation	Perform Internal Audits	Facilitation services will be provided as lead auditors	Augus: – November, 2000

5.4 Activity Set-4: External Audit of the Quality System for ISO 9001 Certification

SL. No.	Activity	Responsibilities	CYBERQ Responsibilities	Date of Completion
1	Appointment of Certification Agency	Decide upon the Certification Agency and formally enter into agreement with them	Support, coordinate, and advise	April 17, 2000
2	Pre-Assessment Audit	Organize and prepare for the Pre-Assessment Audit	Support, coordinate, and advise (before and after)	June 21-30, 2000
3	Certification Audit	Organize and prepare for the Certification audit	Support, coordinate, and advise (before)	July 20 – 31 for Calcutta and Mumbai

6.0 Management Responsibility

This section describes the means by which the Company acknowledges its responsibility for Quality Policy, the definition and allocation of individual management responsibilities, the nomination of a management representative and the operation of a system review by Company management.

6.1 Quality Policy

6.1.1 The Policy statement contained in this manual shall define the Company's objectives and commitment to Quality (Section 3.0). It will be relevant to the Company's goals and its customer requirements.

6.1.2 Copies of the Policy Statement shall be prominently displayed throughout the Company premises.

6.2 Organisation

6.2.1 Responsibility and Authority

6.2.1.1 The organogram showing functional relationships and areas of authority, shall be found in Appendix C of this manual. Defined authority shall be found in the relevant procedure manual.

6.2.1.2 Job descriptions for all members are held within the Company and include the following details:
Job details - title, grade
Accountable to
Liaises with
Principle responsibilities/duties
Responsibilities relating to the Quality System

6.2.1.3 All process owners shall have the authority and responsibility to define the job responsibilities of employees who report to them. The input-output throws to and from different processes shall be elaborated in the various procedure manuals.

6.2.1.4 Jdb descriptions of senior managers and all process owners who control, perform and verify work affecting quality are contained in Appendix E of this manual.

6.2.2 Resources

6.2.2.1 Adequate and appropriate resources shall be identified and provided so as to ensure that the specified requirements can be met and maintained.

6.2.2.2 In the unforeseen absence of any employee with designated responsibility and authority, responsibility and authority is designated upwards as per the organogram for re-delegation.

6.2.2.3 The Chief Executive Officer shall nominate by memorandum the person to assume his/her responsibilities and authorities in his/her absence.

6.2.3 Management Representative

6.2.3.1 The Vice President - Resources is nominated by the Company as Management Representative for the Quality Management System and irrespective of other responsibilities.

6.2.4 The various elements which define the organisation of the quality process are illustrated as follows :

Appendix B - Process Architecture of
Appendix C - Organogram of
Appendix D - The Responsibility Matrix : ISO 9001 Process Vs Process owner
Appendix E - Job Descriptions of Process Owners

6.3 Management Review

6.3.1 The Quality Management System shall be reviewed regularly by a core committee called Management Review Group, which consists of all process owners as member.

6.3.2 The purpose of the review shall be to assess the effectiveness of the system and to determine whether any changes in procedure, method or philosophy are considered necessary to meet current and future needs

This refers to ISO 9001 Clause 4.1 and ISO 9000-3 Clause 4.1

7.0 The Quality System

This section outlines the way in which the Company's Quality Management System is identified, documented and maintained.

7.1 The Quality System is documented in three levels. The Quality Management Representative shall be responsible for issue and control of Levels 1 & 2 Level 3 will be controlled by the appropriate Process Owner.

Level 1- Quality Manual that describes the Company's approach to the requirements of ISO 9001.

Level 2- Quality Procedure Manuals that detail the activities considered to ensure conformance to the specified requirements.

Level 3- Quality Plans relating to specific contracts, products or processes, giving precise details on how work is to be carried out.

7.2 A list of Quality Procedure Manuals (Appendix H) shall be maintained by the Quality Management Representative.

7.3 The Quality Plans will include as appropriate :

- Process owner associated with the element
- Details of controls, processes, equipment, skills and other resources.
- Process owner associated with the element
- Entry criteria for associated processes/half-processes
- The path associated
- The verification procedures involved
- The exit criteria
- The ISO 9001 reference
- Quality records to be established and maintained

This refers to ISO 9001 Clause 4.2 and ISO 9000-3 Clause 4.2 & 5.5

8.0 Contract Review

Each contract, before signing, shall be reviewed to ensure the following :

- adequacy of requirement definition and their documentation
- requirement which differs from the original tender / RSD are addressed properly
- the "if applicable" clauses in the tender / RSD are addressed properly
- process capability to meet contractual obligation is generated
- procedure for direct and official channel of communication between the customer and quality process owner is available on quality issues
- complete and unambiguous transformation of customer needs to customer's functional requirement
- requirements will include among other things, specification of performance, safety and privacy criteria, which will in turn facilitate acceptance testing
- the purchaser's requirement specification is developed in close cooperation with the customer, whose responsibility is also fixed
- common terminology is used
- interfaces between the software products and other software / hardware are fully and clearly specified
- the contract document and the customer's requirement specification has come under Document Control System and Configuration management Process.

This refers to ISO 9001 Clause 4.3 and ISO 9003 Clause 4.2.

Reference :

1. Contract Review Manual (:/Q/M/CTRV/C2)
2. Software Requirements Specification Manual (:/Q/M/SRS/C2)

9.0 Analysis and Design

There are well documented procedures to ensure that

- the customer's requirement specification is verified and validated
- the project is managed as per our project management standard
- every project has a quality plan as per our standard
- software engineering principles are correctly applied with particular reference to issues involved in SSAD and OOAD guidelines.
- Proper verification and validation is done

- baseline items are managed properly as change requests come in during the progress of the project.

This refers to ISO 9001 Clause 4.4 and ISO 9000-3 Clause 5.4 and 5.5 .

Reference :

1. Project Management Manual (Q/M/PJMG/C1)
2. Structured Systems Analysis and Design Guideline (Q/M/SSAD/C1)
3. Object Oriented Analysis and Design Guideline (Q/M/OOAD/C1)
4. Software Verification Validation and Testing Guideline (Q/M/SVVT/C1)
5. Configuration Management Manual (Q/M/CNMG/C1)
6. Reengineering Guideline (Q/M/RE/C1)

10.0 Document Control

There are well established procedures to control and manage all documents which are used or referred during any project from contract through planning to execution.

The document control system ensures that

a. pertinent documents are available as and when required to persons authorised to use them.
b. no confusion or other problems arise due to circulation of obsolete documents.
c. all document production/changes are properly reviewed and authorised prior to release.
d. a master list of documents is maintained.

The documentation standards give guidelines for preparing documents.

This refers to ISO 9001 Clause 4.5 and ISO 9000-3 Clause 6.2.

Reference :

1. Documentation Standard (
2. Document Control System Manual

11.0 Purchase

There are well laid down procedures to ensure conformance of purchased products to specified requirements.

- Sub-contractors shall be selected on the basis of their ability to meet sub-contractual requirements.
- Purchasing documents shall contain a clear description of the product or service required.
- All purchasing activities are regularly reviewed.
- The customer can verify the quality of the products at the source.

This refers to ISO 9001 Clause 4.6 and ISO 9000-3 Clause 6.7.

Reference :

1. Purchasing Manual

12.0 Purchaser Supplied Product

There are procedures to ensure that

- software/hardware supplied by the customer are properly analysed.
- such products are validated.
- such products are stored properly.
- security and other aspects are taken care of.
- any non-conformity or defect is promptly recorded, brought to the notice of the customer and issues arising thereof are resolved.

This refers to ISO 9001 Clause 4.7 and ISO 9000-3 Clause 6.8.

Reference :

1. Software Verification Validation and Testing Guideline (...Q/M/SVVT/C1)
2. Project Management Manual (...Q/M/PJMG/C1)
3. Configuration Management Manual (...Q/M/CNMG/C1)

13.0 Product Identification and Traceability

There are procedures to ensure identification and traceability of all our products throughout the software development life cycle and beyond.

The details of the procedure are documented in the Configuration Management Manual , Software Verification Validation and Testing Guideline and the Document Control System Manual.

This refers to ISO 9001 Clause 4.8 and ISO 9000-3 Clause 6.1.

Reference :

1. Software Verification Validation and Testing Guidelines (...Q/M/SVVT/C1)
2. Configuration Management Manual (...Q/M/CNMG/C1)
3. Document Control System Manual (...Q/M/DCS/C1)

Date : Aug 19, 1997			
Time	Project/Function	Auditee	Auditors
09:30 -10:00 AM	Opening Meeting	All Project Managers and Functional Heads should be present	
10:00 - 10:30 AM	Auditors briefing		
10:30- 1:00 PM	Document Review	AS	RN, PS, CM, VP
02:00 - 04:00 PM	ALCOA	A. Ghosh	RN, PS, CM, VP
04:00 - 06:00 PM	VDU Plus	GO	CM, VP
04:00 - 06:00 PM	Training	S. Suri	RN, PS
Date : Aug 20, 1997			
10:00 - 1:00 PM	Over Par II	AS	RN, PS
10:00 - 01:00 PM	KEYSTONE	MS	CM, VP
02:00 - 03:00 PM	HFC	A. Ghosh	RN, PS
03:00 - 04:00 PM	MCS	DKM	RN, PS
02:00 - 03:00 PM	FIN ACCOUNT SW	DKM/MS	CM, VP
03:00 - 04:00 PM	HRD	USY	CM, VP
04:00 - 06:00 PM	Facilities Manager	DKM/ Ranjana/ Sunil	RN, PS, CM, VP
Date : Aug 21, 1997			
09:30 - 10:30 AM	Purchase	RG/RA	RN, PS, CM, VP
10:30 - 11:30 AM	Contract Review (Mktg.)	RR	RN, PS, CM, VP
11:30 - 01:00 PM	Q A		RN, PS
11:30 - 01:00 PM	Info SAP	AS	CM, VP
02:00 - 04:00 PM	Preparation of Audit Report		RN, PS, CM, VP
04:00 - 05:00 PM	Closing Meeting	All Project Managers and Functional Heads should be present	

Annexure 5

NONCOMPLIANCE REPORT FORMAT

(1) Customer :		(2) Date :	(3) Reference Number :
(4) Document :	(5) Paragraph :	(6) Area of Audit :	
(7) Noncompliance Category : ☐ Major ☐ Minor ☐ Observation			
(8) Noncompliance :			
(9) Auditor Signature :			(10) Date :
(11) Team Leader Signature :			(12) Date :
(13) Customer Signature :			(14) Date :

THE FOLLOWING SECTION TO BE COMPLETED BY THE AUDITEE MANAGEMENT WITHIN 1WEEK OF NONCOMPLIANCE ACCEPTANCE (SIGNATURE IN BLOCK 13)

(15) Corrective Action To Be Taken :		
	(16) Implementation Date :	
(17) Auditee Approval :		(18) Date :
(19) Proposed Corrective Action Acceptance (Auditor) :		(20) Date :

(21) Explanation for Changes to Original :	
(22) Team Leader Approval :	(23) Date :

(24) Corrective Action Verified By (Auditor) :	(25) Date :
(26) Team Leader Approval :	(27) Date :

Annexure 6
Sample Audit Report

Date Audit conducted : Aug 19-21, 1997

The audit was conducted by :
- Rajiv Nag - Team Leader
- Pankaj Sood - Team Member
- Chhanda Mitra - Team Member
- V. Padmanabhan - Team Member

Audit Scope : 1. Documentation Review (Quality Manual and Operations Manual)
2. Audit of the following projects :
- OverPar II
- Keystone
- MCS
- Info SAP
- Fin Account SW
- Alcoa
- HFC
- VDU Plus

3. Audit of
- Purchase
- Training
- Facilities Management
- Contract Review & Onsite processes
- HRD (Recruitment/Skills database/ Manpower planning)
- Qty Assurance (Internal Audits, Mgt. Review, Metrics)

Objective: To verify compliance of documentation to ISO 9001 standards and to verify implementation of quality system to documented QMS and to ISO 9001.

Audit findings :
The audit program is enclosed as Annexure I.

1. The audit team is very pleased to note the marked improvement across all projects and support functions at AGS in complying with the documented QMS. There was ample evidence to confirm that not only is the QMS being followed but the effectiveness of the processes has increased significantly since the previous Internal audit.

2. All projects showed good management control with regard to Contract reviews and project planning, in particular, the Alcoa, VDU Plus and the Keystone projects.

Annexure 7
List of Activity Codes

Activity Cod	Activity Description
001	Sales Process
00101	Pre-sales support
00102	Proposal Preparation
00103	Contract Preparation
00104	Business Development Meeting
00105	Meeting with Customer
00106	Feasibility Study
002	Analysis & Design
00201	Requirements Analysis
00202	Requirement Specifications Preparation
00203	High Level Design
00204	Low Level Design
00205	Design Documents Preparation
003	Program Specs. & Coding
00301	Program Specifications Preparation
00302	Coding
00303	Unit Test Plan Preparation
00304	Unit Test Data Generation
00305	Unit Testing
004	Integration & System Testing
00401	Integration Test Plan Preparation
00402	Integration Test Data Generation
00403	Integration Testing
00404	System Test Plan Preparation
00405	System Test Data Generation
00406	System Testing
005	Installation & Acceptance
00501	Software Installation
00502	Acceptance Testing
00503	User's Manual preparation
00504	User's Training
00505	Delivery
006	Project Management
00601	Project Planning
00602	Project Plan Preparation
00603	Project Organizing
00604	Project Monitoring & Control
00605	Meeting / Discussion
00606	Project Status Reporting
00607	Configuration Management
00608	Problem Analysis
00609	Change Request's Impact Analysis
00610	Meeting with Customer
00611	Meeting
020	Quality Assurance
02001	Develop Process Definitions
02002	Conduct Internal Audit
02003	Facing Internal Audit
02004	External Audit
02005	Analysis of Metrics
02006	Maintenance of Process Database

02007	Management Review Meeting
02008	Planning & Co-ordination
02009	Helping other members in implementation
02010	Configuration Audit
025	Recruitment
02501	Interviews
02502	Out-station Interviews
02503	Planning & Co-ordination
02504	Appointment Formalities
02505	Maintenance of Recruitment/Skill Database
02506	Follow-up Activities
02507	Bounty Payment Management
02508	Correspondence with Placement Agencies
02509	Inducting new employees
026	Appraisal
02601	Appraisal
02602	Appraisal Meeting
02603	Appraisal Result Reporting
02604	Planning & Co-ordination
027	Training
02701	Attending Internal Training
02702	Preparation of Training Material
02703	Attending External Training
02704	Self Development
02705	On the job Training
02706	Conducting training course
02707	Planning, Co-ordination & Monitoring
02708	Maintenance of Training Materials
02709	Corresponding with training vendors
02710	Identification of training needs
02711	Feedback Analysis
028	HR & Personnel
02801	Inter departmental co-ordination
02802	Maintenance of Personnel files
02803	Allocation of Manpower
02803	Policy & Practices
02804	Monthly Reports
02805	Employee Redressal
02806	Corporate Recognition Award
02807	On-site Deployment
02808	Data Entry for Payroll System
02809	Exit Interview
029	On-site Consulting
02901	Co-ordination
02902	Co-ordination with Customer
02904	Co-ordination for Resources
02905	Arranging Interviews
02906	Planning
02907	Facing Interviews
035	Facilities Management
03501	Planning & Co-ordination
03502	Technical Procurement
03503	S/W Installation & Configuration
03504	Infrastructural Development
03505	Technical Support
03506	System Administration
03507	Database Administration
03508	Network Administration
03509	Resource Allocation

040	Office Administration
04001	Transport Arrangement
04002	Canteen Facilities
04003	House-keeping
04004	Front-Office Function
04005	Non-technical Procurement
04006	Employee Welfare
04007	Employee Travel - Domestic
04008	Employee Travel - International
04009	Office Equip. & Furniture Maintenance
04010	Stores Maintenance
04011	Workstation Allocation
04012	Hotel/Guest House Booking
04013	Telephone/Mobile System Facilities
04014	Planning & Co-ordination
04015	Miscellaneous Jobs
045	Library
04501	Library Administration
04502	Purchasing of Books&Periodicals
050	Idling
05001	Not assigned to any project
05002	No work assigned on project
05003	Non availability of infrastructure
05004	Waiting for VISA/Departure
05005	Waiting for customer feedback
060	Tour
06001	Tour - intra city
06002	Tour - inter city
06003	Foreign Tour
065	Holiday
070	Leave
099	Others
10000	Reviews
10001	Sales Process
10102	Proposal Preparation
10103	Contract Preparation
10106	Feasibility Study
10002	Analysis & Design
10201	Requirements Analysis
10202	Requirement Specifications Preparation
10203	High Level Design
10204	Low Level Design
10205	Design Documents Preparation
10003	Program Specs. & Coding
10301	Program Specifications Preparation
10302	Coding
10303	Unit Test Plan Preparation
10304	Unit Test Data Generation
10305	Unit Testing
10004	Integration & System Testing
10401	Integration Test Plan Preparation
10402	Integration Test Data Generation
10403	Integration Testing
10404	System Test Plan Preparation
10405	System Test Data Generation
10406	System Testing
10005	Installation & Acceptance
10503	User's Manual preparation
10006	Project Management

10602	Project Plan Preparation
10607	Configuration Management
20000	Rework before delivery to customer
20002	Analysis & Design
20201	Requirements Analysis
20202	Requirement Specifications Preparation
20203	High Level Design
20204	Low Level Design
20205	Design Documents Preparation
20003	Program Specs. & Coding
20301	Program Specifications Preparation
20302	Coding
20303	Unit Test Plan Preparation
20304	Unit Test Data Generation
20305	Unit Testing
20004	Integration & System Testing
20401	Integration Test Plan Preparation
20402	Integration Test Data Generation
20403	Integration Testing
20404	System Test Plan Preparation
20405	System Test Data Generation
20406	System Testing
20005	Installation & Acceptance
20503	User's Manual preparation
20006	Project Management
20602	Project Plan Preparation
20607	Configuration Management
30000	Rework after delivery to customer
30002	Analysis & Design
30201	Requirements Analysis
30202	Requirement Specifications Preparation
30203	High Level Design
30204	Low Level Design
30205	Design Documents Preparation
30003	Program Specs. & Coding
30301	Program Specifications Preparation
30302	Coding
30303	Unit Test Plan Preparation
30304	Unit Test Data Generation
30305	Unit Testing
30004	Integration & System Testing
30401	Integration Test Plan Preparation
30402	Integration Test Data Generation
30403	Integration Testing
30404	System Test Plan Preparation
30405	System Test Data Generation
30406	System Testing
30005	Installation & Acceptance
30503	User's Manual preparation
30006	Project Management
30602	Project Plan Preparation
30607	Configuration Management
40000	Defect Logging & Analysis
40003	Program Specs. & Coding
40305	Unit Testing
40004	Integration & System Testing
40403	Integration Testing
40406	System Testing
40005	Installation & Acceptance

Annexure 8

A BRIEF DESCRIPTION OF THE CMM ASSESSMENT PROCESS

A.8.1 Types of assessments: The assessment process defined by the SEI is very different from that followed during ISO assessments. The SEI defines two types of assessments that may be carried out with reference to the CMM:

a) Sub contractor Evaluation (SCE) : This is an external assessment carried out by SEI authorized lead assessors to determine the capabilities of a software vendor. This is done with the objective of qualifying software vendors, generally for work to be done for the US Department of Defense.

Since it is an audit carried out on behalf of the customer, this can be considered a second party audit.

b) CMM Based Appraisal – Internal Process Improvement (CBA-IPI): This is the most common form of assessments in the CMM world. Most of the assessments done and reported by the SEI are done by the CBA-IPI method. Donna Dunaway et al [CMM-96] describe in great detail the methodology to be followed during the CBA-IPI. We have attempted to provide a brief description of this process below.

The CBA-IPI, as the term implies, is essentially an internal assessment. To that extent, it can be considered to be a First Party audit, led by a SEI authorized lead assessor. Senior management is the sponsor for the CBA-IPI and hence it is done on their behalf. The findings are received and acted upon by the senior management.

A.8.2 Assessment team: The assessment team is generally made up of around 9 persons, apart from the lead assessor. The size of the assessment team depends no doubt on the size of the organization being assessed; however, we find that this for most organizations, the size of the assessment team is as we have mentioned above. The team members (called ATMs) are drawn from different functions and projects in the organization. Around 5 persons from the projects, 2 from the SEPG and Quality group and 2 from the support groups like Training, System Administration etc. is a good mix.

A.8.3 Assessees: The entities involved from the "assessees" or the "interviewees" side are:

- Project managers / project leaders (these are the software project managers, in CMM parlance – See Annexure 1
- Functional Area representatives – These are the practitioners who provide information to the ATMs on how specific practices are carried out e.g the FAR group on Configuration management would discuss how the organization carries out CM activities etc. More details on this have been given later.

A.8.4 Assessment phases: The assessment is conducted in two phases:

- Phase I or pre onsite phase
- Phase II or on site period

A.8.4.1 Phase I: During the phase I, the following activities are carried out:

- Introduction to CMM – 3 days training
  - Participants : ATMs, including the back up ATMs. Other people from within the organization may also attend, subject to a maximum of 20
- Assessment Participants briefing – half day
  - Participants : All the assessees and the ATMs. Generally, however, we find that the entire organization is called to this briefing where the Chief executive first talks of the management vision that led to the need for an assessment. He discusses the need for continuous quality improvements and for everybody to view the assessment exercise as an opportunity for identifying quality improvements and not view this as an "examination" that needs to be passed somehow or the other. The Assessment Team Leader (ATL) then provides an overview of the CMM to the entire organization and explains the CBA-IPI process to them. One can notice similarities between the opening meeting of the ISO certification audit and this briefing, except that this briefing is to the entire organization and is much more detailed (takes around half a day vs. the 45 minutes that the opening meeting in ISO generally takes)
- Assessment Team members' advanced training – 5 days
  - Participants : All ATMs, including back up ATMs. This training is conducted by the ATL.
- Administration of the Maturity Questionnaire – 2 hours
  - Participants : All Project Managers / project leads as well as representative team members. Representatives from support groups like training, HR, systems administration etc. also fill in the maturity questionnaire (sample enclosed)
- Initial Document Review – 2 days generally
  - A document review is conducted by the Assessment team. The documented QMS, project documents like project plans, SRS etc., records like review records, test logs etc. and the metrics baseline reports are reviewed. The mapping of all of these to the CMM KPAs and to each key practice is done by a detailed exercise of tagging notes and posting notes against each key practice on a "wall chart" where the CMM practices are printed out in bold print to enable everybody to read and discuss.

During the ATMs advanced training, the team members are trained on preparing exploratory questions to use during the on site period. This set of exploratory questions is finalized by the ATMs during the interim period between Phase I and the on-site period (generally within two weeks of the end of Phase I).

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A.8.4.2 Onsite period: During the on-site period (phase II), which happens around 4-6 weeks after Phase I, the following activities are carried out:

- Interviews with Project managers / Project leads

The project managers / project leads of the selected projects are interviewed by the ATMs. The exploratory question scripts are used as the basis for all these discussions. Since the documents have already been reviewed by the ATMs during Phase I, these interviews serve as confirmation of the practices in the projects. Each interview lasts for around 1½ hours. The interviewees are encouraged to provide detailed answers to the questions asked by the ATMs.

- Discussions with the Functional Area Representatives (FAR groups):

As explained briefly above, special sessions are held with team members who explain how specific practices are carried out. The FAR groups usually consist of 4-5 members.

Generally, the following FAR groups are formed during the assessment and discussions are held with each:

- Configuration Management FAR group
- Requirements Management, Analysis and design
- Coding, testing and implementation
- Peer reviews
- Software Quality Assurance
- SEPG and metrics council
- Training
- Support functions like HR, System administration, recruitment etc.
- Technology management group (for Level 5 assessments)
- Defect Prevention (for Level 5 assessments)
- Senior management which discusses how they manage a multitude of projects, resolve inter group issues and look for continued process improvements

Obviously, the FAR groups constituted depend on the Levels to which the organization is being assessed. Sometimes some of the FAR sessions may be merged, e.g. Training may be merged with the support groups, Peer reviews may be merged with any one of Analysis and Design or coding and testing or SQA.

There may also be additional FARs depending on the organizational needs e.g. one organization where we were part of the Assessment Team had a Marketing FAR session and the Requirements Management was merged with this.

The discussions with the FAR groups are in the nature of group discussions where FAR members are encouraged to discuss various practices in the area of interest with the ATMs only asking questions to clarify specific doubts and to keep the discussion within a frame of reference – otherwise the discussions can tend to stray.

- Consolidate findings – The ATMs tag notes that they have taken during the interviews and the group discussions and map it onto the KPAs of CMM. This happens at the end of each day. A golden rule that ATMs follow is that findings have to be consolidated the same day itself.

- Prepare and present draft findings – Draft findings are prepared and presented to all interviewees / assessees to confirm that the ATMs indeed heard and understood them correctly. We think this is a very good practice in the CBA-IPI which the ISO audit methodology could adopt. It ensures that there is no bias in the ATM findings and that language nuances are not wrongly represented by the ATMs.

- Give Final rating: Based on the feedback from the draft findings session, the ATMs modify their findings and start on the final rating exercise. A decision is made on whether the goals for each KPA for the maturity level at which the organization is being assessed are fully met or partially met or are not met at all. Only if all the goals for all the KPAs at a certain level are fully met is the organization rated to have achieved that maturity level.

- Present final findings: The final findings are now presented by the ATL to the organization. The participants are generally the same as was in the initial Assessment Participants briefing in Phase I – the entire organization is generally called in (especially if there is an inkling of the "good" news to be given. However, the focus of the final findings is to identify strengths, improvement opportunities and best practices in certain parts of the organization that others could follow. Again, we believe that this type of value addition is a very good practice in the CBA-IPI. We have seen certain ISO audits, especially those conducted by KPMG where a lot of value addition is done but we have seen many others where this is not so. This happens because the ISO audit methodology does not demand that this be done while the CBA-IPI requires the ATL to add thus value to the organization.

- Executive briefing: The Assessment team then briefs the executive management separately on next steps and any other issue that it believes that senior management could focus on.

- Wrap up activities: The ATMs prepare reports to SEI which include the final findings presentation and feedback by the ATL and the ATMs.

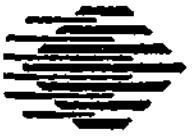
A.8.5 Representative Time frames The time frames for all these activities depend on the size and nature of an organization – however, representative time frames are given below:

Phase I – Pre on site period:

a) Training – Introduction to CMM :	Day 1 to Day 3
b) Assessment participants briefing:	Day 4; first half
c) Maturity questionnaire:	Day 4; 2nd half
d) ATMs advanced training:	Day 4 to Day 8
e) Initial Document review:	Day 9 to Day 11

Phase II – On site period:

a) Interviews with PMs/PLs:	Day 1 to Day 4
b) Discussions with FAR groups:	Day 1 to Day 4
c) Consolidate notes:	Day 1 to Day 4
d) Prepare draft findings	Day 4 to Day 5
e) Present draft findings	Day 5
f) Modify findings	Day 5 to day 6
g) Final rating	Day 6
h) Prepare final findings	Day 6
i) Present final findings	Day 7
j) Executive briefing	Day 7
k) Wrap up activities	Day 8 to Day 9



Software Process Maturity Questionnaire

Capability Maturity Model, version 1.1

April 1994

This document contains questions about the implementation of important software practices in your software organization. The questions are organized in groups of key process areas such as software project planning and software configuration management. A short paragraph describing each key process area precedes each group of questions. Unless directed otherwise by the person who administers this questionnaire, please answer the questions based on your knowledge and experience in your current project.

To help us better interpret your answers to the questions about software process in your organization, this document begins with questions about your own background in software work.

Please read and answer all of the questions. If you wish to comment on any questions or qualify your answers, please use the comment spaces provided.

Your answers will be held in strict confidence by the appraisal team. Specific answers will not be identified within your organization, nor in any other manner. Your name will be used for administrative purposes only: to guide the appraisal team during response analysis and help them contact you for any needed clarifications.

Thank you for your help.

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, Pennsylvania

Filling in Your Answers

We will be using optical scanning technology to enter your answers, so please print or write neatly throughout the questionnaire.

- Feel free to use the margins if you need more space for your written answers or other comments, but please don't write over the check boxes or crosshair (+) symbols.
- Please keep your marks within the check boxes. Any mark will do: ■ ☒ ☑
- You should use a pen with dark blue or black ink.

Definitions of Terms

The Capability Maturity Model on which this Maturity Questionnaire is based uses a number of terms which may be used differently in your organization.

- **Organizational terms** are defined on the blue placard. You may wish to review it now, and refer to it as necessary as you complete the questionnaire.
- **Technical terms** are defined on the pages where they are used.

Respondent Identification

(Please specify)

YOUR NAME:

TODAY'S DATE:

PROJECT NAME:

WORK TELEPHONE:

Section I Respondent Background

1 Which best describes your current position? *(Please mark as many boxes as apply)*

- ☐ PROJECT OR TEAM LEADER
- ☐ MANAGER
- ☐ TECHNICAL MEMBER
- ☐ SOFTWARE ENGINEERING PROCESS GROUP (SEPG) MEMBER
- ☐ OTHER *(Please specify)*

2 On what activities do you currently work? *(Please mark as many boxes as apply)*

- ☐ SOFTWARE REQUIREMENTS
- ☐ SOFTWARE QUALITY ASSURANCE
- ☐ SOFTWARE DESIGN
- ☐ CONFIGURATION MANAGEMENT
- ☐ CODE AND UNIT TEST
- ☐ SOFTWARE PROCESS IMPROVEMENT
- ☐ TEST AND INTEGRATION
- ☐ OTHER *(Please specify)*

3 Have you received any CMM-related training? ☐ NO ☐ YES *(Please describe)*

4 What is your software experience in: *(Please specify for each category)*

Your present organization? ..... ☐ YEARS

Your overall software experience? ..... ☐ YEARS

5 Have you participated in previous forms of Software Process Assessments, Software Capability Evaluations, and/or <u>other</u> forms of software process appraisals? *(Please mark one box)*

- ☐ NO
- ☐ YES → How many? *(Please specify for each category)*
  - ☐ # OF SPAs (Software Process Assessments)
  - ☐ # OF SCEs (Software Capability Evaluations)
  - ☐ # OF OTHER SEI-BASED METHODS *(Please describe briefly:* e.g., mini-assessments or instant profiles*)*
  - ☐ BASED ON <u>NON-SEI</u> PROCESS IMPROVEMENT WORK *(Please describe briefly:* e.g., ISO 9000/9001 audit*)*

Instructions

1 To the right of each question there are boxes for the four possible responses: Yes, No, Does Not Apply, and Don't Know.

Check Yes when:

- The practice is well established and consistently performed.
  - The practice should be performed nearly always in order to be considered well-established and consistently performed as a standard operating procedure.

Check No when:

- The practice is not well established or is inconsistently performed.
  - The practice may be performed sometimes, or even frequently, but it is omitted under difficult circumstances.

Check Does Not Apply when:

- You have the required knowledge about the project or organization and the question asked, but you feel the question does not apply to the project.
  - For example, the entire section on "Software Subcontract Management" may not apply to the project if you don't work with any subcontractors.

Check Don't Know when:

- You are uncertain about how to answer the question.

2 Use the Comments spaces for any elaborations or qualifications about your answers to the questions.

3 Check one of the boxes for each question. Please answer all of the questions.

Forward Traceability Table

FUNCTION SPEC.	SRS REF.	STP REF.	SDD REF.	STD REF.	No. of Test Cases
4.1.26	3.2.1.1.1	4.1.4.1	4.1.1.1.1.3	4.1	10
			4.1.1.1.1.3.2.1		
			4.1.4.1.1.2		
			4.1.1.1.1.1		
4.1.27	3.2.1.1.2	4.1.4.2	4.1.1.1.1.4	4.2	9
			4.1.1.1.1.2		
			4.1.1.1.1.3.2.1		
			4.1.1.1.2.4		
			4.1.1.1.1.1		
4.1.28	3.2.1.1.3	4.1.4.3	4.1.1.1.1.5	4.3	19
			4.1.1.1.1.1		
		4.1.4.4	4.1.1.1.1.6	4.4	9
			4.1.1.1.1.6.2.1		
			4.1.1.1.5.2		
			4.1.1.1.1.2		
			4.1.1.1.2.4		
4.1.29	3.2.1.1.4	4.1.4.5	4.1.1.1.1.7	4.5	7
			4.1.1.1.1.7.2.1		
			4.1.1.1.1.2		
			4.1.1.1.1.1		
4.1.30	3.2.1.1.5	4.1.4.6	4.1.1.1.1.8	4.6	6
			4.1.1.1.1.7.2.1		
			4.1.1.1.1.3.2.1		

LIST OF QUALITY CERTIFIED NASSCOM MEMBER COMPANIES
UPDATED AS ON 28.12.1999

Company	ISO 9000	TickIT	SEI
Alcatel Network Systems Ltd.	ISO 9001	..	..
Ampersand Software Applications Limited	ISO 9001	•	..
Apcosoft Infoway Pvt. Ltd.	ISO 9001	•	..
Aptech Limited	ISO 9001 ISO 9002	..	..
Ashok Leyland Information Technology Limited	ISO 9001 ISO 9002	..	..
BAeHAL Software Limited	ISO 9001	..	..
BFL Software Limited	ISO 9001	..	..
Birlasoft Limited	ISO 9001	..	..
Bhorucom Software Pvt. Ltd.	ISO 9001	..	..
Cadence Design Systems (India) Pvt. Ltd.	ISO 9001	•	..
Canbank Computer Services Ltd.	ISO 9001	•	..
Cegelec India Limited	ISO 9001		..
CG Maersk Information Technologies Limited	ISO 9001		..
CG-Smith Software Limited	..	..	Level 5
Chenab Information Technologies Pvt. Ltd.	ISO 9001		..
Citicorp Information Technology Industries Ltd.	..		Level 5
Citicorp Overseas Software Ltd.	..		Level 4
CMC Limited	ISO 9001		..
Cognizant Technology Solutions	ISO 9001		Level 4
Command International Software	ISO 9001		..
Computervision Research & Development (India) Ltd	ISO 9001		..
Complete Business Solutions (India) Ltd.	ISO 9001		Level 5
Congruent Software Private Limited	ISO 9001		..

LIST OF QUALITY CERTIFIED NASSCOM MEMBER COMPANIES
UPDATED AS ON 28.12.1999

Company	ISO 9000	TickIT	SEI
Contech Software Private Limited	ISO 9001		..
CoSoft India Limited	ISO 9001		..
Digital Equipment India Limited	ISO 9001		..
Data-Core (India) Limited	ISO 9001		..
Cybertech Systems and Software Limited	ISO 9001		..
Datamatics Limited	ISO 9001	•	..
Datamatics Technologies Pvt. Ltd.	ISO 9002		..
DCM Data Systems Ltd.	ISO 9000		..
Daltatec Solutions Limited	ISO 9001		..
Deutsche Software (India) Ltd.	ISO 9001	•	..
DSQ Software Limited	ISO 9001		Level 4
EDS - Electronic Data Systems (India) Pvt. Ltd	ISO 9001		..
Eastern Software Systems Limited	ISO 9001		..
Engineers India Limited	ISO 9001		..
Electronics Corporation of India Limited	ISO 9001 ISO 9002		..
Future Software Pvt. Ltd.	ISO 9001		Level 4
Genisys Integrating Systems (India) Pvt. Ltd.	ISO 9001		..
Gulf Computers Pvt. Ltd	ISO 9001		..
Growth Compusoft Exports Ltd	ISO 9002		..
Geometric Software Solutions Co. Ltd.	ISO 9001		..
HCL Technologies Limited	ISO 9001		..
HCL Perot Systems	ISO 9001		Level 4
Hexaware InfoSystems Limited	ISO 9001		Level 4

Honeywell India Software Operations Pvt. Ltd.
Hughes Software Systems Limited
IBM Global Services India Pvt. Limited
ICICI Infotech Services Limited
IIS Infotech Limited
ITC Limited - ISD
Indus Software Pvt. Ltd
Intellagroup Asia Pvt. Ltd
IMRGlobal Limited
Information Technologies (India) Limited
Infosys Technologies Limited
Infotech Enterprises Limited
Ireda Corporation
i2 Technologies India Pvt. Ltd
iDLX Technology Partners Pvt. Ltd
International Computers India Limited
Kale Consultants Limited
Kanencia Computer Consultants Pvt. Ltd

ISO 9001		Level 4
ISO 9001		
ISO 9001 ISO 9002	•	Level 5
ISO 9001		
ISO 9001	•	
ISO 9001	•	
ISO 9001		
ISO 9001		
ISO 9001	•	
ISO 9001		
ISO 9001	•	Level 5
ISO 9002		
ISO 9001		
ISG 9001		
		Level 3
ISO 9001		Level 5
ISO 9001		
ISO 9002		

LIST OF QUALITY CERTIFIED NASSCOM MEMBER COMPANIES
UPDATED AS ON 28.12.1999

Company	ISO 9000	TickIT	SEI
Maars Software International Limited	ISO 9001		..
MCS Software Solutions Ltd	ISO 9001	•	..
Mahindra British Telecom Ltd.	ISO 9001	•	Level 3
MASCON Technical Services Ltd.	ISO 9001		..
Mascot Systems Pvt. Ltd.	ISO 9001	•	..
Mastek Limited	ISO 9001	•	Level 4
MECON (India) Limited	ISO 9001		..
Metamor Global Solutions Limited	ISO 9001	•	..
Momentum Systems	ISO 9001		..
Microland Limited	ISO 9001		..
Motorola India Electronics Limited	..		Level 5
MTC (India) Pvt. Ltd.	ISO 9001		..
Network Systems & Technologies (P) Limited	ISO 9001		Level 3
Newgen Software Technologies Limited	ISO 9001		..
NIIT Limited	ISO 9001	•	Level 5
OCS International (P) Ltd.	ISO 9001		..
Octon Technologies Ltd.	ISO 9001		..
Oracle Software India Limited	ISO 9001		Level 4
Orient Information Technology Limited	ISO 9001		..
Origin Information Technology (India) Limited	ISO 9001		Level 4
Patni Computer Systems Limited	ISO 9001		Level 3
Pentafour Software & Exports Limited	ISO 9001 ISO 9002		Level 3
Philips Software Centre Pvt. Ltd.	ISO 9001	•	Level 3

LIST OF QUALITY CERTIFIED NASSCOM MEMBER COMPANIES

UPDATED AS ON 28.12.1999

Company	ISO 9000	TickIT	SEI
Polaris Software Lab Limited	ISO 9001	•	Level 4
PricewaterhouseCoopers Ltd	ISO 9001	•	..
PSI Data Systems Limited	ISO 9001		..
R Systems (India) Pvt. Ltd.	ISO 9001		..
Ram Informatics Limited	ISO 9001	•	..
Ramco Systems	ISO 9001	•	..
Resonance Technologies (P) Limited	ISO 9001	•	..
River Run Software Group Pvt. Ltd.	ISO 9001		..
Robert Bosch India Limited	ISO 9001		..
Rolta India Limited	ISO 9001		..
RS Software (India) Limited	ISO 9001		..
Rubamin Systems	ISO 9001	•	Level 5
Satyam Computer Services Limited	ISO 9001	•	..
Siemens Information Systems Limited	ISO 9001		..
Siemens Communication Software	ISO 9001	•	..
Sierra Optima Limited	ISO 9001	..	..
Silicon Automation Systems (I) Ltd.	ISO 9001	..	..
Silverline Industries Limited	ISO 9001	..	..
Softek Limited	ISO 9001	..	..
Softpro Systems Pvt. Ltd.	ISO 9001	•	..
Sonata Software Limited	ISO 9001	..	..
SQL Star International Limited	ISO 9001	..	..
SRA Systems Limited	ISO 9001	..	..
Syntel Software Pvt. Ltd.			

LIST OF QUALITY CERTIFIED NASSCOM MEMBER COMPANIES
UPDATED AS ON 28.12.1999

Company	ISO 9000	TickIT	SEI
SystemLogic (India) Pvt. Ltd.	ISO 9001	..	..
Systems & Software	ISO 9001	..	..
Tata Consultancy Services	ISO 9001	..	Level 5
Tata Honeywell Limited	ISO 9001	..	..
Transformation Systems Pvt Ltd	ISO 9001	•	..
Tata Elxsi Limited	ISO 9001	•	Level 4
Tata Infotech Limited	ISO 9001 ISO 9002	..	..
Tata Interactive Systems	ISO 9001	•	..
Tata Technologies (India) Limited	ISO 9001	..	..
TCG Software Services Pvt. Ltd.	ISO 9001	..	..
TCIL Bellsouth Limited	ISO 9001	..	..
Telecommunications Consultants India Limited	ISO 9001	..	..
Thermax Systems & Software Limited	ISO 9001	..	..
Trigent Software Limited	ISO 9001	•	..
Value Software Technologies (P) Ltd.	ISO 9001	..	..
Verifone India Pvt. Ltd.	ISO 9001	..	..
Visesh Infosystems Limited	ISO 9001	..	..
VJIL Consulting Limited	ISO 9001	..	..
Wipro Infotech Group	ISO 9001	•	Level 5
Xerox Modicorp Limited	..	..	Level 3
Yokogawa Blue Star Limited	ISO 9001	..	

Annexure 12
List of CMM – Level 4 & 5 organizations in the world
Source : SEI

ListofMaturityLevel4and5Organizations

Lastupdated7February2000

Pleasebeawareofthefollowingissuesregardingthislist.

- TheSEIdoesnotcertifycompaniesatmaturitylevels.
- TheSEIdoesnotconfirmtheaccuracyofthematuritylevelsreportedinthenotedsources.
- ThislistofLevel4and5organizationsisbynomeansexhaustive;weknowofotherhighmaturityorganizationsthathavechosennottobelisted.
- TheSEIdidnotuseinformationstoredwithinitsProcessAppraisalInformationSystemtoproducethisdocument.
- Theorganizationslistedgaveexplicitpermissiontopublishthisinformation.
- Noinformationobtainedinconfidencewasusedtoproducethislist.

Organization	PointofContact	Level	Dateof Appraisal	Assessor(s)
BFLSoftwareLimited, Bangalore, India	Sujatha Balakrishnan, sujatha.ravi@bflsoftware.com	4	June1999	CarolynSwanson
BoeingCompany,Aircraft&Missiles&PhantomWorks SouthernCalifornia,LongBeach,CA	GeorgeH.Kasai, george.h.kasai@boeing.com LindaA. Abelson, linda.a.abelson@boeing.com	5	Dec1997	Andy Felschow Jeff Facemire
Boeing Company,MilitaryAircraft&MissileSystemsF/A-18 MissionComputer,St.Louis,MO	BruceA.Boyd, bruce.a.boyd@boeing.com RobertL.Allen, robert.l.allen3@boeing.com	4	Nov1999	RoyQueen Bob Manders Jeff Perdue BillFairer
BoeingCompany,ReusableSpaceSystemsandSatellite Programs,HuntingtonBeach&SealBeach,CA	Don Dillehunt, donald.d.dillehunt@boeing.com	5	Oct1999	Andy Felschow Jeff Facemire
BoeingCompany,SpaceTransportationSystems,Kent,WA	ChuckMartin, Charles.Martin3@PSS.boeing.com	5	July1996	SteveMasters MarkPaulk
CG-SmithSoftware, Bangalore, India	G.N. Raghavendra Swamy, raghav@cgs.cgsmith.soft.net	5	Sept1999	Richard Storch
CiticorpInformationTechnologyIndustriesLimited(CITIL), Mumbai, India	VivekV. Govilkar, vivek.govilkar@citicorp.com	5	Nov1999	Ken Dymond S. Santhanakrishnan AnandKumar
FutureSoftwarePrivateLimited, Chennai, India	M.G.Thomas, thomasmg@future.futsoft.com	4	June1999	Pradeep Udhas

HCL PerotSystems, Noida, India	Rakesh Soni, rakesh.soni@hpsglobal.com	4	July1999	Pradeep Udhas
HoneywellInternational,AvionicsIntegratedSystems(formerly AlliedSignal,Guidance&ControlSystems), Teterboro,NJ	Steve Janiszewski, stephen.janiszewski@honeywell.com	4	Nov1996	LarryBramble
IBMGlobalServicesIndia, Bangalore, India	Asha Goyal,gasha@in.ibm.com Maya Srihari,smaya@in.ibm.com	5	Nov1999	Richard Storch
InternationalComputersIndia Ltd(ICIL), Pune,India	Ashok Sontakke, a.r.sontakke@icil.co.in	5	Feb1999	Richard Knudson
LittonGuidanceandControlSystems,WoodlandHills,CA	Ray Madachy, madachyr@littongcs.com	4	Dec1998	Mark Amaya
LockheedMartinFederalSystems, Owego,NY	Ed Fontenot, ed.fontenot@lmco.com WarrenA. Schwomeyer, warren.schwomeyer@lmco.com	5	Dec1997	John Travalent GillesBurger Mary Busby John Jurik CindyBlackwell Rich Clements Warren Schwomeyer Alan Sholtes
LockheedMartinManagement&DataSystems,KingofPrussia, PA	M.LynnPenn, mary.lynn.penn@lmco.com	4	Dec1998	Andy Felschow CarolGranger-Parker DennisRing
LockheedMartinMissionSystems, Gaithersburg,MD	Paul Weiler,paul.weiler@lmco.com Al Aldrich,al.aldrich@lmco.com	5	Oct1999	Paul Byrnes
LockheedMartinNavalElectronicsandSurveillanceSystems-Syracuse,SyracuseNY	Peter Barletto,pete.barletto@lmco.com	5	Nov1999	CarolParker Peter Barletto
LockheedMartinNavalElectronicsandSurveillanceSystems-Manassas(formerlyUnderseaSystems), Manassas,VA	DanaRoper,dana.roper@lmco.com	5	Feb1999	Judah Mogilensky John Travalent DonaldWhite
LockheedMartinSpaceElectronicsandCommunications Systems- Manassas(formerlyLoralFederalSystems), Manassas,VA	DanaRoper, dana.roper@lmco.com	4	June1995	Judah Mogilensky John Travalent Chris Manek
MotorolaAustraliaSoftware Centre,Adelaide, Australia	Terry Wardle, A11374@email.mot.com	4	Aug1997	John Pellegrin

MotorolaIndiaElectronicsLtd.(MIEL), Bangalore, India
NCRCorporation, TeradataDevelopmentDivision,Massively ParallelSystems,SanDiego,CA
NorthropGrumman,AirCombatSystems,IntegratedSystems andAeronauticsSector,ElSegundo,CA
NorthropGrumman,IntegratedSystems& Aerostructures,AEW &EWSystems(formerlySurveillance&Battle Management), Bethpage,NY
OracleSoftwareIndiaLimited,IndiaDevelopmentCenter, Bangalore, India
Raytheon(formerlyRaytheonE-Systems),Garland,TX
RaytheonC3IFullertonIntegratedSystems,Commandand ControlSystems/MiddleEastOperations,Fullerton,CA
RaytheonMissileSystems,SoftwareEngineeringCenter, Tucson,AZ
SatyamComputerServices Ltd, India
Tata ConsultancyServices,HP Centre, Chennai, India
Tata ConsultancyServices,SEEPZ, Mumbai, India
Tata ConsultancyServices,SEEPZ, Mumbai, India
Tata ConsultancyServices, Shollinganallur, Chennai, India
Tata ConsultancyServices,USWest, Chennai, India

	5	Nov1993	John Pellegrin
Ron Weidemann, ron.weidemann@sandiegoca.ncr.com	4	Oct1999	Ron Weidemann
LeithaPurcell, purcele@mail.northgrum.com	4	Oct1993	Don Dortenzo
DennisCarter, cartede@mail.northgrum.com	4	Oct1998	Andy Felschow
Ashish Saigal,asaigal@in.oracle.com	4	May1999	Pradeep Udhas
MaryE.Howard, mary_e_howard@raytheon.com	4	Dec1998	NeilPotter
JaneA.Moon, jmoon@west.raytheon.com Janet Bratton, jabratton@west raytheon.com	5	Oct1998	Paul Byrnes JaneMoon RonaldUlrich Ivan Flinn Bruce Duncil Janet Bratton Jim Hudec
MichaelD.Scott, mscott1@west.raytheon.com	4	Oct1998	John Ryskowski MichaelScott
Prabhuu Sinha,prabhuu@satyam.com	5	March1999	Richard Knudson
Gargi Keeni, gkeeni@mumbai.tcs.co.in P. Vasu,pvasu@hp.india.com	5	July1999	Ron Radice
P.Suresh, p.suresh@seepz.tcs.co.in	5	Aug1999	Ron Radice
Gargi Keeni, gkeeni@mumbai.tcs.co.in P.Suresh, p.suresh@seepz.tcs.co.in	5	Aug1999	Ron Radice
Gargi Keeni, gkeeni@mumbai.tcs.co.in R. Ravishankar, rravisha@chennai.tcs.co.in	5	Nov1999	Ron Radice
Gargi Keeni, gkeeni@mumbai.tcs.co.in R. Umasankar,rumasan@uswest.com	5	April1999	Ron Radice V. Muralidharan JohnHarding

TelcordiaTechnologies,Piscataway,NJ
USAirForce,OgdenAirLogisticsCenter,Technology& IndustrialSupportDirectorate,SoftwareEngineering Division,HillAFB,UT
USAirForce,OklahomaCityAirLogisticsCenter,Directorate ofAircraftManagement,SoftwareDivision,TestSoftware andIndustrialAutomationBranches(OC-ALC/LAS),Tinker AFB,OK
USArmy,CECOM,SEC,FireSupportSoftwareEngineering, FortSill,OK
USNavy,FleetMaterialSupportOffice, Mechanicsburg,PA
WiproGEMedicalSystems, Bangalore, India
WiproTechnologies,EnterpriseSolutionsDivision, Bangalore, India
WiproTechnologies,GlobalR&D(formerlyTechnology Solutions), Bangalore, India

Bill Pitterman, wpitterm@telcordia.com	5	May1999	Pat O'Toole BillCurtis NormHammock
David Putman,oo-alc.tis- sepg@hill.af.mil	5	July1998	MarkPaulk Brian Larman Donna Dunaway Bonnie Bollinger Millie Sapp MikeBallard
KelleyButler, kelley.butler@tinker.af.mil	4	Nov1996	Judah Mogilensky
DonCouch,couchdc@fssec.army.mil Phil Sperling, sperlips@fssec.army.mil	4	Nov1997	DonCouch David Zubrow Wolf Goethart
KathleenD. Chastain, kathleen_chastain@fmso.navy.mil	4	Oct1998	Kathleen Chastain David Shupe Deborah Yorlets RonaldDoyle JosephBobby James McGowan
K.V. Ramaswami, kv.ramaswami@geind.ge.com	5	Jan1999	Richard Knudson C. Rama Rao
T.V. Subbarao, subbarao.tangirala@wipro.com	5	Dec1998	Richard Storch
V. Subramanyam, vsm@wipinfo.soft.net	5	June1999	Richard Knudson MarkPaulk

8.3 Summary Results

8.3.1 Baselines and Control Limits

Table 2- Baselines and Control Limits

Project Type	Baseline (B)	S.D (S)	n	UCL (B+n*S)	LCL (B-n*S)	Unit
PRODUCTIVITY						
Y1	796	336	1	1132	460	ELOC/PD
Y2M	281	107	1	388	174	ELOC/PD
Y2T	554	254	1	808	301	ELOC/PD
Y3T	5310	2395	1	7704	2915	ELOC/PD
Y3M	2102	1149	1	3251	953	ELOC/PD
Client Server	0.94	0.36	1	1.31	0.58	FP/PD
System Software	19	12	1	31	7	HPS EUPD Size Count/Phr
DEFECT DENSITY						
Y1	0.29	0.20	1	0.48	0.09	Defect/EKLOC
Y2M	0.68	0.50	1	1.18	0.17	Defect/EKLOC
Y2T	0.14	0.06	1	0.21	0.08	Defect/EKLOC
Client Server	0.29	0.22	1	0.51	0.07	Defects/FP
WEIGHTED DEFECT DENSITY						
Y1	0.51	0.37	1	0.88	0.14	Defect/EKLOC
Y2M	1.63	1.17	1	2.8	0.46	Defect/EKLOC
Y2T	0.25	0.10	1	0.35	0.15	Defect/EKLOC
Client Server	0.43	0.31	1	0.74	0.12	Defect/FP
REVIEW EFFECTIVENESS						
Y2M	81%	22%	1	100%	59%	Review defects/Total defects
Y2T	93%	12%	1	100%	81%	Review defects/Total defects

Project Type	Baseline (B)	S.D. (S)	n	UCL (B+n*S)	LCL (B-n*S)	Unit
Client Server	43%	18%	1	61%	26%	Review defects/Total defects
DEFECT AGE						
All Project Types	0	-		1	N.A.	
EFFORT VARIANCE						
All Project Types	0 %	-		+10%	-10%	
SCHEDULE VARIANCE						
All Project Types (except SS)	0 %	-		+10%	-10%	
System Software (SS)	0 %	-		+2 days	-2 days	

8.3.2 Phase-wise Efforts and Defects Distribution

Table 3- Phase-wise Efforts and Defects Distribution

Project type	Phase	Effort Distribution	Defects** Distribution
Y2T	IA & Renovation	60%	83-100%
	Testing	40%	0-17%
Y2M	IA & Renovation	50%	–
	Testing	50%	–
Client Server	SRS	8%	19%
	Design	34%	38%
	Coding & Testing*	47%	43%
	User Acceptance Testing	11%	–

* includes System Testing

** These are weighted defects

Chart 5 – C/S : Phase-wise Effort distribution

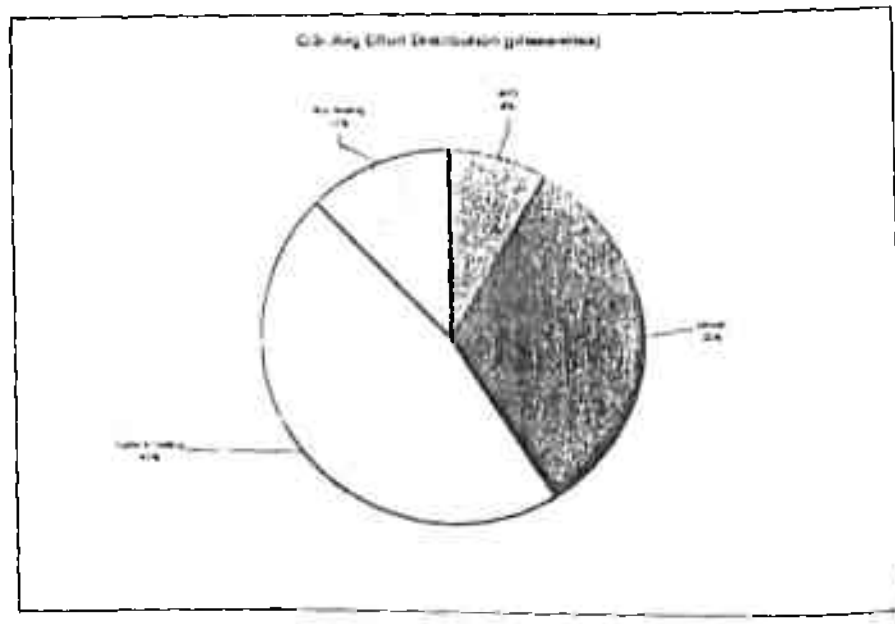
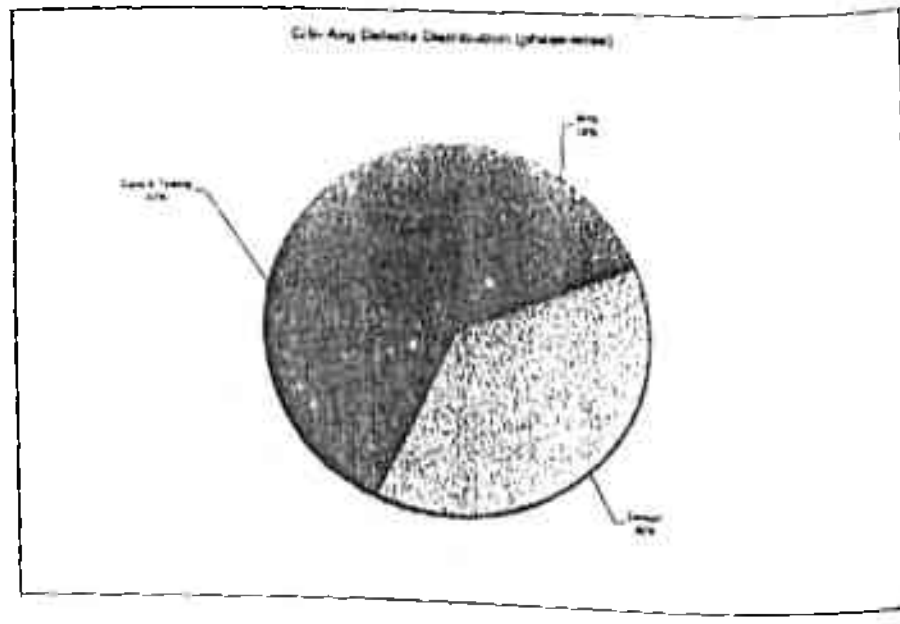


Chart 6 – C/S : Phase-wise Defects distribution



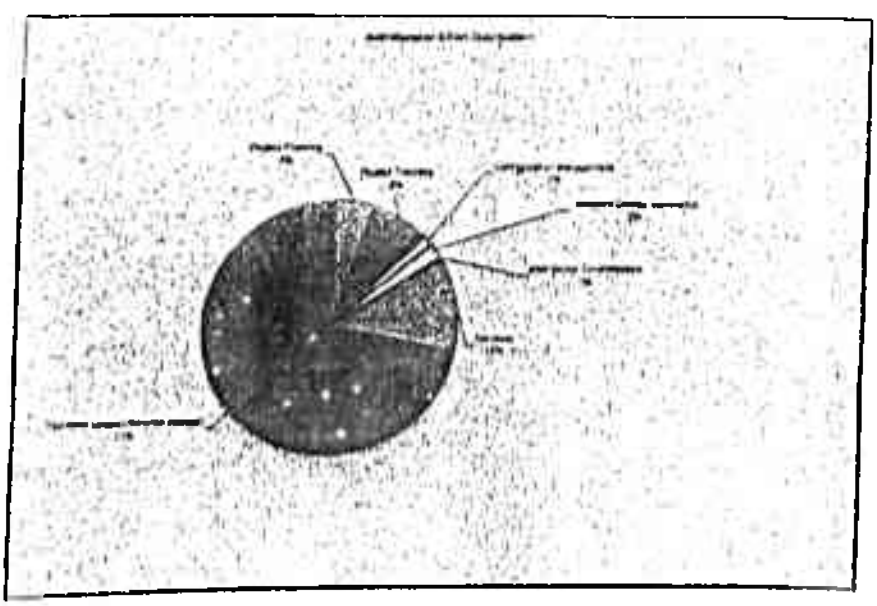
8.3.3 Activity-wise Efforts Distribution

Table 4- Activity-wise Efforts Distribution*

Activity	% of Total Efforts
Project Planning	5%
Project Tracking	7.5%
Configuration Management	1.25%
Software Quality Assurance	2%
Inter-Group Co-ordination	0.5%
Reviews	12%
Technical (project lifecycle phases)	71.75%

* For all project categories

Chart 7 – Activity-wise Effort Distribution



8.4 Project Category-wise Analysis

8.4.1 Y2K- Y1 Category

Chart 8- Y1 Productivity

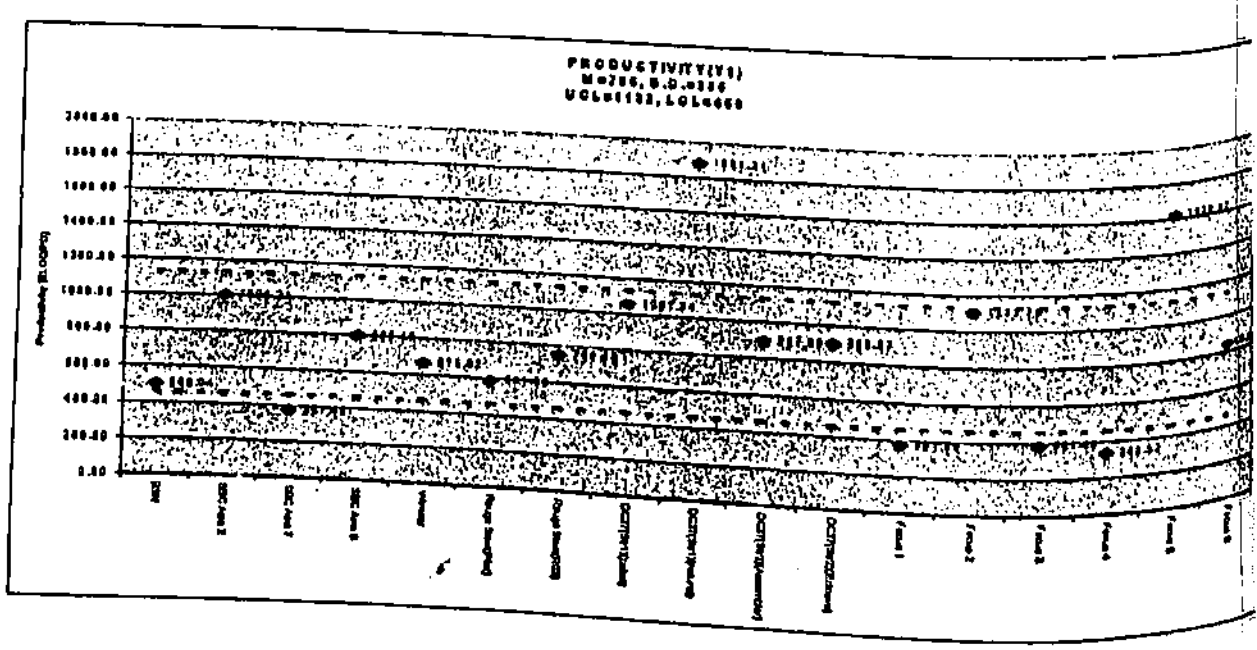


Chart 9- Y1 Defect Density

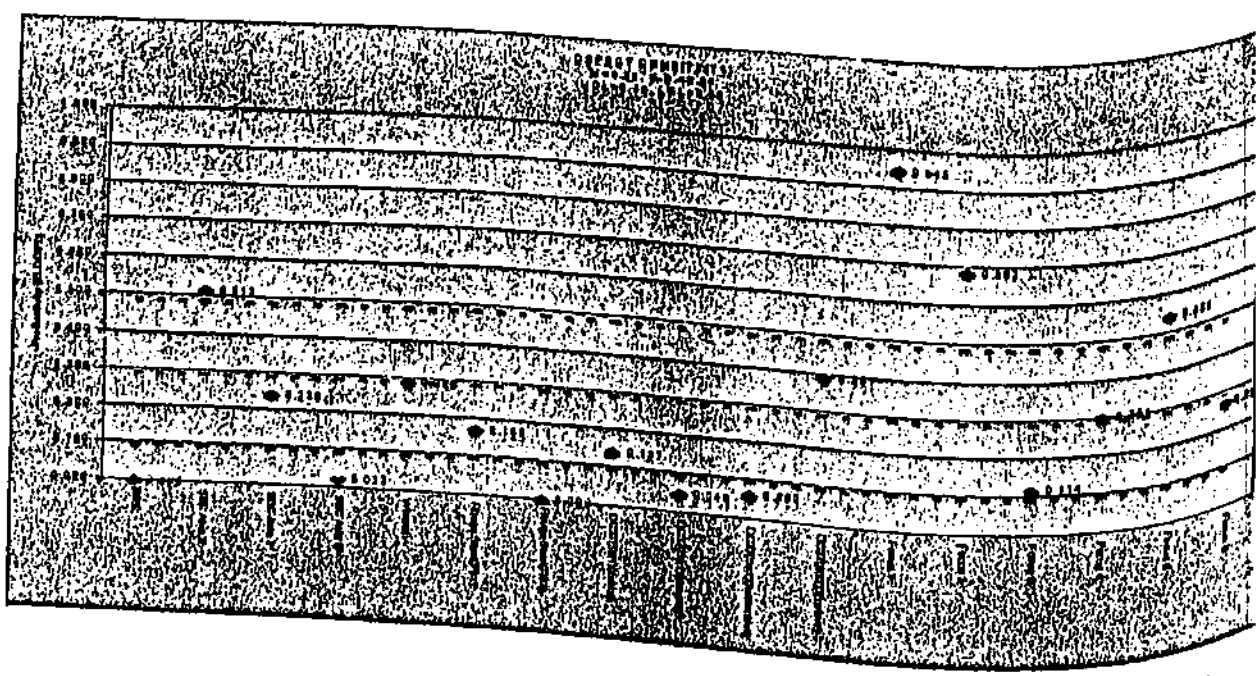


Chart 10- Y1 Weighted Defect Density

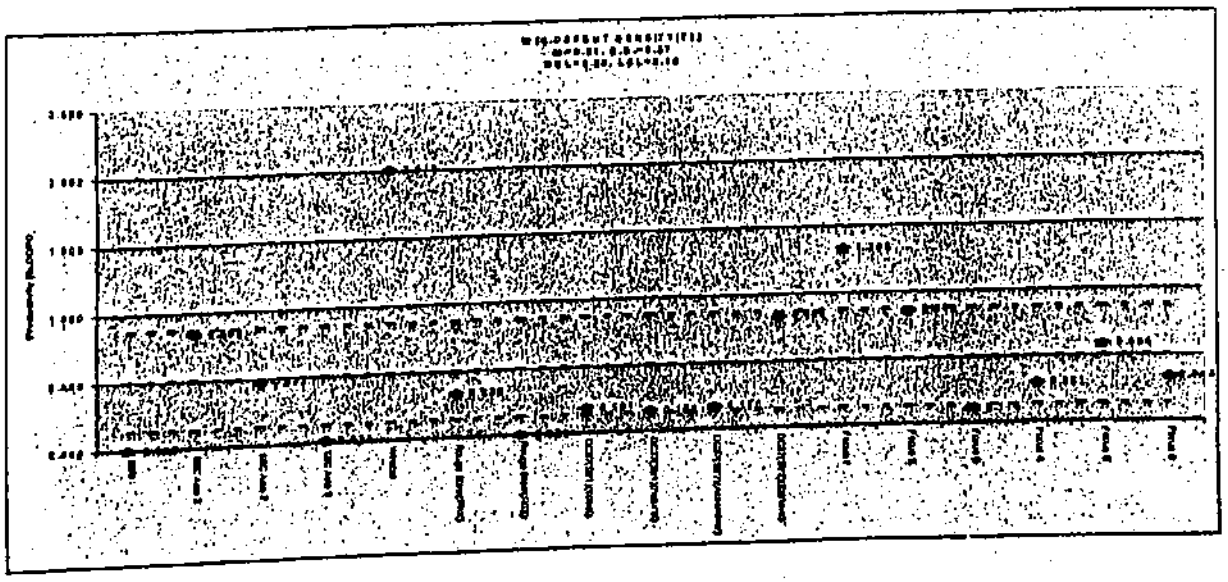


Chart 11- Y1 Effort Variation

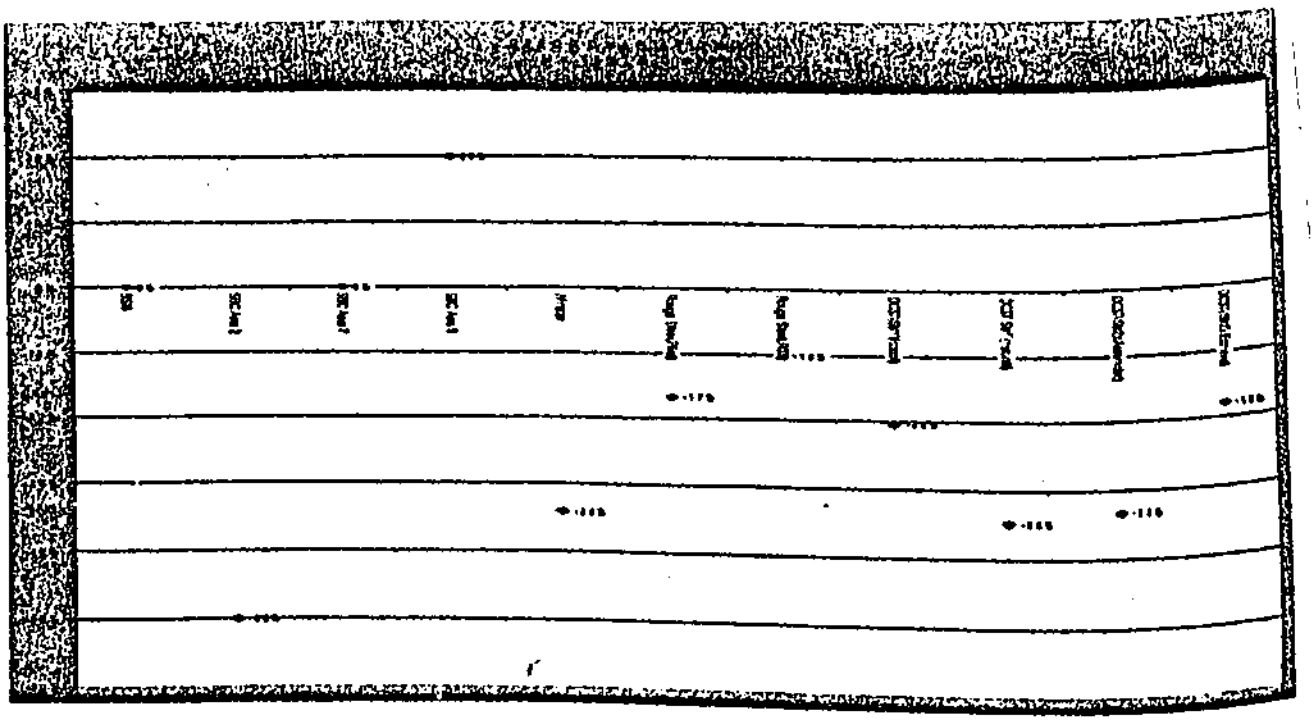
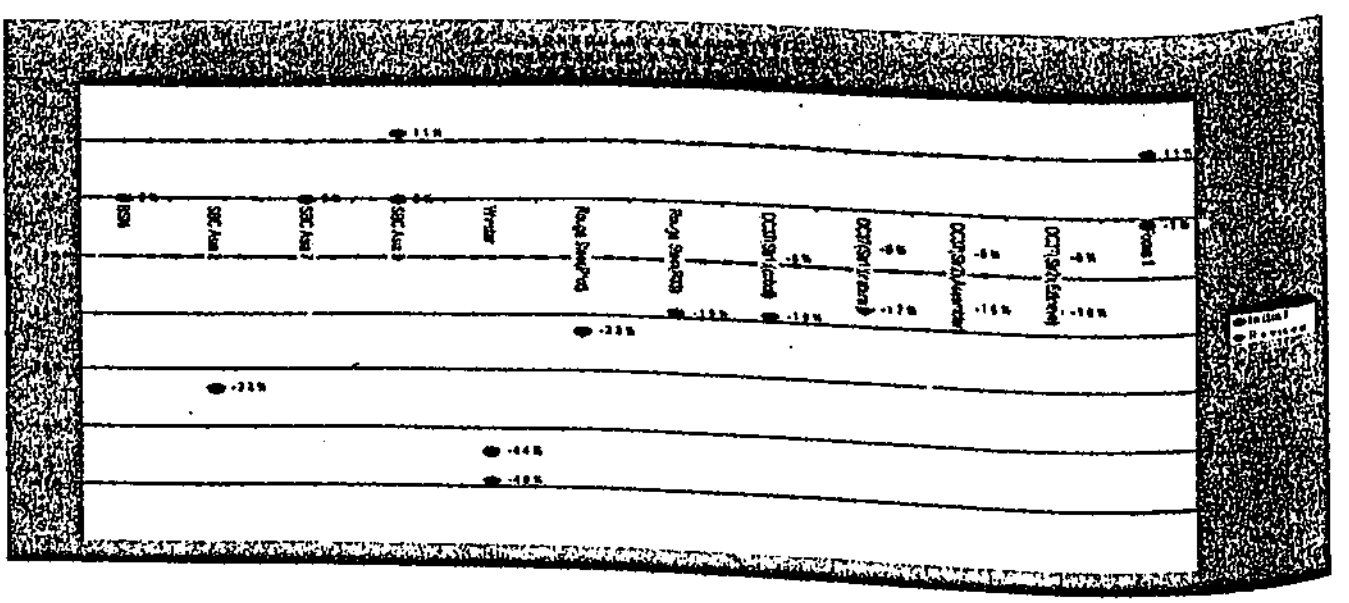


Chart 12- Y1 Schedule Variance



8.4.7 Client Server

Chart 31- C/S Productivity

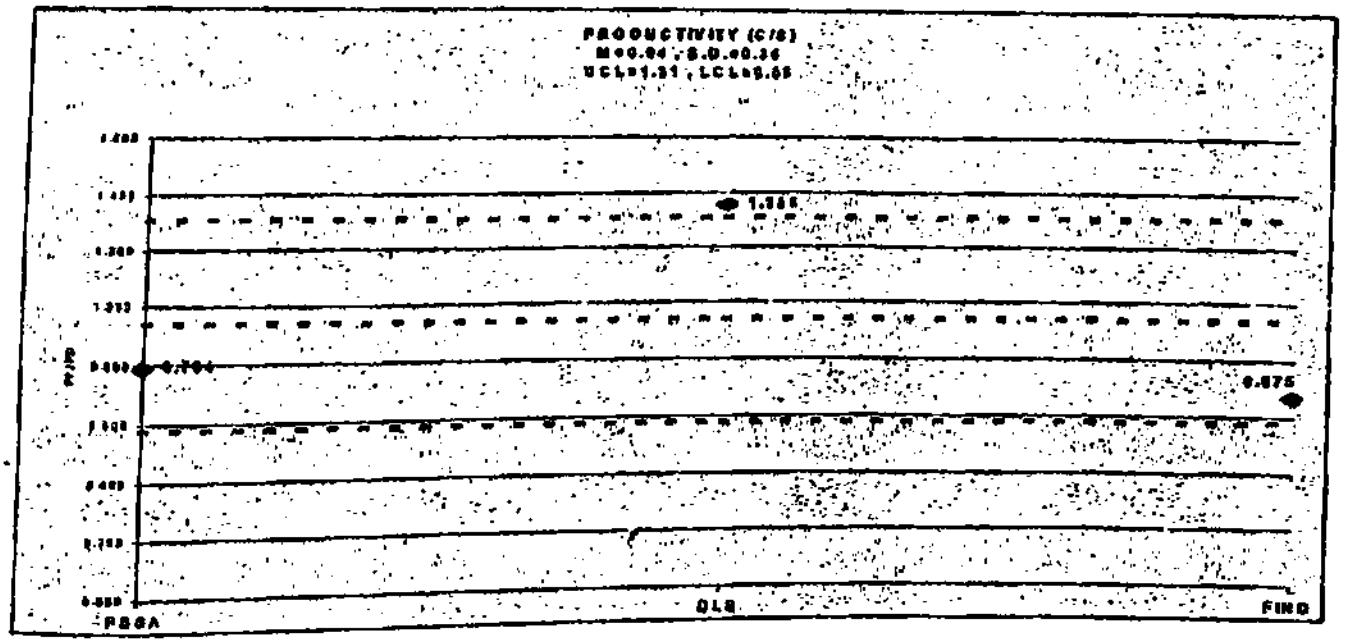


Chart 32- C/S Defect Density

Chart 13- C/S Weighted Defect Density

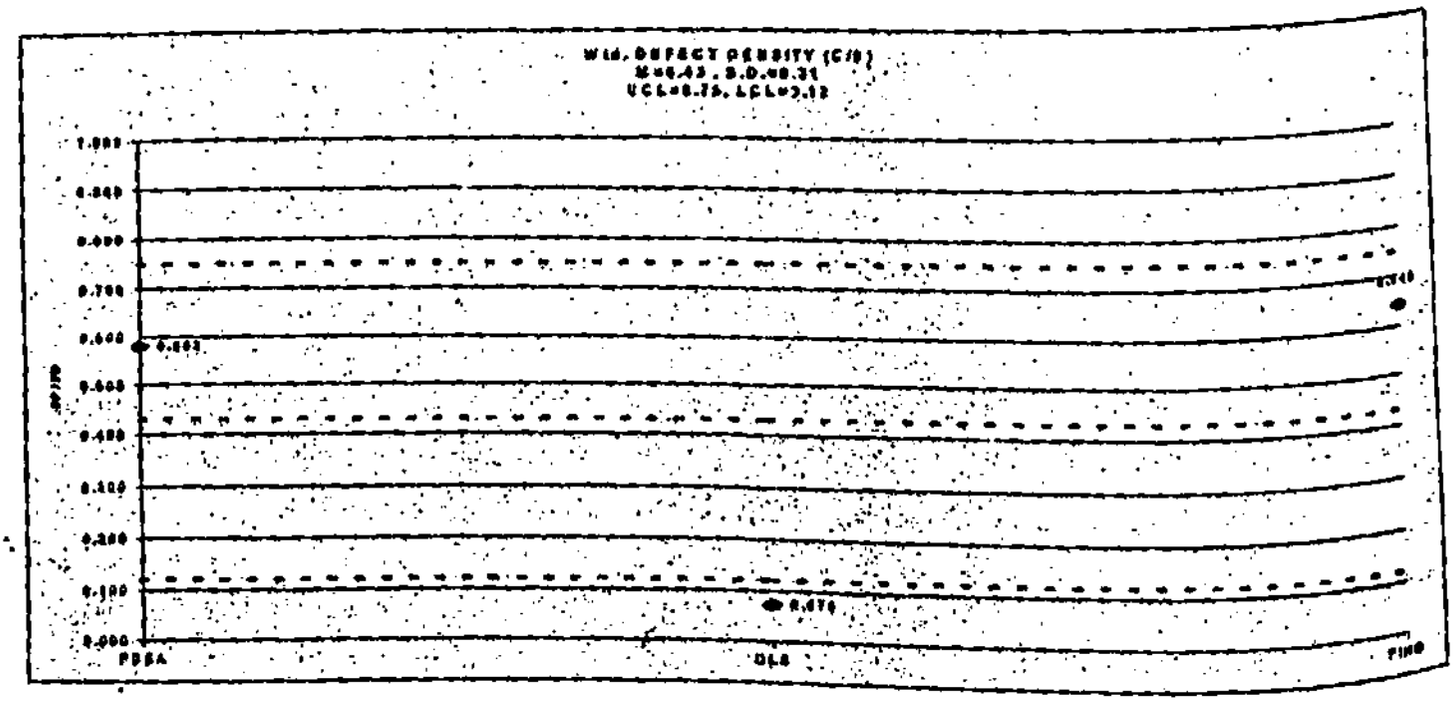


Chart 34- C/S Effort Variance

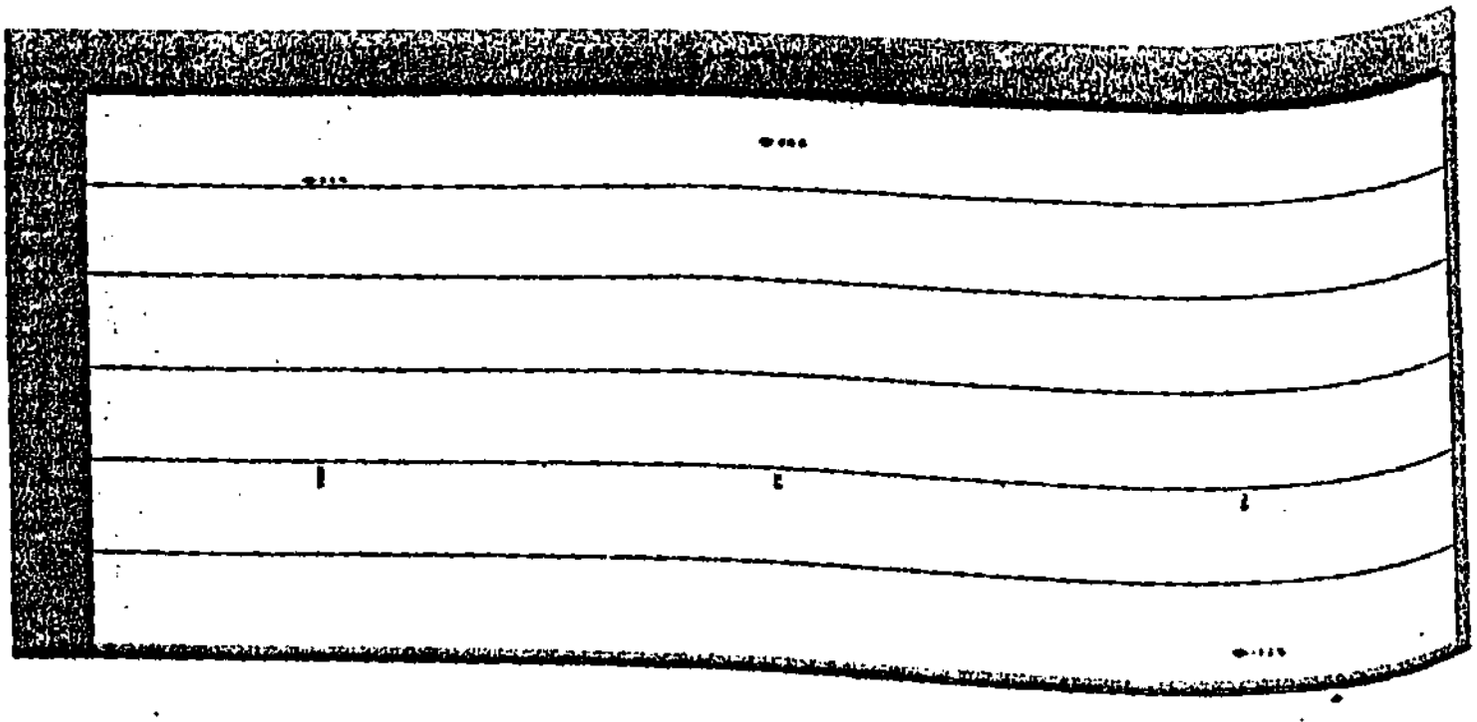


Chart 35- C/S Schedule Variance

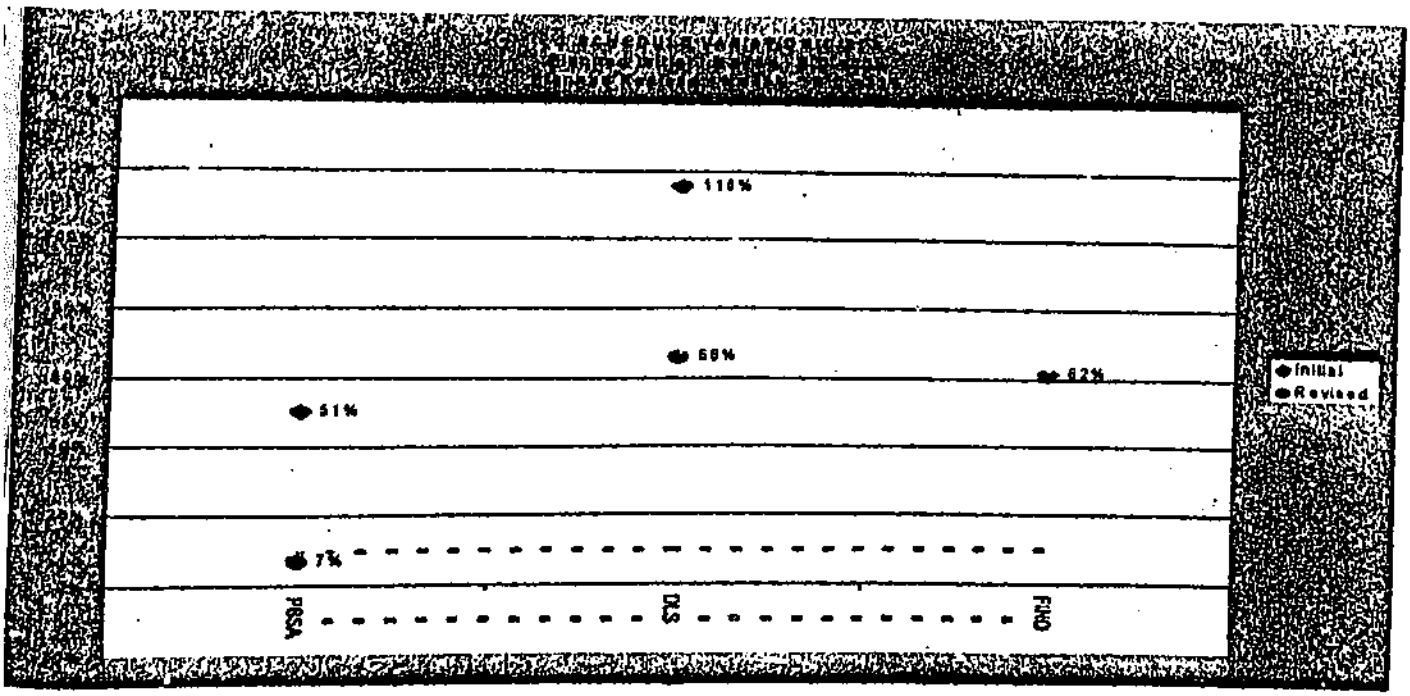


Chart 36- C/S Review Effectiveness

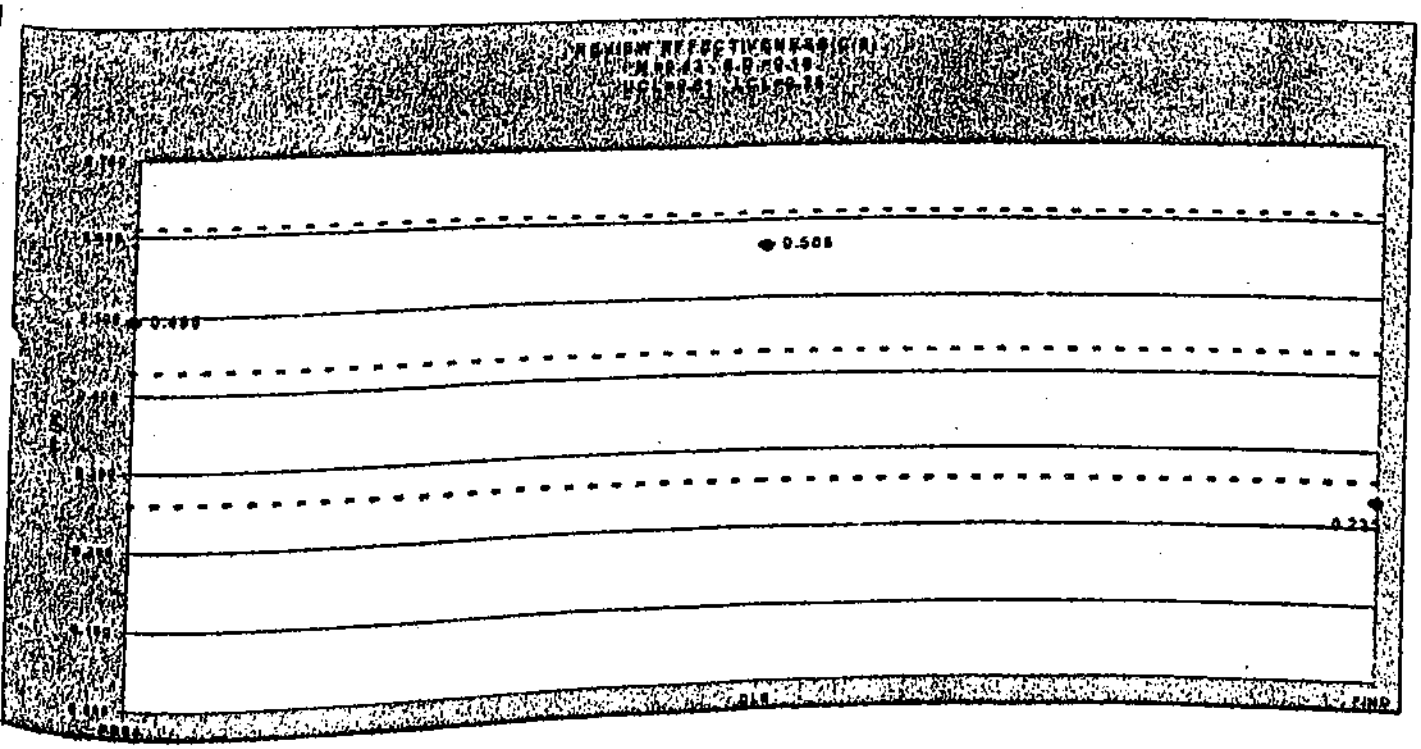


Chart 46- Overall Training Ratings

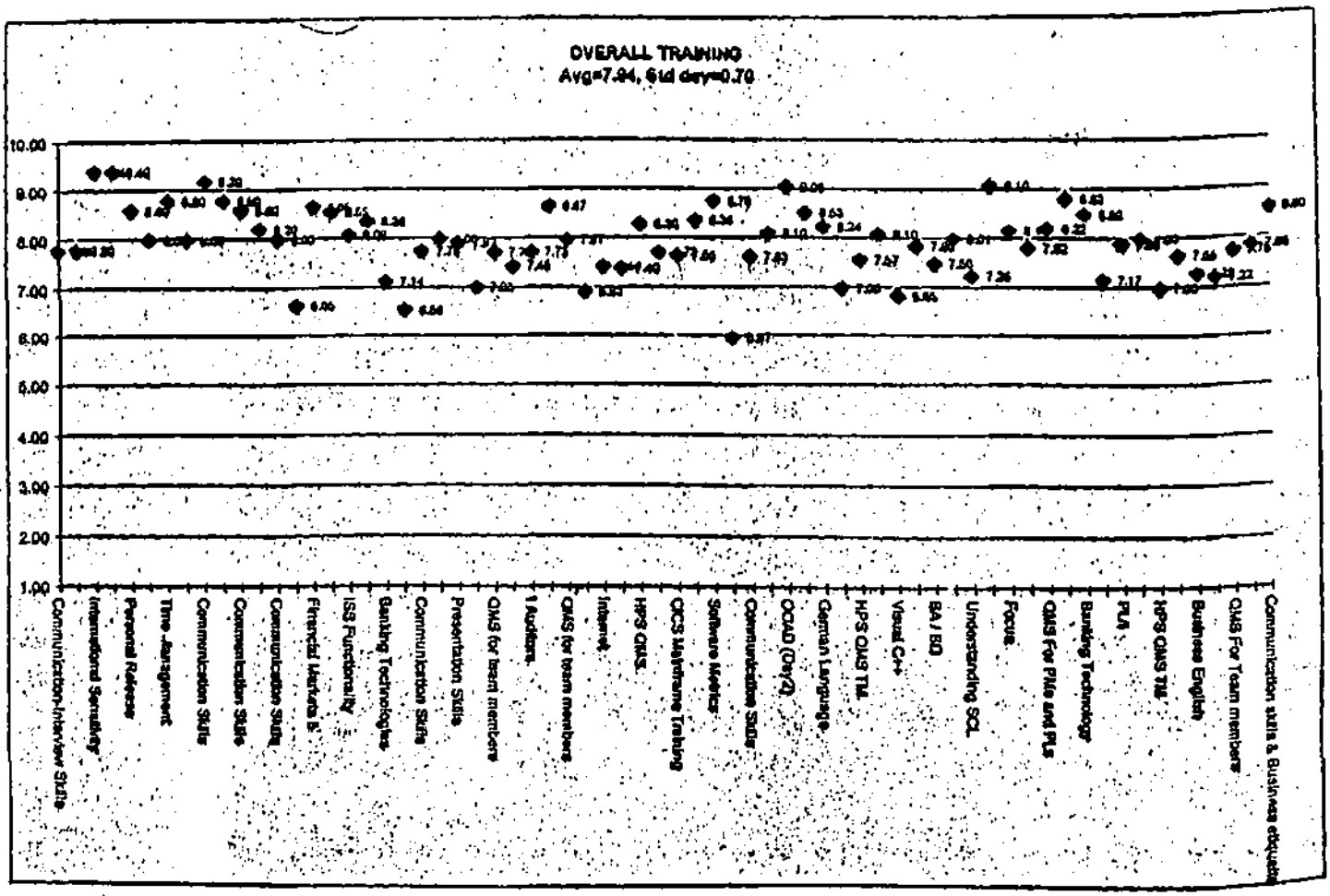


Chart 47- Average Rating Across Training Categories

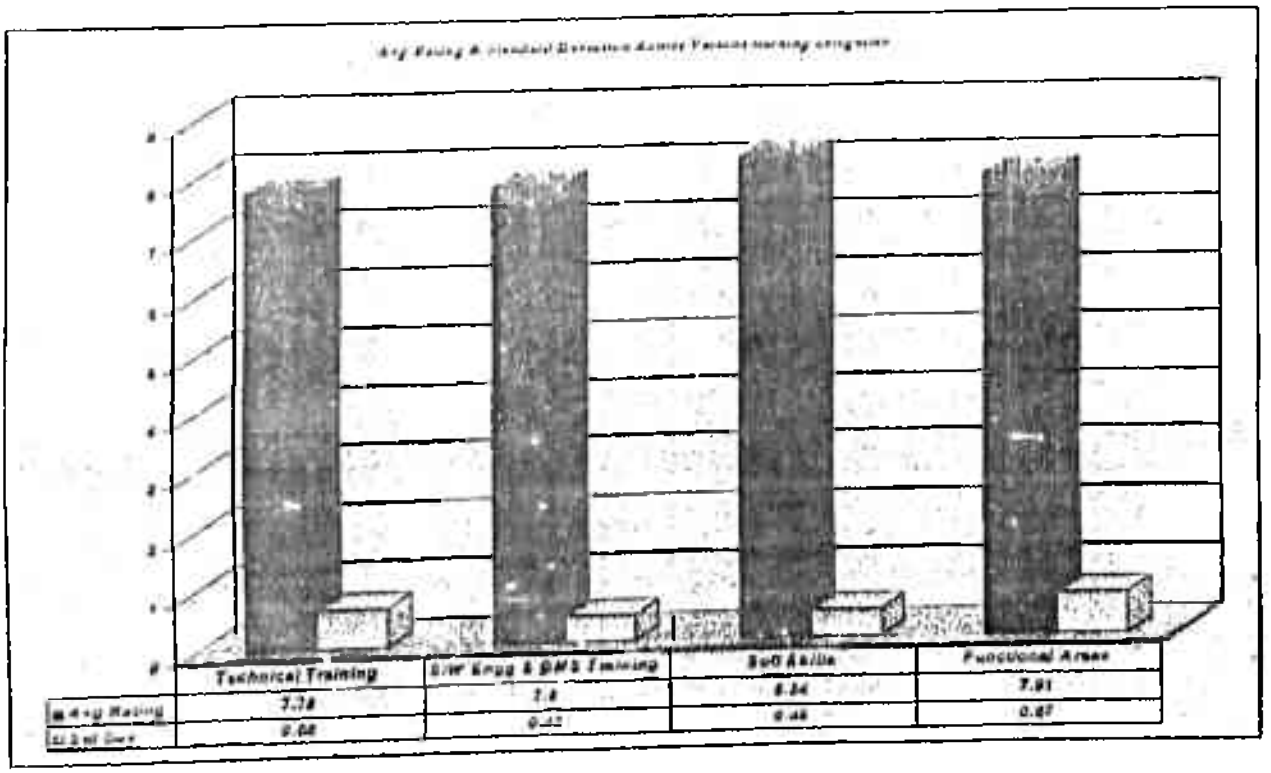


Chart 48- Technical Training Ratings

Chart 49- S/W Engg. And QMS Training

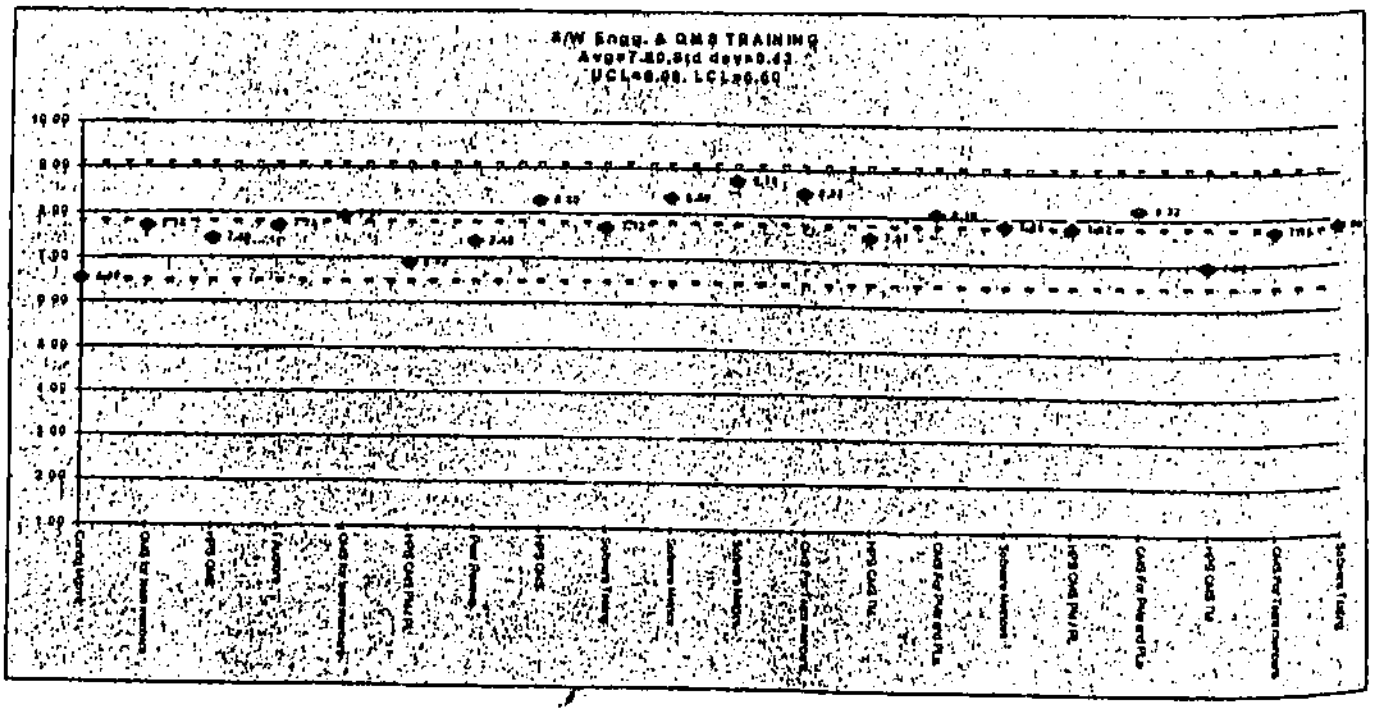


Chart 50- Soft Skills Training

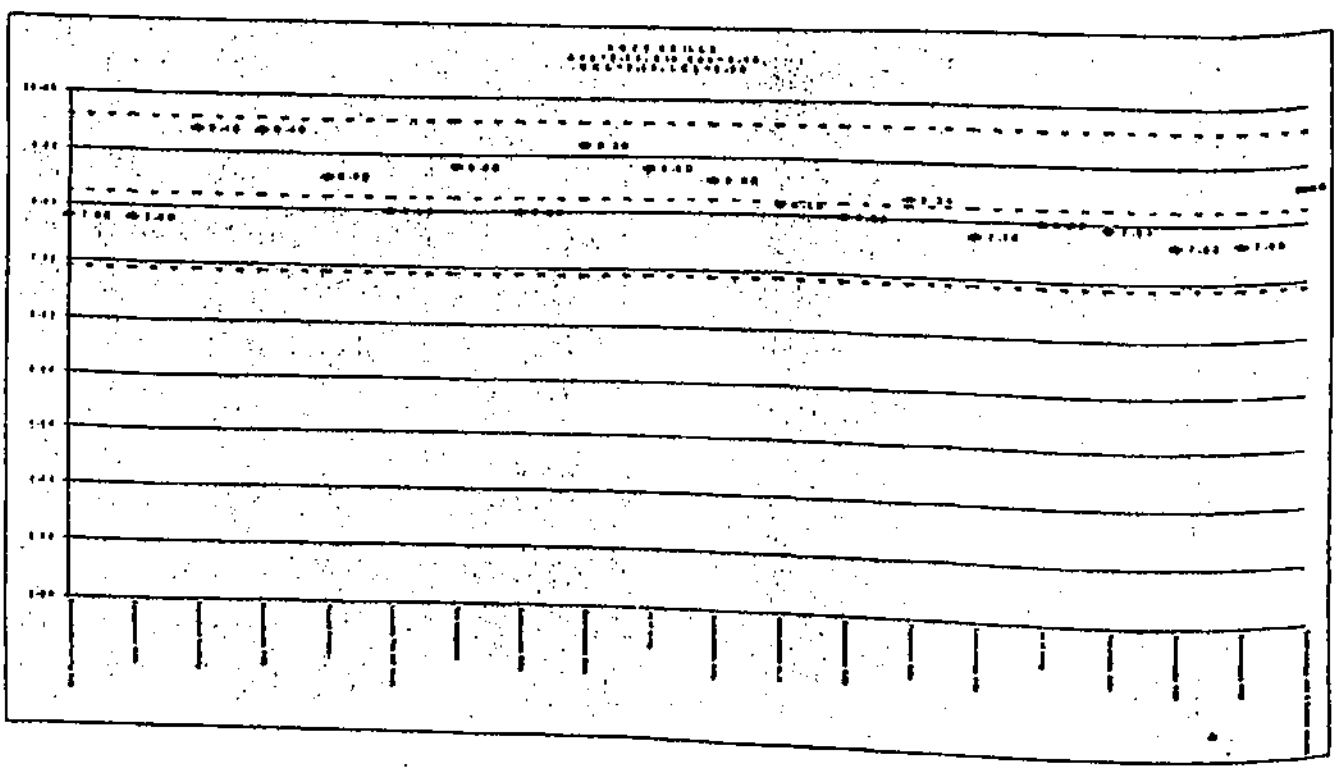


Chart 51- Functional Areas Training

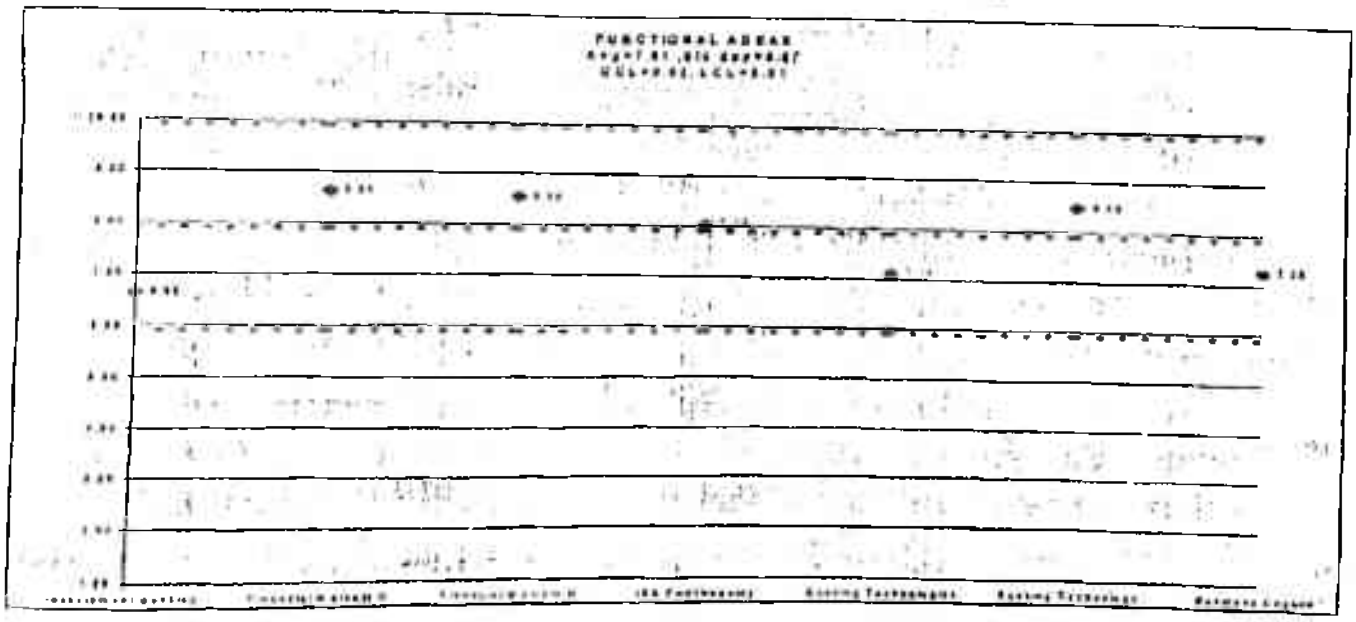
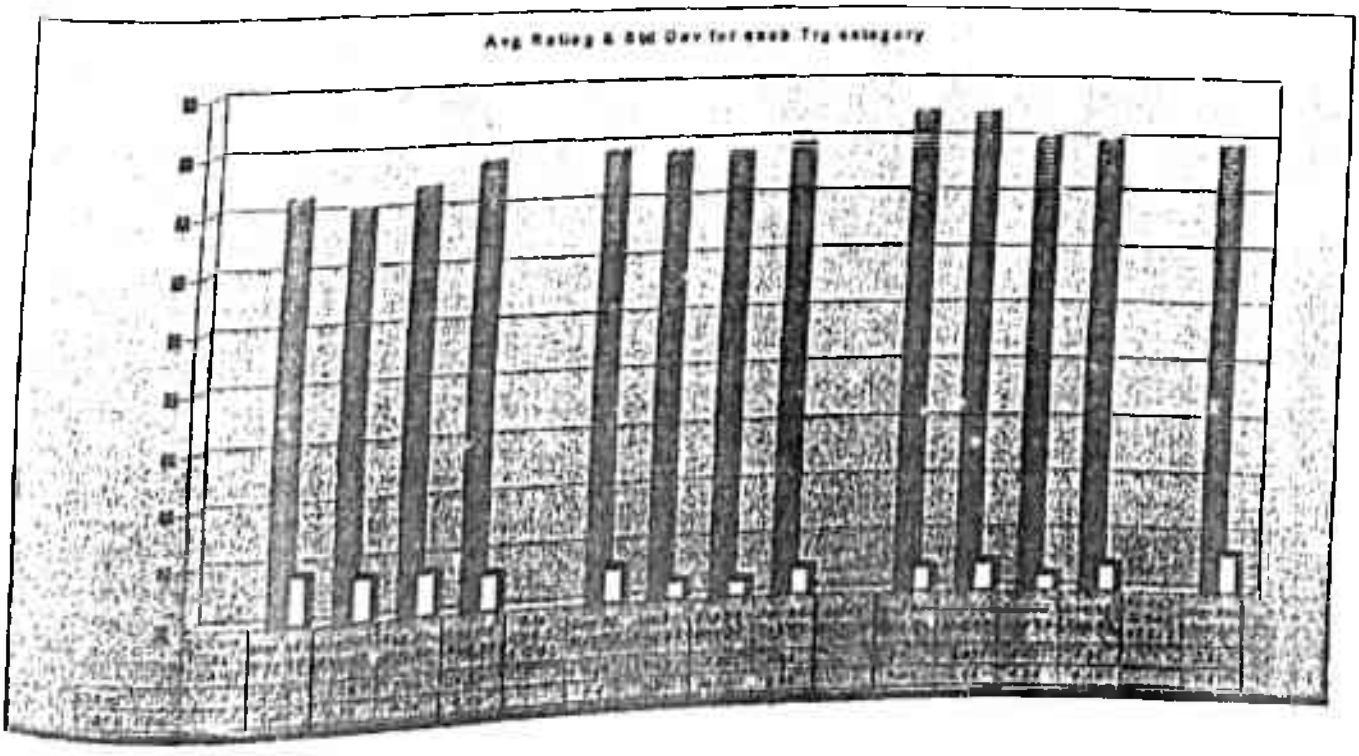


Chart 52- Quarterly Trends in each Training Category



6. Baselines

Organization-wide metrics

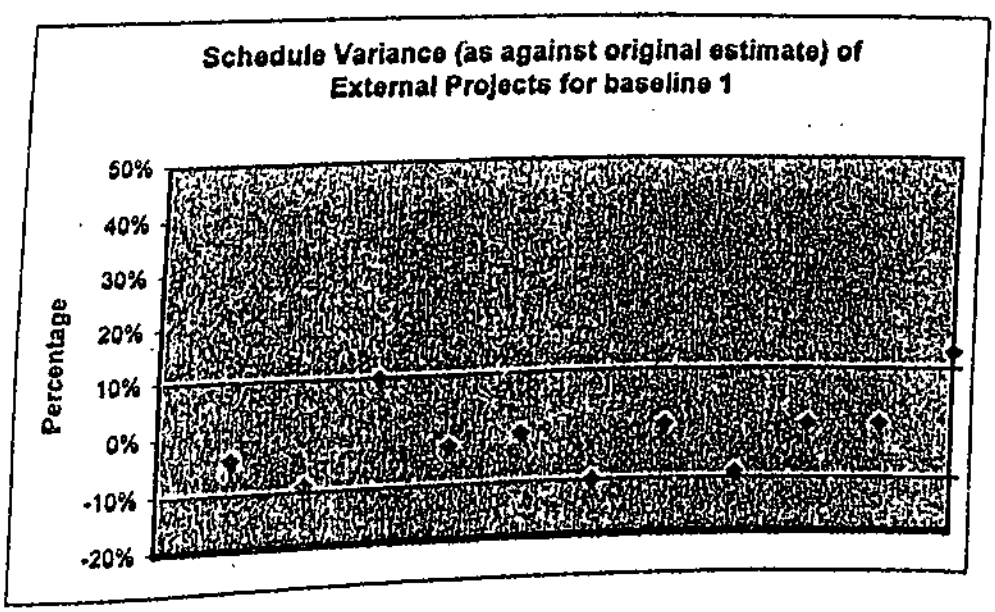
6.1.1. Schedule Variance (as against original estimate) of External Projects

This metric is defined as:

Schedule Variance (as against original estimate) = $\frac{\text{(Actual duration in days – Original estimated duration in days) * 100}}{\text{(Original estimated duration in days)}}$

The metric is used to monitor the project performance. A cause and analysis report for a given schedule slippage helps in identification of areas for process improvement. The schedule slippage for different phases identifies where additional effort is to be spent to compensate the slippage.

The data is given in Annexure A of this document. The graphical representation of the data is as follows:



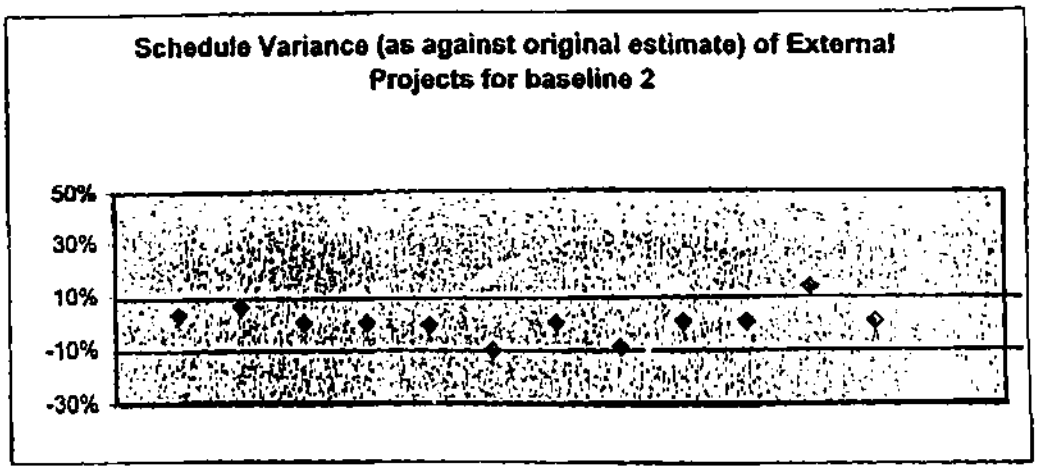
Based on this the baselined capabilities are:

Mean	-1%
Std Dev	7%
UCL	10%
LCL	-10%

Analysis:

Based on above observations it is concluded that because of fairly large variability in the data points, a target driven control limit will be set. This is also required as because strict adherence to schedule is one of our Quality objectives. The target-driven limits are ± 10%. In the above plot only one point lies outside the control limits and that is also to a very small extent. Hence it

can be concluded that the projects are under control with respect to the above control limits except one case.



Analysis:

Based on above observations a target driven control limit is set. This is also required as because strict adherence to schedule is one of our Quality objectives. The target-driven limits are ± 10%. In the above plot only one point lies outside the control limits and that is also to a very small extent. Hence it can be concluded that the projects are under control with respect to the above control limits except one case as in the previous baseline.

6.1.2. Schedule Variance (as against last revised estimate) of External Projects

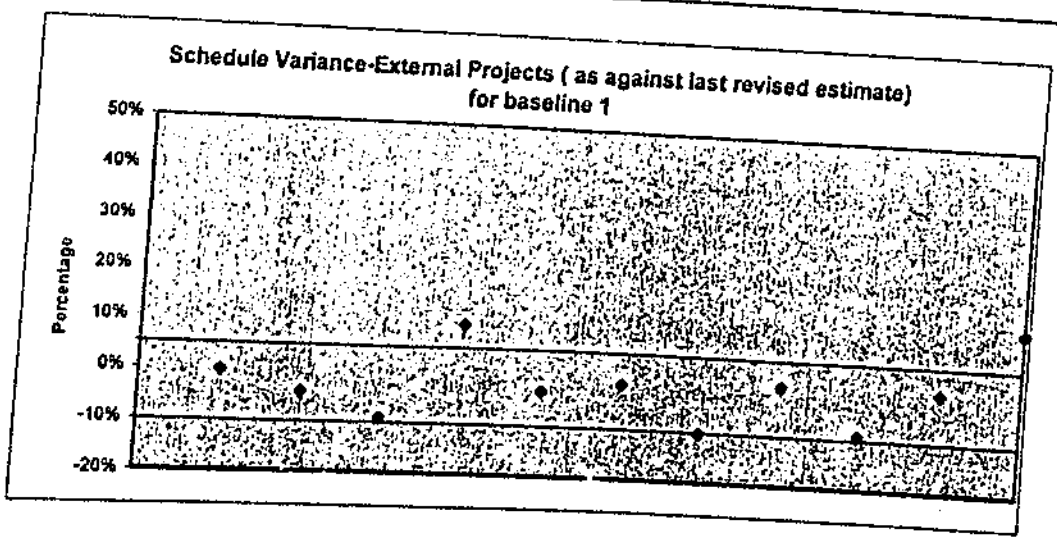
This metric is defined as:

$$\text{Schedule Variance (as against last revised estimate)} = \frac{\text{(Actual duration in days – Revised estimated duration in days)} * 100}{\text{(Revised estimated duration in days)}}$$

Here revision is done during project execution.

The metric is used to monitor the project performance. A cause and analysis report for a given schedule slippage helps in identification of areas for process improvement. The schedule slippage for different phases identifies where additional effort is to be spent to compensate the slippage.

The data is given in Annexure A of this document. The graphical representation of the data is as follows:

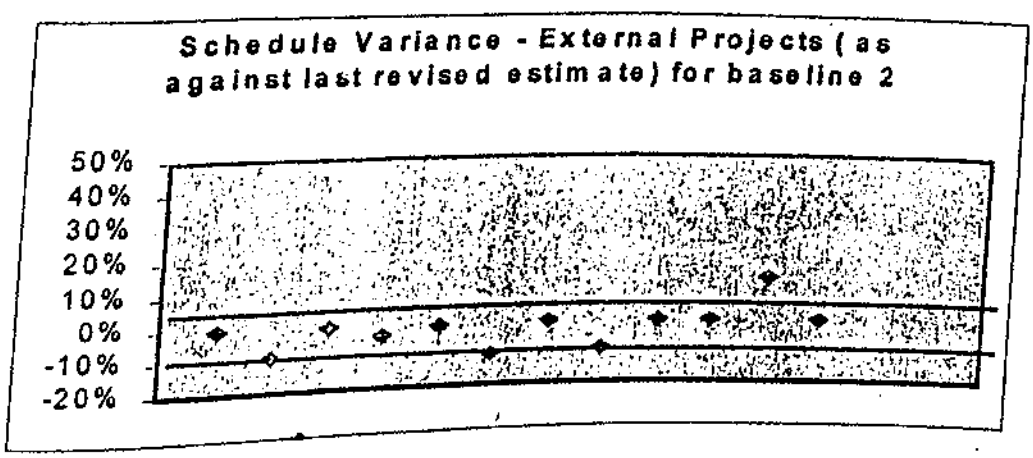


Based on this the baselined capabilities are:

Mean	-1%
Std Deviation	7%
UCL	5%
LCL	-10%

Analysis:

Above observations are based on revised schedules and thus it is expected to have less schedule variance. Hence the target driven upper control limit is set to 5% whereas the lower control limit is set to -10%. In the above plot two points are outside the control limits. It is concluded that the projects are under control with respect to much tighter control limits except the two cases. A cause analysis can be done to check whether revised estimate differs significantly from the original estimates.



Analysis:

Here the target driven upper control limit is set to 5% whereas the lower control limit is set to -10%. In the above plot only one point is outside the control limits. It is concluded that the projects are under control with respect to much tighter control limits except the mentioned one. Compared to the 1st baseline this one can be considered as an improvement.

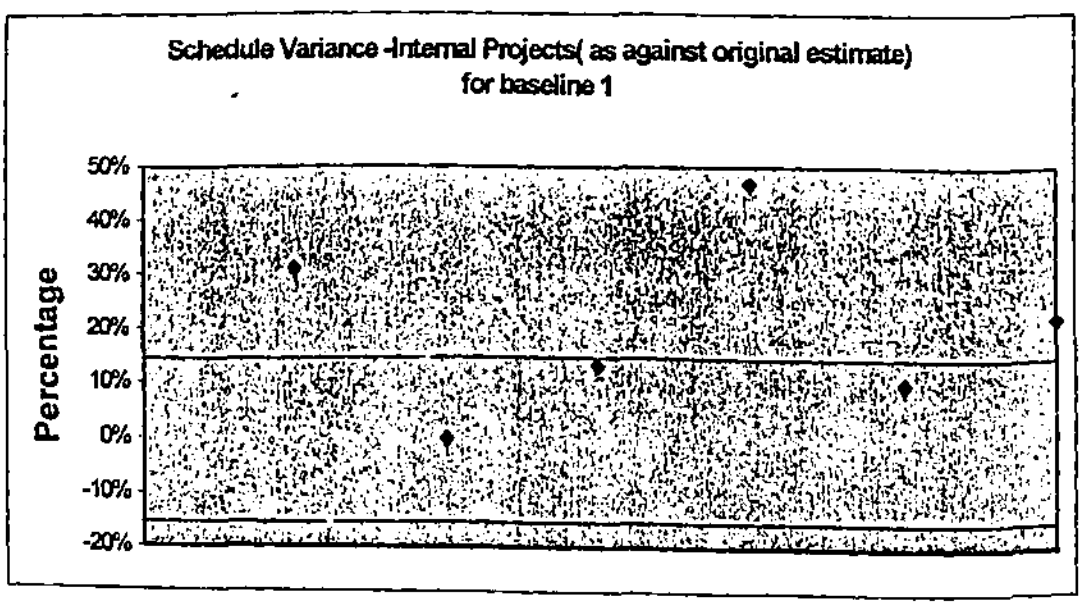
6.1.3. Schedule Variance (as against original estimate) of Internal Projects

This metric is defined as:

Schedule Variance = (as against original estimate) $\frac{\text{(Actual duration in days – Planned duration in days) * 100}}{\text{(Planned duration in days)}}$

The metric is used to monitor the project performance. A cause and analysis report for a given schedule slippage helps in identification of areas for process improvement. The schedule slippage for different phases identifies where additional effort is to be spent to compensate the slippage.

The data is given in Annexure A of this document. The graphical representation of the data is as follows:



Based on this the baselined capabilities are:

Mean	21%
Std Dev	17%
UCL	15%
LCL	-15%

Analysis:

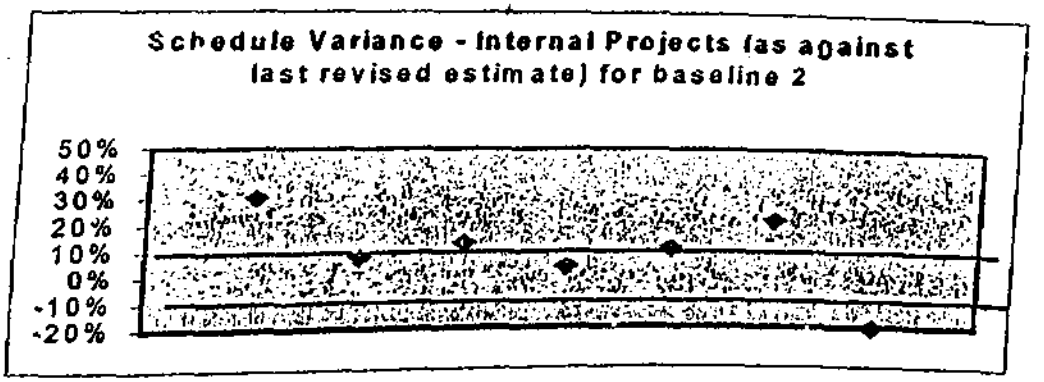
In case of internal projects, data shows that the schedule variance is more than that of external ones. It may be due to internal clients whose requirements are not formally frozen or may be due to dearth of data points. Due to these reasons wider limits are chosen. Here too it is target

Based on this the baselined capabilities are:

Mean	13%
Std Deviation	12%
UCL	10%
LCL	-10%

Analysis:

Above data points are obtained through revised schedules and thus it is expected to have less variability. Hence the control limits are chosen to be tighter than the earlier ones. This time it is chosen to be ± 10%. However with respect to those limits three points are seen to be under control and one point is brought closer to the upper limit. A cause analysis of the two outlying data points can be done for the estimation model adopted by them.



Analysis:

The same analysis holds good as in the previous baseline.

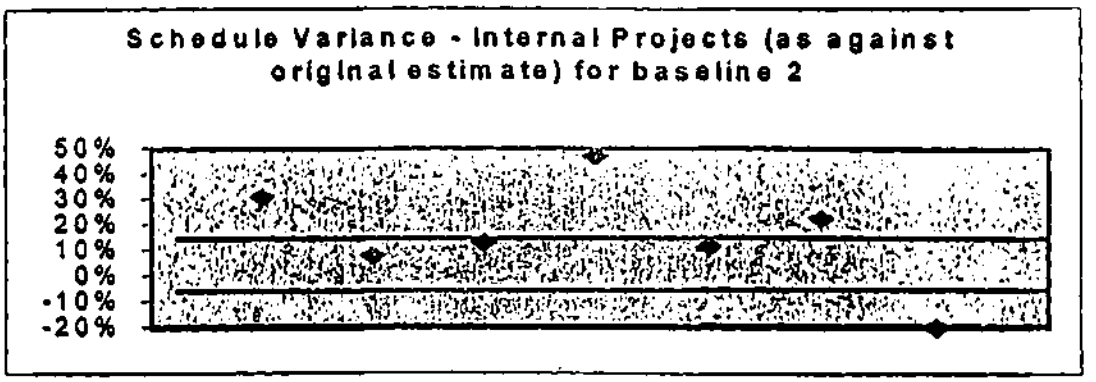
6.1.5. Effort Variance (as against original estimate) of External Projects

This metric is defined as:

Effort Variance (as against original estimate) = $\frac{\text{(Actual effort in person hrs– Original estimated effort in person hrs)} * 100}{\text{(Original estimated effort in person hrs)}}$

This metric provides an indication to the accuracy of effort estimation techniques. It also serves as a basis for monitoring the project performance and revision of effort estimates.

driven and the values are ± 15% as set by the Senior Management. However, only three of the points are shown to be under control with respect to above limits. A cause analysis can be done for these data points.



Analysis:

The same analysis holds good as in the previous baseline.

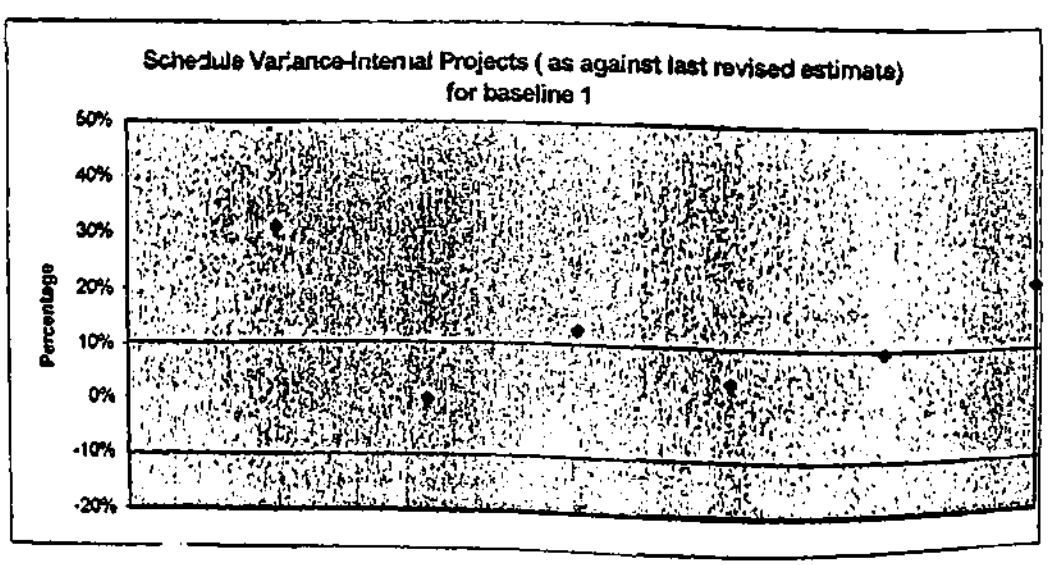
6.1.4. Schedule Variance (as against last revised estimate) of Internal Projects

This metric is defined as:

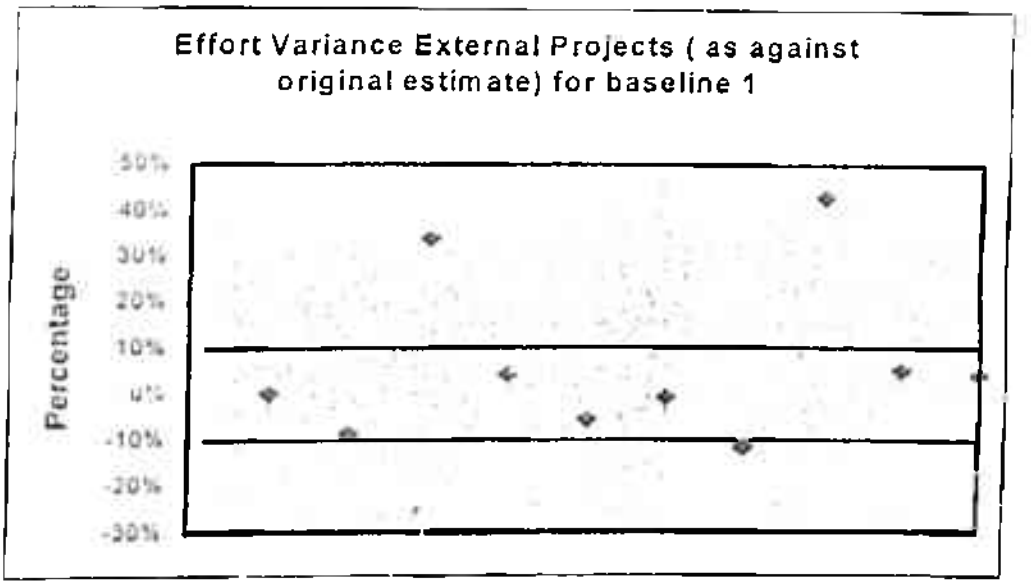
Schedule Variance (as against last revised estimate) = (Actual duration in days – Revised Planned duration in days) * 100 / (Revised Planned duration in days)

The metric is used to monitor the project performance. A cause and analysis report for a given schedule slippage helps in identification of areas for process improvement. The schedule slippage for different phases identifies where additional effort is to be spent to compensate the slippage.

The data is given in Annexure A of this document. The graphical representation of the data is as follows:



The data is given in Annexure I of this document. The graphical representation of the data is as follows:

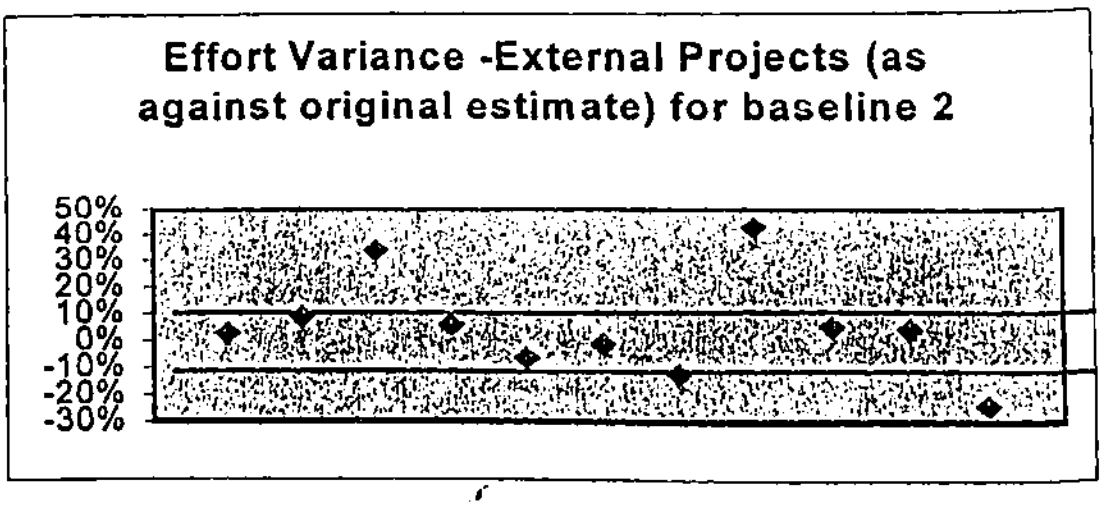


Based on this the baselined capabilities are:

Mean	6%
Std Deviation	18%
UCL	10%
LCL	-10%

Analysis:

In case of effort variance too target driven limits are set .The limits are ± 10% as set by the Senior Management. Two points are outside these limits whereas other projects are under control in terms of effort estimation. The effort variance is quite large in case of the two outlying points and it might be a matter of concern. A cause analysis is to be done for size estimation model adopted by them.



Analysis:

In this case also the same analysis holds good as in the previous baseline, however, the 11th data-point shows an under-estimation which can also be a matter of concern.

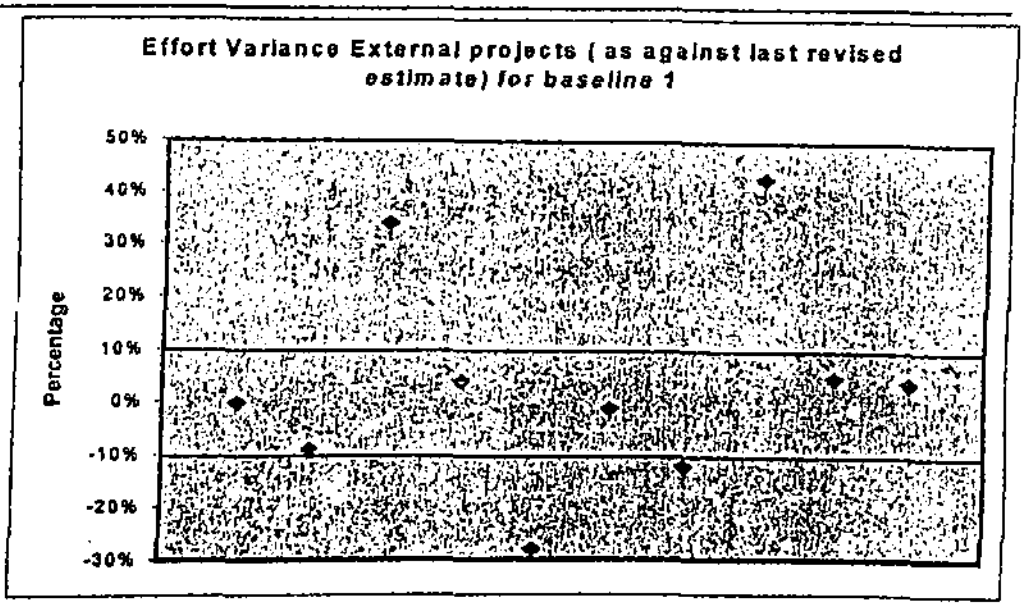
6.1.6. Effort Variance (as against last revised estimate) of External Projects

This metric is defined as:

Effort Variance (as against revised estimated estimate) = $\frac{\text{(Actual effort in person hrs – Revised estimated effort in person hrs) * 100}}{\text{(Revised estimated effort in person hrs)}}$

This metric provides an indication to the accuracy of effort estimation techniques. It also serves as a basis for monitoring the project performance and further revision of effort estimates

The data is given in Annexure A of this document. The graphical representation of the data is as follows:



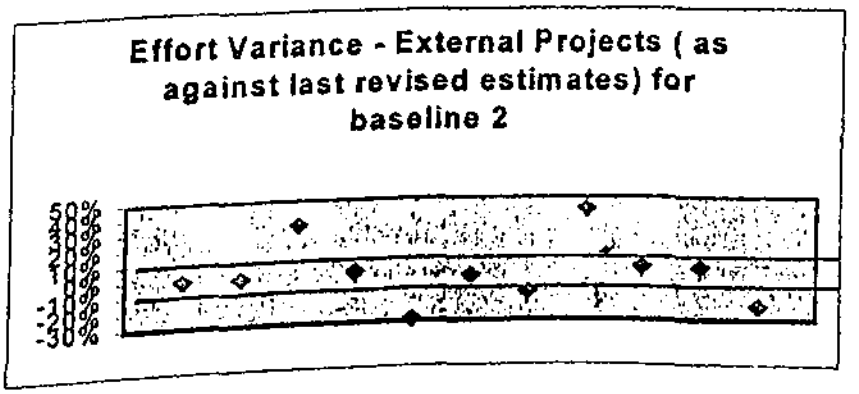
Based on this the baselined capabilities are:

Mean	4%
Std Deviation	21%
UCL	10%
LCL	-10%

Note – A data point having extreme value of 220% has been removed to smoothen out the variability.

Analysis:

In case of revised effort variance too target driven limits are set. The limits are ± 10% as set by the Senior Management. Here four points are outside these limits of which two are lying below the lower control limit. This over-estimation might be a result of panic. The effort variance is quite large in case of the two outlying points and it might be a matter of concern. Root Causal analysis might bring out some insight needed for managing and estimating these sort of projects.



Analysis:

In this case also the same analysis holds good as in the previous baseline, only here, one more point lies outside the control limits.

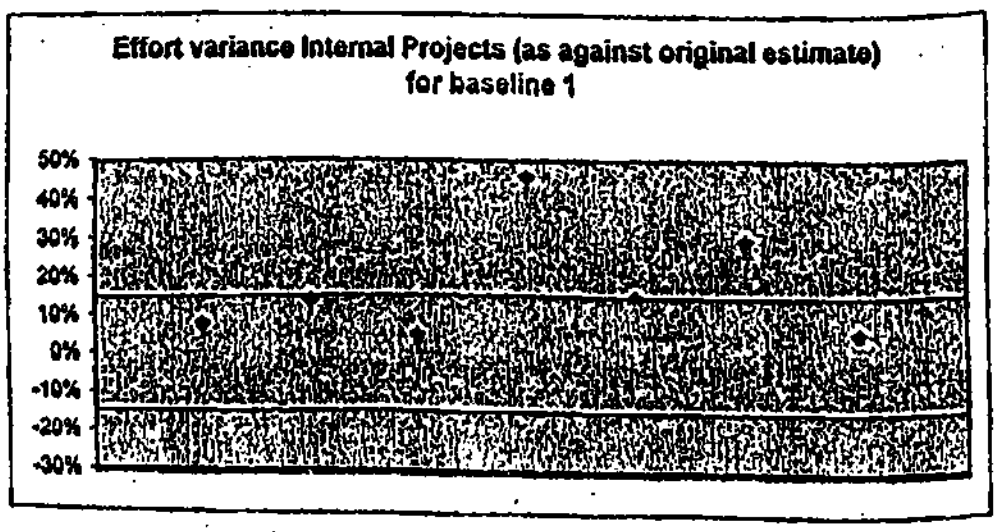
6.1.7. Effort Variance (as against original estimate) of Internal Projects

This metric is defined as:

Effort Variance (as against original estimate) = (Actual effort in person hrs – Original estimated effort in person hrs) * 100 / (Original estimated effort in person hrs)

This metric provides an indication to the accuracy of effort estimation techniques. It also serves as a basis for monitoring the project performance and revision of effort estimates

The data is given in Annexure I of this document. The graphical representation of the data is as follows:



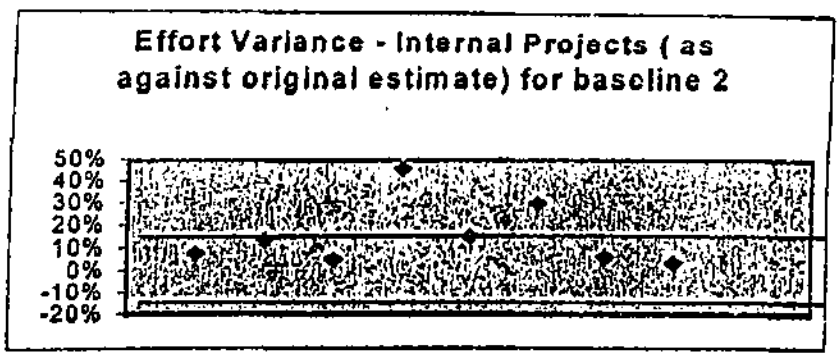
Based on this the baselined capabilities are:

Mean	18%
Std Deviation	15%
UCL	16%
LCL	-15%

Analysis:

Effort variance in internal projects is more than the external projects. The reasons behind it might be scarcity of data points, unfrozen requirement or lack of seriousness. The control limits

therefore should be much wider than in case of external projects and here the limits are ± 15%. The plot shows only two points are outside the limits. Some cause analysis may be done for these two cases which might bring out interesting features.



Analysis:

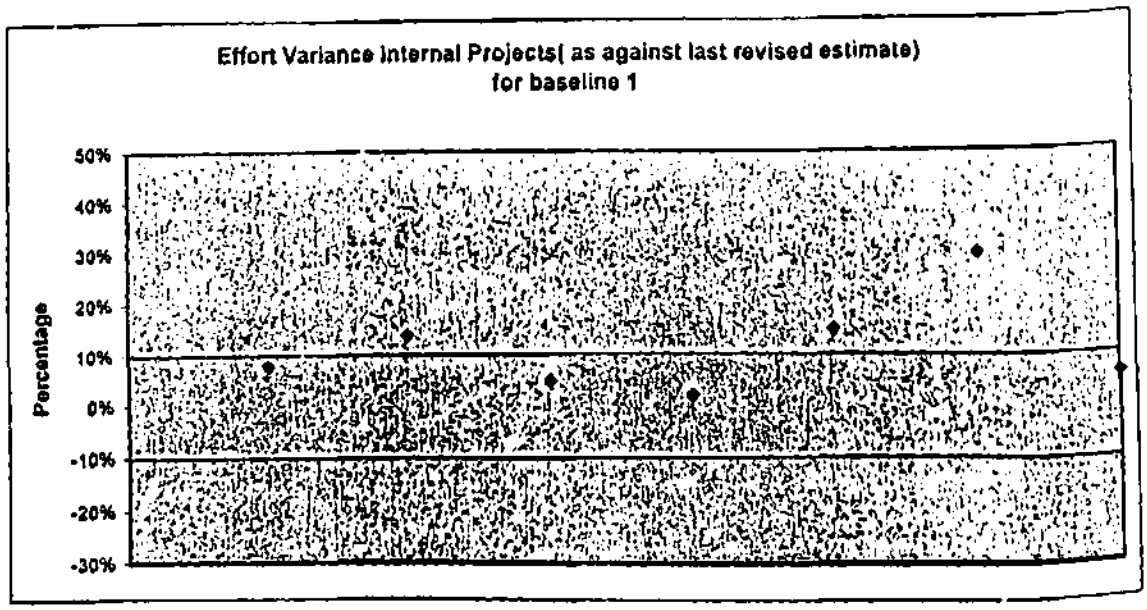
Here also the same analysis holds good as in the previous baseline.

6.1.8. Effort Variance (as against last revised estimate) of Internal Projects

This metric is defined as:

Effort Variance (as against revised estimated estimate) = (Actual effort in person hrs – Revised estimated effort in person hrs) * 100 / (Revised estimated effort in person hrs)

This metric provides an indication to the accuracy of effort estimation techniques. It also Serves as a basis for monitoring the project performance and further revision of effort estimates

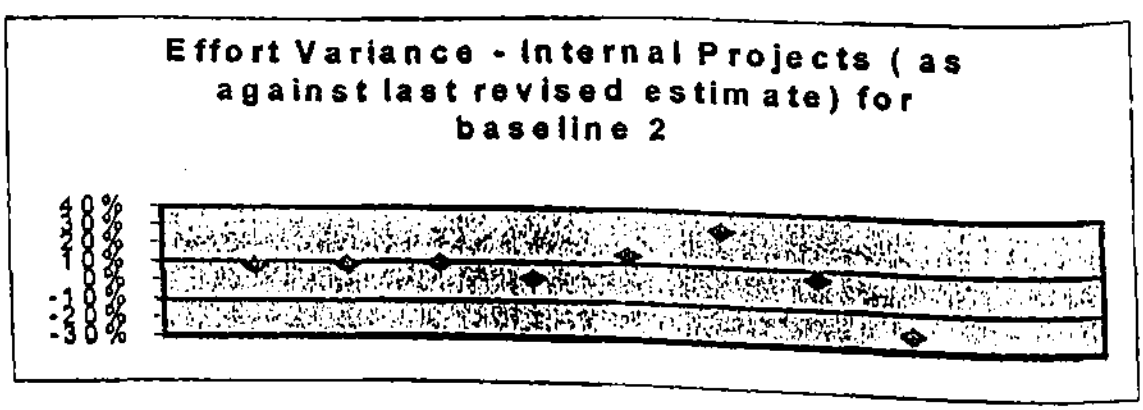


Based on this the baselined capabilities are:

Mean	11%
Std Deviation	9%
UCL	10%
LCL	-10%

Analysis:

Revised Effort variance in internal projects is expected to be less than the original ones. Depending on that assumption the target driven limits are set to be ± 10%. The plot shows three points are outside the limits. A root cause analysis can bring some interesting features, which can be incorporated, to the existing estimation models.



Analysis:

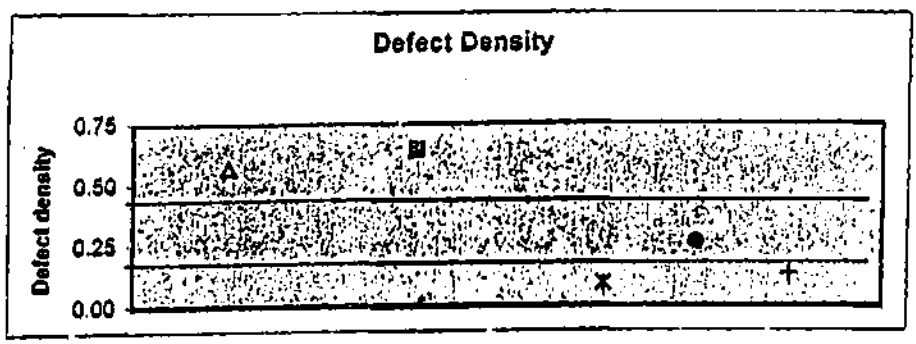
The same analysis holds well as in the previous baseline, however it shows improvement as the no. of points lying outside the limits has decreased by one.

Project Type Specific Metrics

6.1.9. Development Projects

For Effort variance and Schedule variance the baselines have already been established.

A. Defect Density



Based on this the baselined capabilities are:

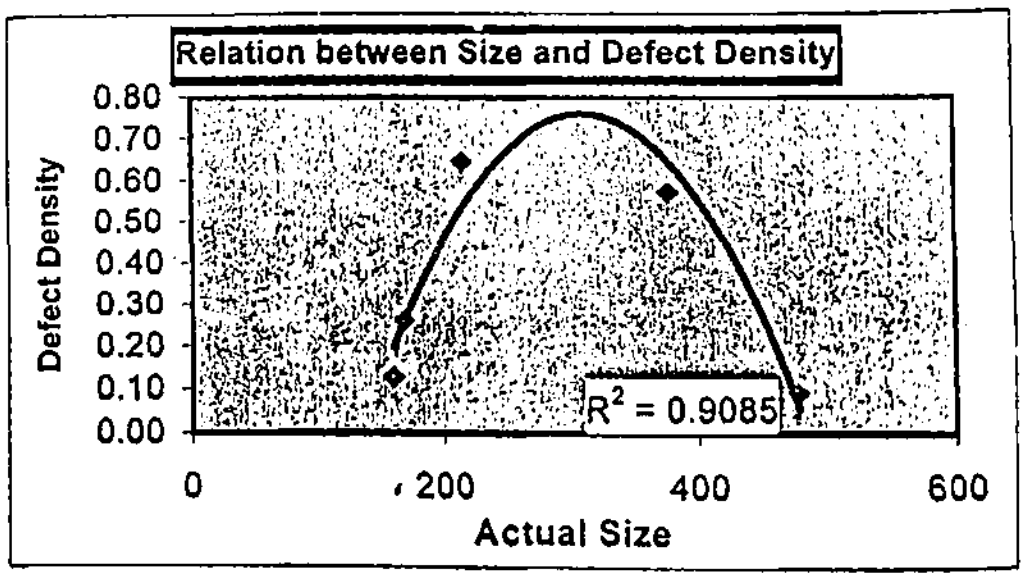
Mean	0.34
Std Dev	0.25
UCL	0.47
LCL	0.21

Note- To smooth out the variability two extreme points having defect densities 2.44 and 0.08 has been removed.

Analysis:

Here the control limits are chosen depending on the inherent distribution of the defects. As quality of deliverables is of prime concern therefore a very narrow bandwidth is chosen. In this case the limits are $\mu \pm .5\sigma$. Though lower limit is set to $\mu - .5\sigma$, goal should be set at 0 defect density and hence the points below the lower limit are actually better than the points within control limits. The plot shows two points are outside the upper control limit of which one is very close to the limit.

Relationship between Actual size (Function point) and Defect density

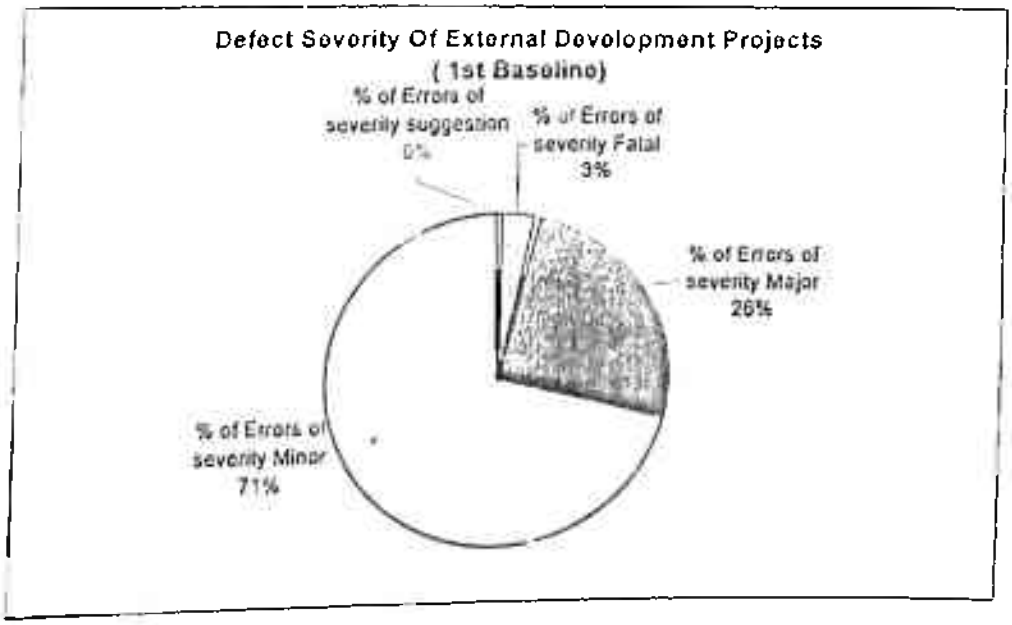


Analysis:

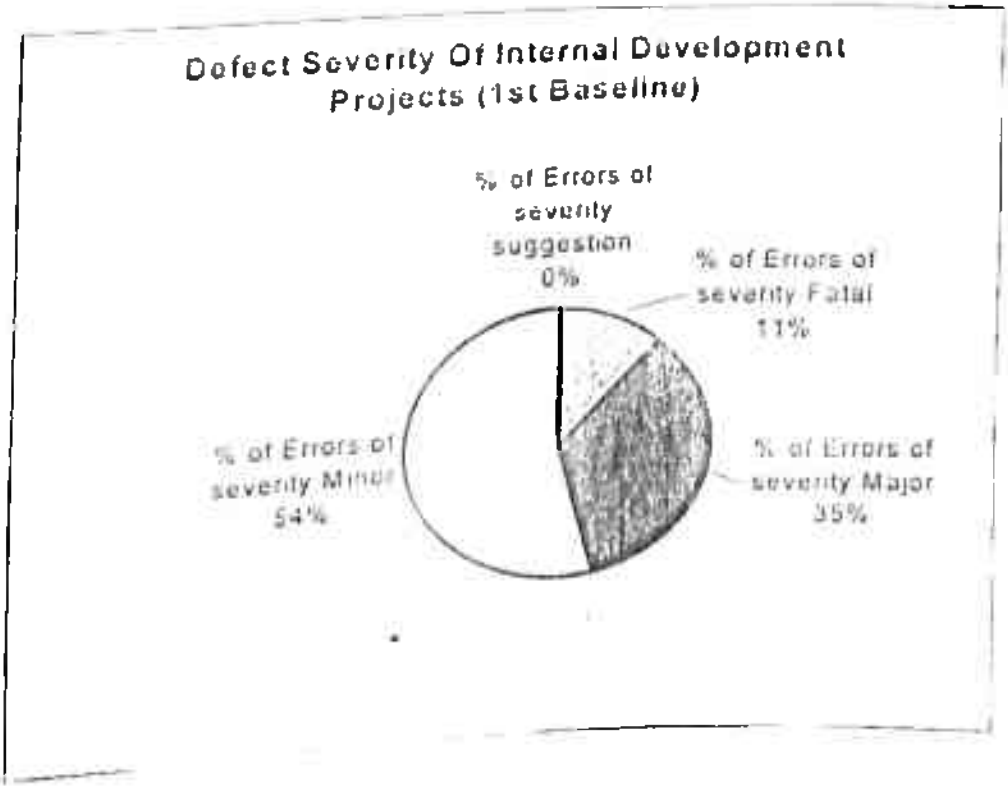
A study of the relation between defect-density and size is of much interest for predictability. Here the plot shows a bell-shaped curve where the maximum defect density is observed for size measure 300. The correlation is quite high showing a perfect fit. The reason for such a good fit may be due to dearth of data points. However for very large as well as for very small size-measure defect-density is considerably small which is surely a good indication. Some cause analysis may be done for the critical point at which the maximum is attained.

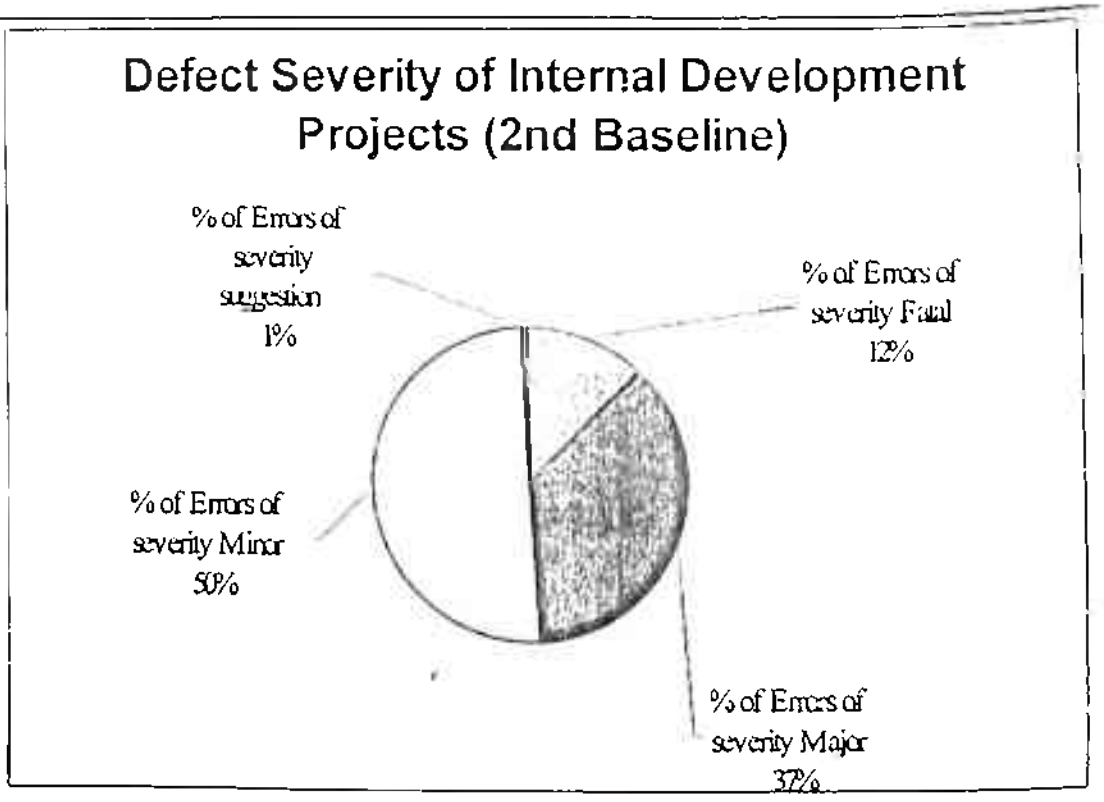
B. Defect distribution by severity

External Projects:



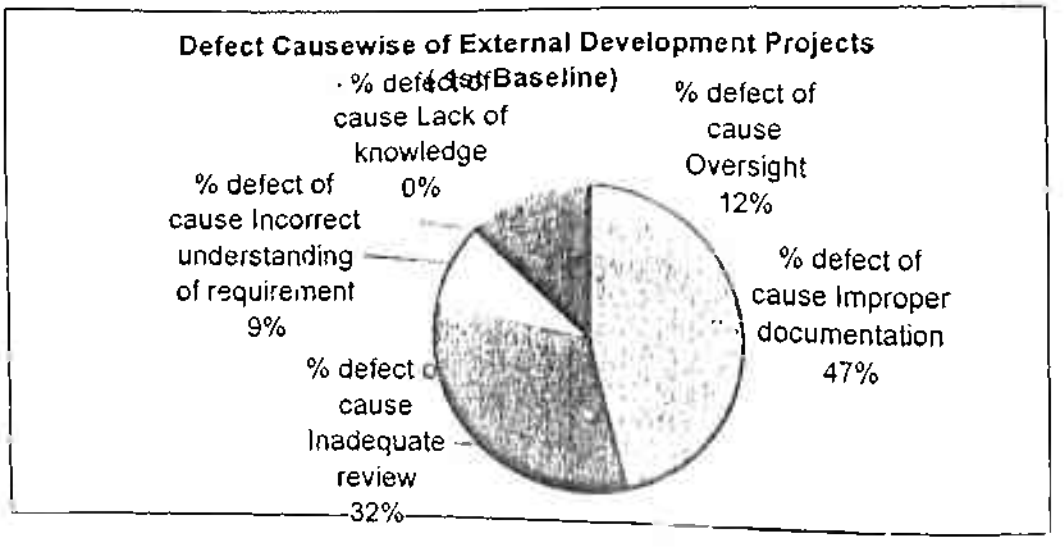
Internal Projects:



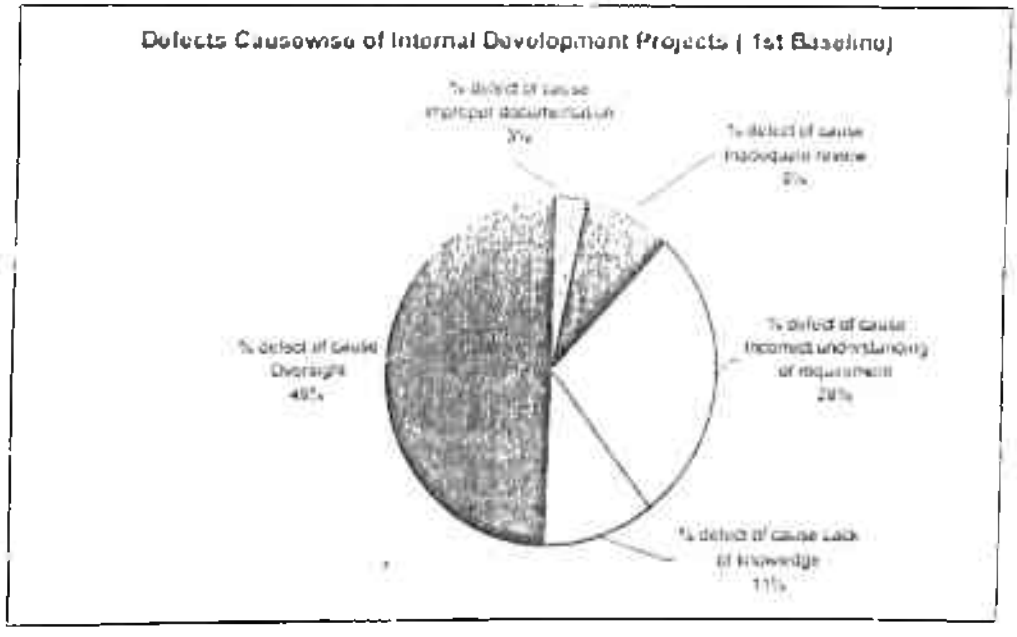


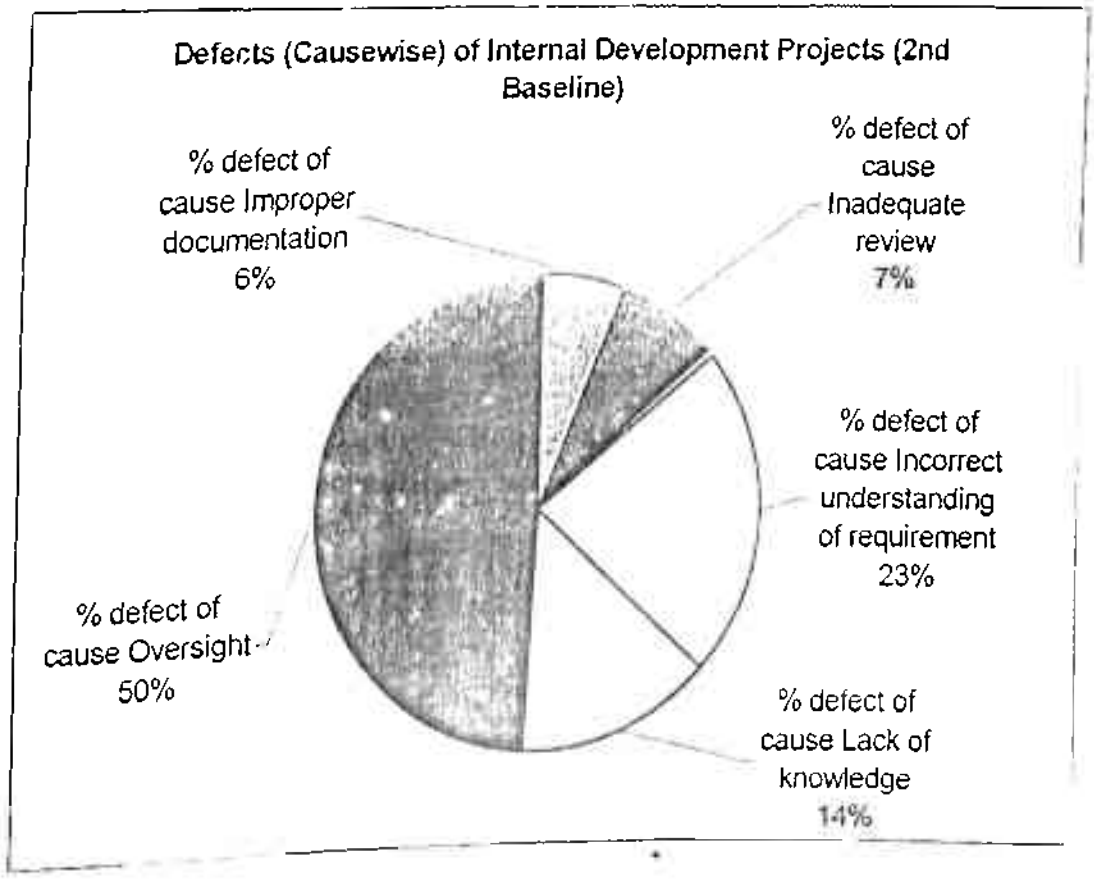
C. **Defect distribution by causes**

External Projects:



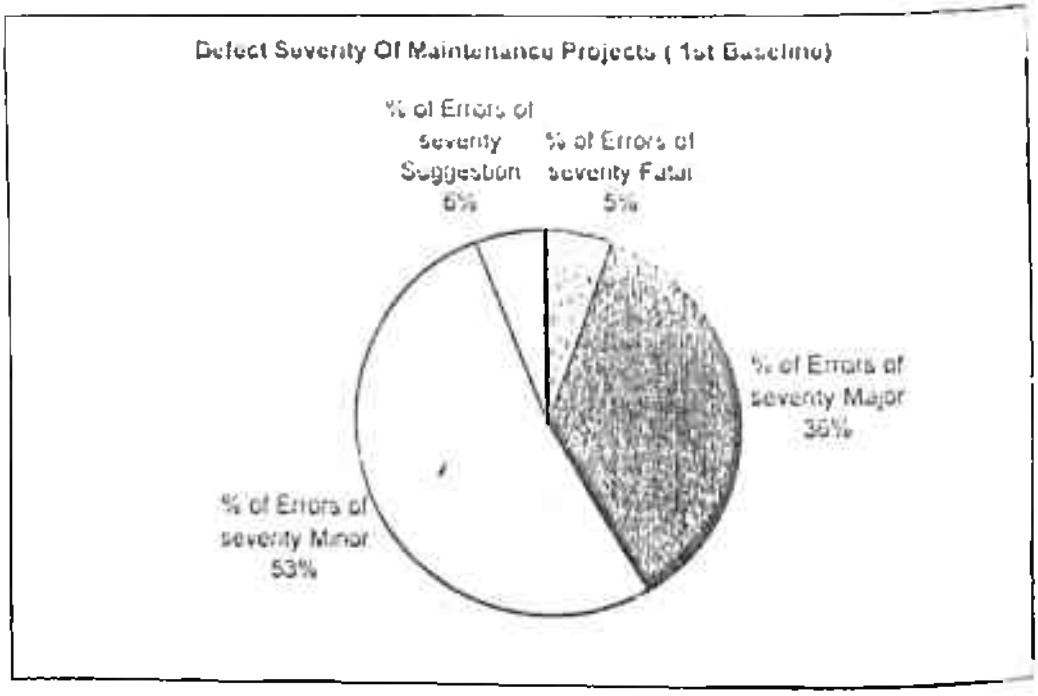
Internal Projects:



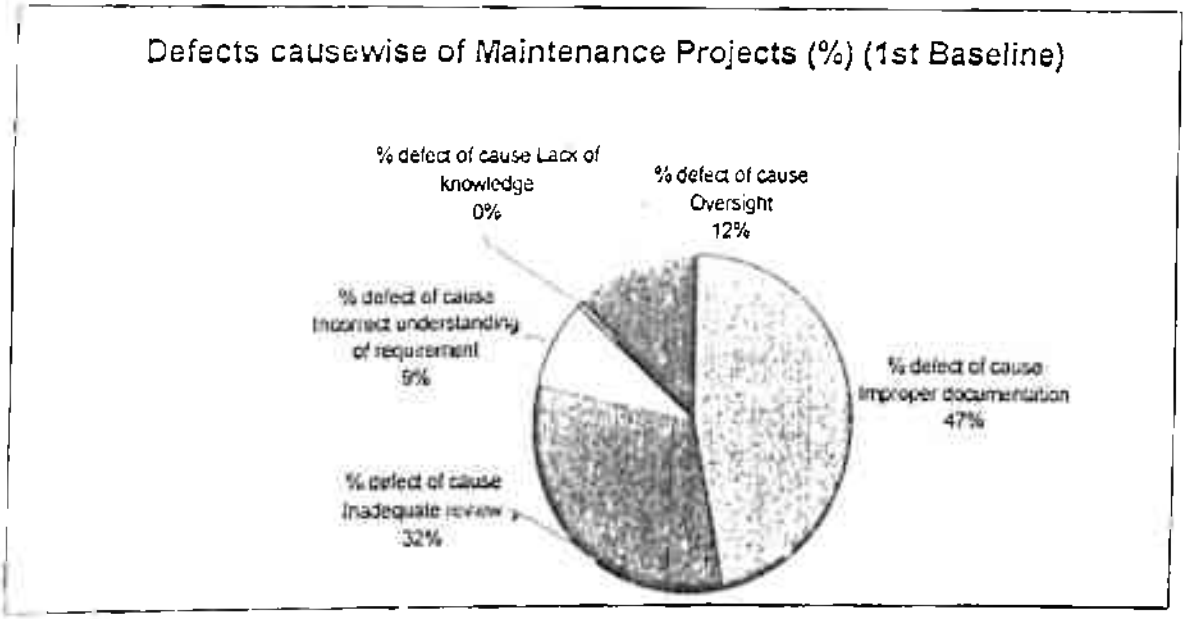


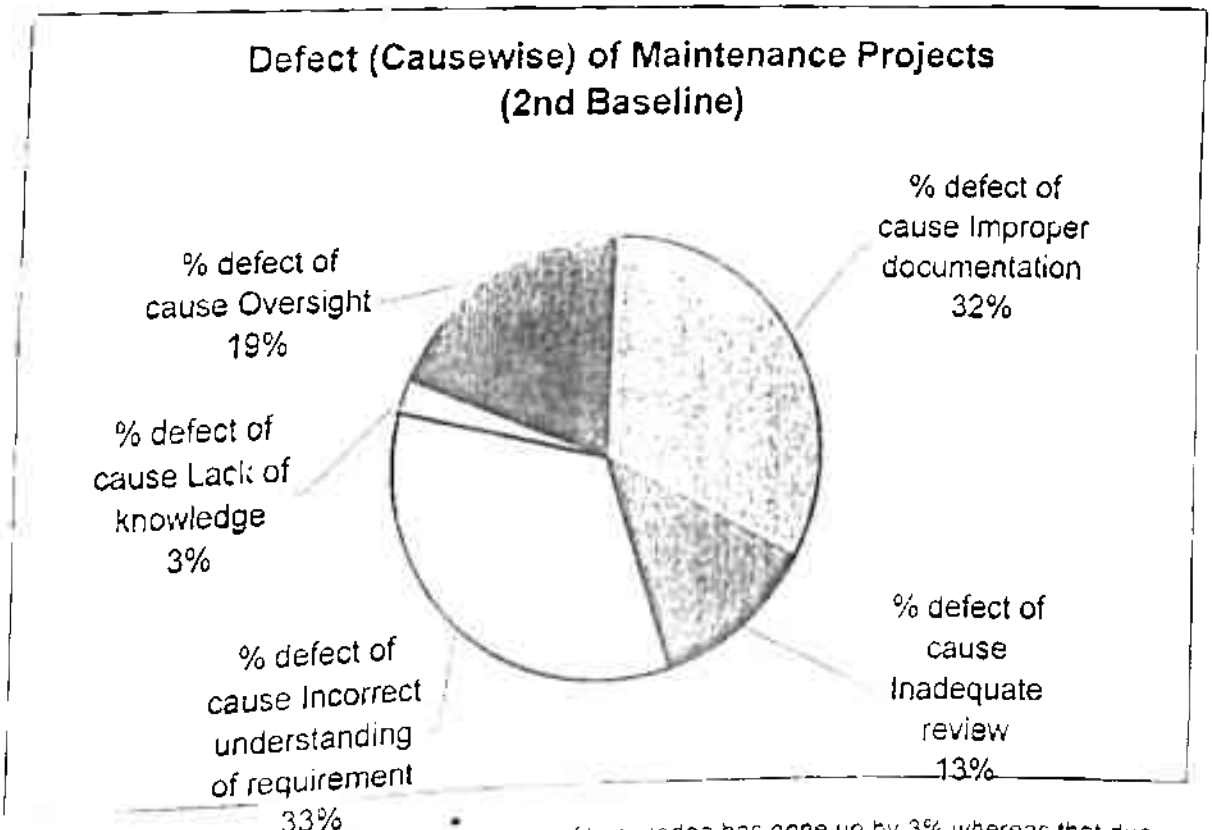
6.1.10. Maintenance Projects

A. Defect distribution by severity



B. Defect distribution by causes

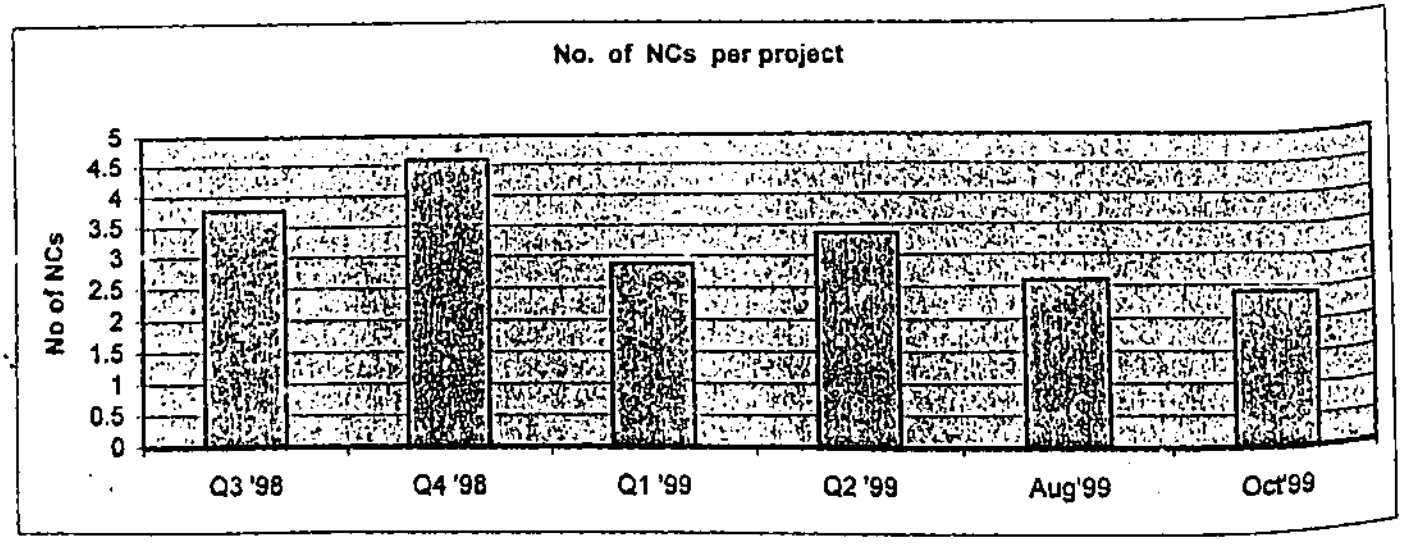




Analysis: In the 2nd baseline the defect due to lack of knowledge has gone up by 3% whereas that due to improper documentation has come down 15% with respect to the cause-wise defect distribution of maintenance project compared to 1st baseline.

7. Quality Metrics:

Project-wise NC s

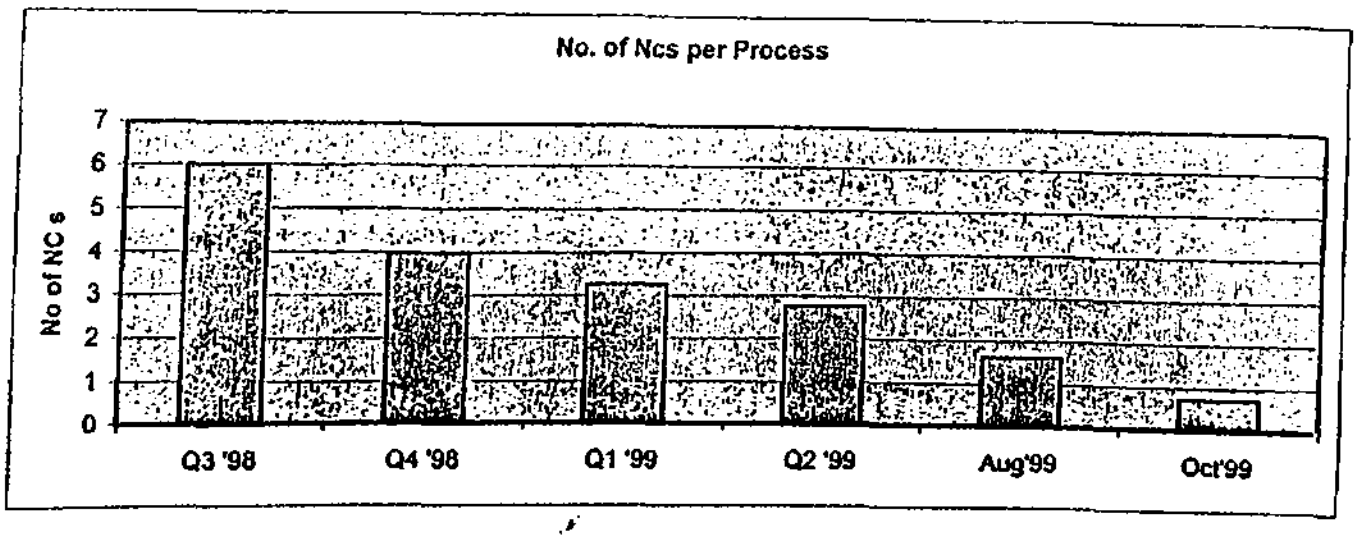


Analysis: Above histogram is drawn on the basis of NC data for the period of July'98 to Oct'99. NC per project is calculated by the ratio of total no. of NC s to total no. of projects. It is to be noted that from July' 99 onwards, audit is carried out on bimonthly basis. In the above plot maximum no. of NC s are recorded in the 2nd quarter. This observation can be explained from two angles,

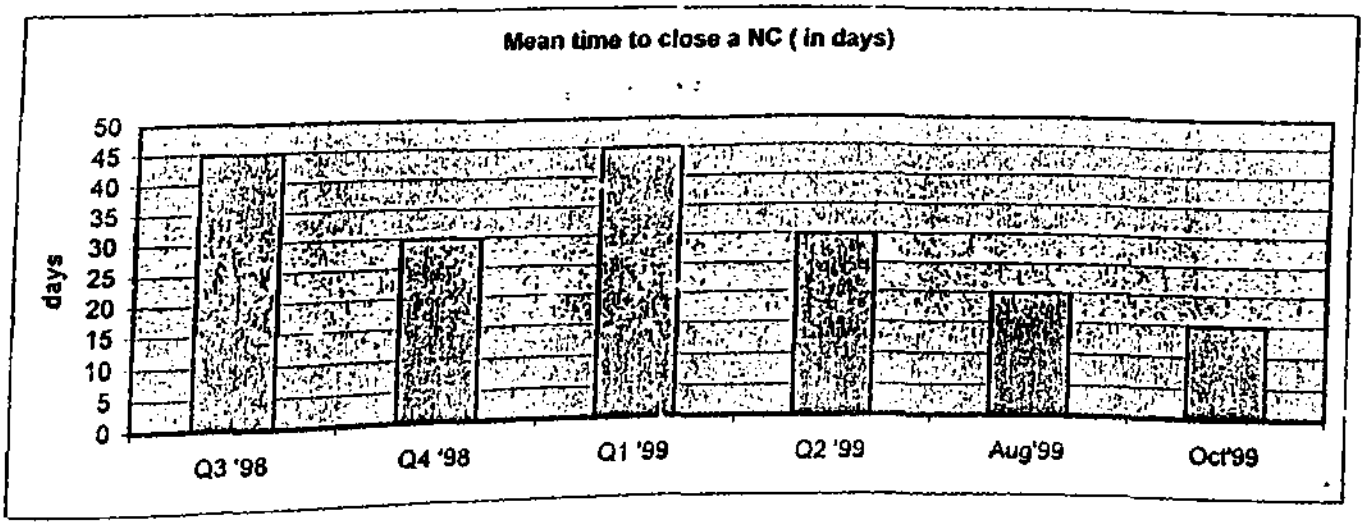
1. Auditors shown excellence in their scrutinizing power
2. Projects did not follow quality standards rigorously

The later one is ofcourse an alarming situation. The following two quarters are showing however less no. of NC s, though the trend is anomalous. From Aug' 99 onwards, trend is more convincing towards improvement. It may be explained as follows:
Due to frequent audits, projects became more cautious in observing standards.
If the same is considered from other angle it might be because of relaxed audit. Cause analysis of these may bring the strengths and weaknesses in this process.

Process-wise NC s



Analysis: Above histogram is drawn on the basis of NC data for the period of July'98 to Oct'99. NC per process is calculated by the ratio of total no. of NC s to total no. of processes. It is to be noted that from July' 99 onwards, audit is carried out on bimonthly basis. In the above plot a very smooth trend is observed towards improvement. Data clearly show that no. of NC s decreasing steadily over the period considered. It is obviously a good sign. Process specific good practices should be brought out as a result of cause analysis and can be exploited for improving organization standard.

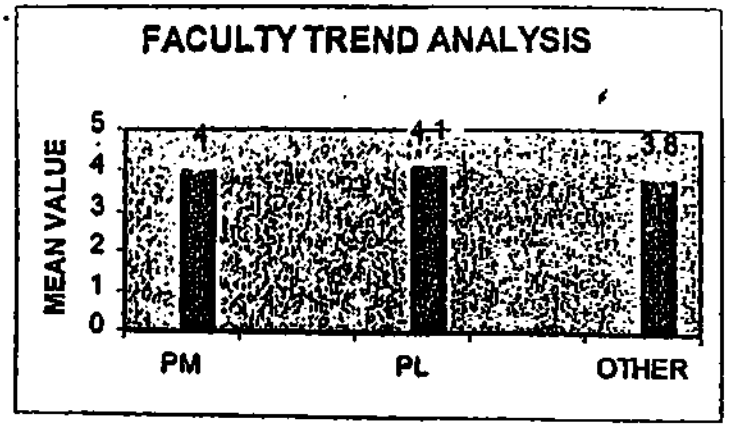


Analysis: Mean time to close a NC is decreasing steadily from the 2nd quarter of 99. Here also a positive effect of frequent audit is observed in the plot. If the same trend is observed in the long run, it will be beneficial for the organization to be able to quote a baseline value for this attribute.

8. T & D Metrics

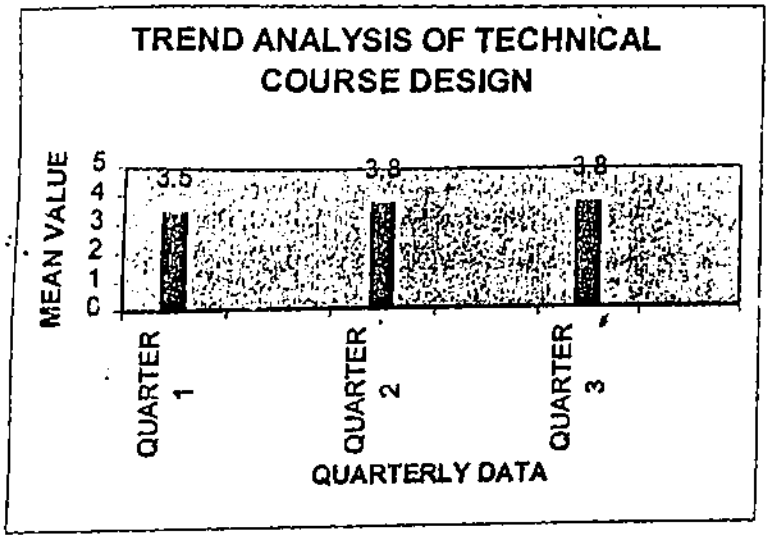
8.1 DESIGNATION WISE FACULTY PRESENTATION SKILLS ANALYSIS IN III[rd] QUARTER:-

Graph below shows that PL's and PM's presentation skills are better than OTHERs who have given the presentation. Thus, it can be concluded that Designation has a positive impact on the way the Faculty in
Question gives the presentation. Experienced people should be motivated so that they help others to improve their presentation skills.



8.2 QUARTERWISE TECHNICAL COURSE DESIGN ANALYSIS: -

Graph below shows that course design is very low in 1st quarter, then it increases in 2nd quarter and then
Remain constant in third quarter. However, still it is not very good. Therefore before designing it, analysis should be made of attendees need and then only it should be designed.



1. Introduction of 1st Baseline Report:

The most important goal of [illegible] is to produce high quality system, application or a product. To achieve this goal, it is essential to apply effective processes coupled with a well-defined measurement process within the context of mature software and its related functional process. Further, for continuous improvements, it is also necessary to instrument the processes adapted for software development by means of an efficient software metric process.
In view of the above, an attempt is made, in this Metrics Report which focus on the baseline values of the metrics collected and analysed for various groups within [illegible]. This is a quarterly report, which contains the metrics initiative happen during this time period.
The objectives and goals of this Metrics Report is not only to carry out measurement but more importantly to cause significant augmentation in the software product quality as well as the organizational productivity thro' a three pronged metric process consisting of measurement, analysis of measurement and the feedback system.

1.1 Evolution of Organization Metrics

Our Quality Policy States

We will achieve customer satisfaction by producing and providing systems, products and services that meet stated and implied needs of the customer. We will do so

By providing leadership to drive the continuous quest for Quality at [illegible]
By developing and nurturing our human resources, recognizing that these are central to our line of business and
By following well-defined and continuously improving processes to ensure that we provide customer satisfaction consistently.

Quality Policy Objective

- **Timely Delivery**
- **High Quality Deliverables (Less number of Defects)**
- **Skill Proficiency**
- **Productivity**
- **Continuos improvement of the above objective**

Related Process

- **Estimation and Project Management (Schedule and Effort)**
- **SDLC and Testing**
- **Training**
- **Internal Audit**

Related Metrics

- **Schedule Slippage and Effort Slippage**
- **Defect Density, Weighted Defect Density, Defect Removal Efficiency, Weighted Defect Removal Efficiency**
- **Productivity**
- **Training Effectiveness, Average No. of Training Hours**
- **Specific Phase or Process wise Audit Findings, Project wise Weighted Audit NCs Profile & Project wise NCs Profile**

2. Baseline Value :

Baseline value is the mean value (simply average) computed for the given distribution with both control limits (UCL and LCL).

2.1 Upper Control Limit (UCL) :

The maximum value till which the process can go in a controlled manner.

2.2 Lower Control Limit (LCL) :

The minimum value till which the process can go in a controlled manner.
Any value within the lower and the upper control limit means the process is controlled.

2.3 Standard Deviation(SD) :

The variance found in the range of values for which the rules are as follows :

2.4 Rules for defining the Control limits :

If the SD <=15% of mean value then the UCL and LCL = mean +- 3 times SD (For a very Tightly controlled process)

If 15% < SD <= 30% of mean value then the UCL and LCL = mean +- 2 times of the SD.

If 30% < SD < = 60% of mean value then the UCL and LCL = mean +- 1 times of the SD

If SD > 60% of mean value then the UCL and LCL = mean +- 0.5 times of the SD

This report covers in detail for all Project wise / Department wise as per our selected set of metrics collected analyzed and the baseline values for various groups.

3. Goals of Metrics

3.1 Estimation Slippage :

Schedule and effort data has been collected for the projects, which have been completed at ATL For the year 1996 onwards.
Collection of data on schedule and Effort for past projects have been consolidated Group wise as Well as company wide. The Goals of these two slippage are 0, Irrespective of any group. But still the base line value of Schedule and Effort Slippage has been identified by the Top management, based on the past experience and business needs

Schedule Slippage :
Baseline Value : Within + - 5%

Effort Slippage :
Baseline Value : within + - 10 %

For some old projects the slippage is high, because it was compared with the original Planned Start Date / End Dates and not with the latest planned start / end dates. This is because, during that duration these process were not introduced.

3.2 Project Specific Metrics :

This Project related metrics would be analyzed Group wise as per our Size model (i.e. Client

Server Model, Object Oriented Systems, Group-ware Projects and Conversion Type Projects) as for both Productivity and Defect related Metrics Size is a main factor, which is very clear from the following Definitions i.e.

Productivity : Project Size/ Actual Effort
Defect Density: No. of Defects/ Size

As per ... Size Models there are 4 Groups of the following types:

- Client Server Model
- Object Oriented Systems
- Group-ware Projects
- Conversion type Projects

The list of Projects in each group is given in the Annexure-1.

For all these groups the above mentioned Metrics has been analyzed and the baseline has been finalized.
With these the Training Effectiveness (for various types of trng.) Metrics also analyzed and the baseline values has been finalized and also the Internal Audit Analysis has been done.

4. Project Group wise Metrics Report

4.1 Client Server Model :

4.1.1 Schedule Slippage : *Ref. Fig. 1.1*

Baseline:

Refer to Section 3.1 of this document.

4.1.2 Effort Slippage : *Ref. Fig. 1.2*

Baseline:

Refer to Section 3.1 of this document.

4.1.3 Productivity : *Ref. Fig. 1.3*

Productivity is computed for the given projects mentioned in Annexure-1 of this group. The baseline value has been identified. All the Project under this group can choose their own goal based on the given control limits.

Table for Productivity

Mean Value	0.88 (CSFP / Mandays)
Standard Deviation	0.20
LCL = M-(2*SD)	0.48
UCL = M+(2*SD)	1.29

4.1.4 Defect Related Metrics:

Table: Control limit for DD, WDD, DRE and WDRE

Defect Density (*Ref. Fig. 1.4*)	
Mean Value	0.17
Standard Deviation	0.07
LCL = M-(1*SD)	0.10
UCL = M+(1*SD)	0.24

Weighted Defect Density (*Ref. Fig.1.5*)	
Mean Value	0.08
Standard Deviation	0.04
LCL = M-(1*SD)	0.04
UCL = M+(1*SD)	0.12

Defect Removal Efficiency (*Ref. Fig. 1.6*)	
Mean Value	80.90
Standard Deviation	7.21
LCL = M-(3*SD)	59.27
UCL = M+(3*SD)	102.53

WDRE (*Ref. Fig.1.7*)	
Mean Value	77.42
Standard Deviation	11.39
LCL = M-(2*SD)	54.65
UCL = M+(2*SD)	100.20

Fig 1.1

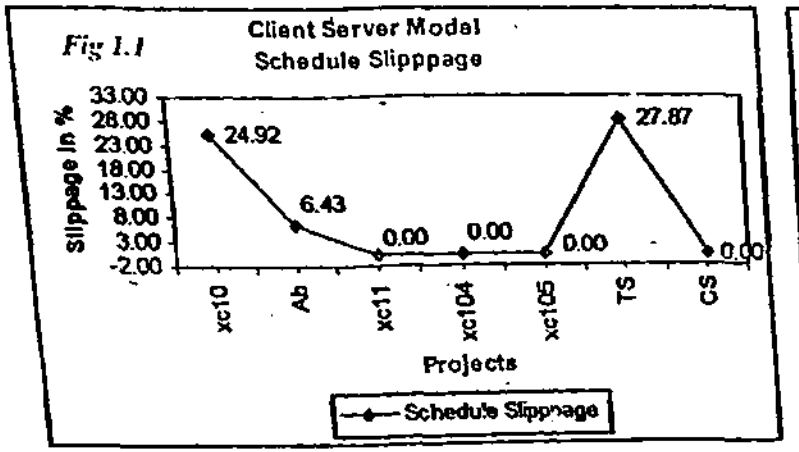


Fig. 1.2

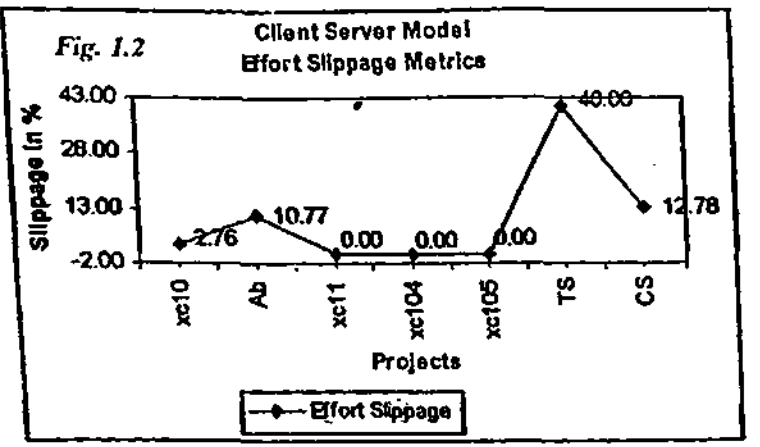
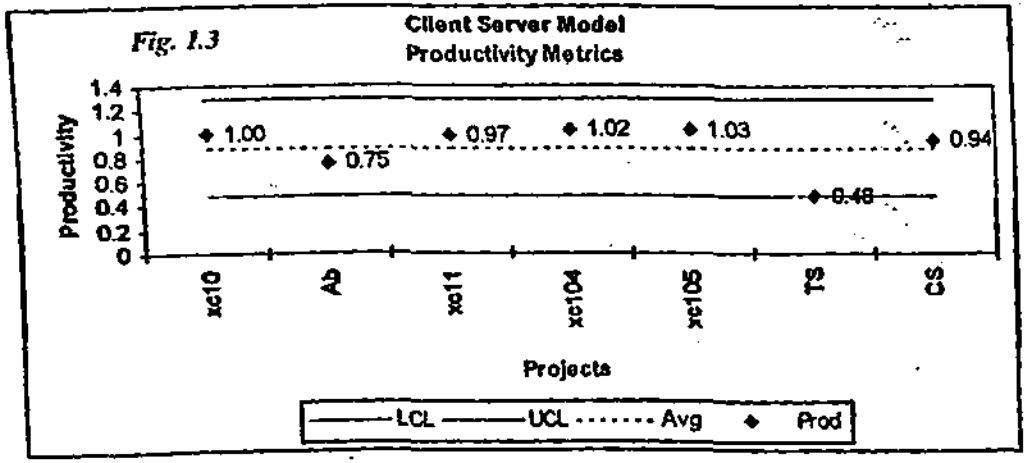


Fig. 1.3



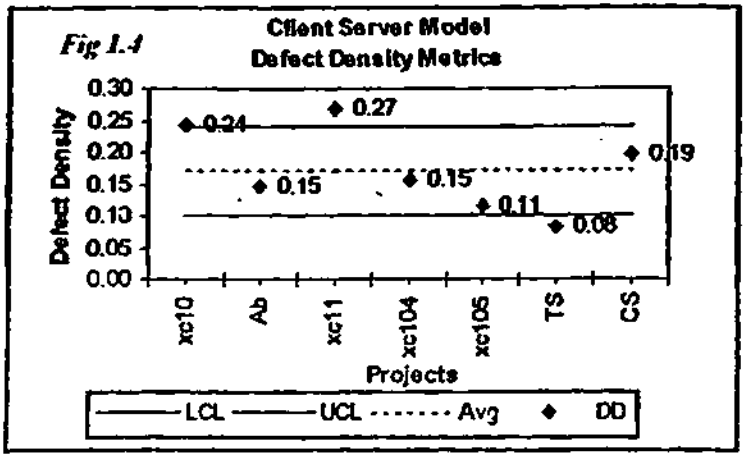

Client Server Model
Defect Density Metrics
Defect Density
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0.24
0.27
0.19
0.15
0.15
0.11
0.08
xc10
Ab
xc11
xc104
xc105
TS
CS
Projects
LCL
UCL
Avg
DD

Fig 1.4

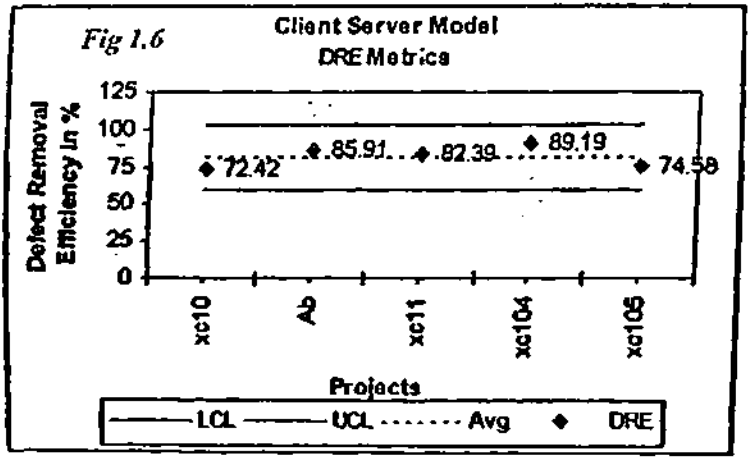

Client Server Model
DRE Metrics
Defect Removal Efficiency in %
125
100
75
50
25
0
72.42
85.91
82.39
89.19
74.58
xc10
Ab
xc11
xc104
xc105
Projects
LCL
UCL
Avg
DRE

Fig 1.6

Fig 1.5

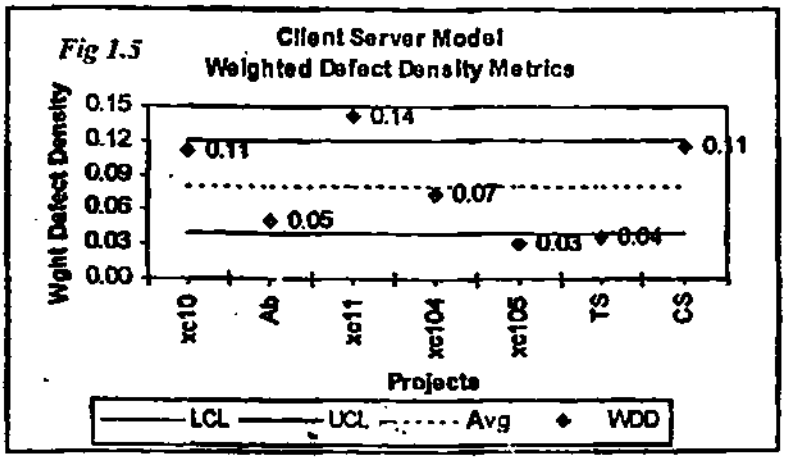
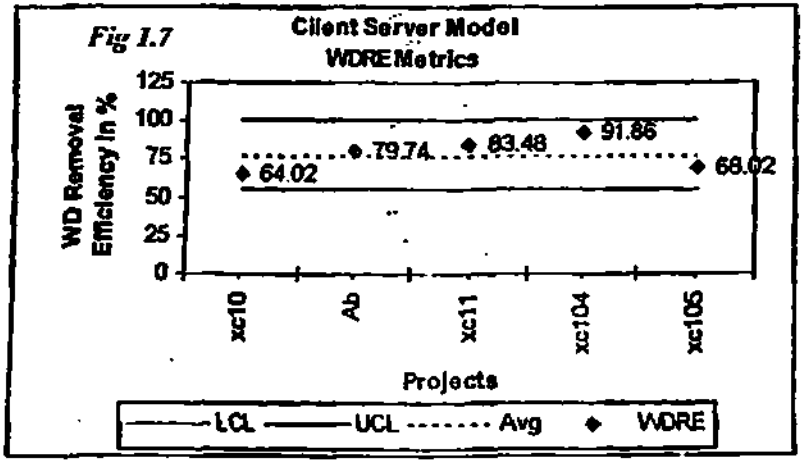

Client Server Model
Weighted Defect Density Metrics
Wght Defect Density
0.15
0.12
0.09
0.06
0.03
0.00
0.14
0.11
0.11
0.07
0.05
0.03
0.04
xc10
Ab
xc11
xc104
xc105
TS
CS
Projects
LCL
UCL
Avg
WDD

Fig 1.7


Client Server Model
WDRE Metrics
WD Removal Efficiency in %
125
100
75
50
25
0
64.02
79.74
83.48
91.86
68.02
xc10
Ab
xc11
xc104
xc105
Projects
LCL
UCL
Avg
WDRE

4.2 Object Oriented Systems :

4.2.1 Schedule Slippage : *Ref. Fig 2.1*

Baseline: Refer to Section 3.1 of this document.

4.2.2 Effort Slippage : *Ref Fig 2.2*

Baseline: Refer to Section 3.1 of this document

4.2.3 Productivity : *Ref Fig 2.3*

Baseline: Productivity is computed for the given projects mentioned in Annexure-1 of this group. The baseline value has been identified. All the Project under this group can choose their own goal based on the given control limits

Productivity	
Mean Value	0.54 (OOSC / Mandays)
Standard Deviation	0.08
LCL = M-(3*SD)	0.30
UCL = M+(3*SD)	0.77

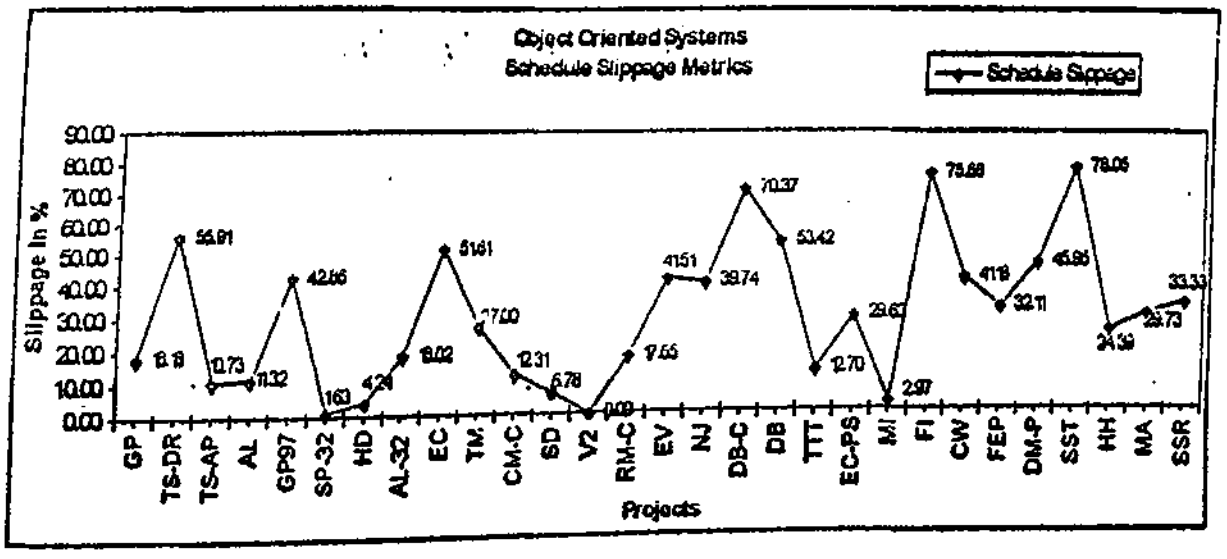
4.2.4 Defect Related Metrics:

Table: Control limit for DD and WDD

Defect Density (*Ref Fig 2.4*)	
Mean Value	0.24
Standard Deviation	0.18
LCL = M-(0.5*SD)	0.14
UCL = M+(0.5*SD)	0.33

Weighted Defect Density (*Ref Fig 2.5*)	
Mean Value	0.11
Standard Deviation	0.09
LCL = M-(0.5*SD)	0.07
UCL = M+(0.5*SD)	0.16

Fig. 2.1



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