Capability Maturity Model Integration

Implementation for

Cyber rapid integrated software solutions (Pvt.) Limited

Thesis

Submitted to:
Mr.Raza Ahmed Khan

Submitted by:
Shazia Ashraf
2003-NUST-MBA-93

NUST INSTITUTE OF MANAGEMENT SCIENCES

NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY

RAWALPINDI PAKISTAN

2006

ACKNOWLEDGEMENT

“How many favors of your Lord will you both (men and jinn) deny?” (Sura Al-Rehman)
All praises belongs to Allah alone, Lord of the world who created the Heaven and the Earth and All that is in between the two indeed in them there are many signs for those who understand

First of all I pay all my praises to ALMIGHTY ALLAH(The most Benevolent , The most Merciful)who gave me the strength to complete my task.Also I would like to take this opportunity to express my sincere thanks firstly to my supervisor Prof.Raza A khan for invaluable guidance with this project. And secondly to my family without their support I would not be able to complete my task.

ABSTRACT

Business processes are seldom static overtime they must evolve in response to ever changing global marketplace in order for an organization to remain efficient and competitive. In an increasingly competitive world, software organizations must implement effective processes to deliver useful and reliable software in time and within budget. IT organizations are adapting CMMI models to help them streamline their software development activities. Capability Maturity Model Integrated (CMMI) developed by Software Engineering Institute of Carnegie Mellon University is aimed to improve the productivity of software development. From CMM to CMMI, they have been adopted worldwide. The software industry in Pakistan faces the challenge of global competition. Continuous improvement of productivity becomes inevitable. To achieve this goal, recently, government and non-government organizations together promote the CMMI.

Organizations now search for standards and guidance to achieve a mature process. However, change and evolution of business and technology imply constant change and evolution of development processes. In this thesis work researcher propose a framework that offers an infrastructure allowing organizations to define and analyze software engineering process at organization level or project level. Besides that, identify the gaps in the organization's processes w.r.t CMMI standards. CMMI models define several Process Areas that indicate where an organization should focus to improve its software process. CMMI is not a process or process description it provides the guidance for improving the organization's processes and ability to manage the development, acquisition and maintenance of product and services. A software development process is a structure imposed on the development of a software product, synonyms includes software life cycle, and software process.CMMI is one of the leading models independent assessment can be used to grade the organization on how well they create software according to how they define and execute their processes.

ANNEXTURE 1

ANNEXTURE 2

LIST OF FIGURES

TABLE OF CONTENT

CHAPTER 1: INTRODUCTION

A process is a naturally occurring or designed sequence of operations or events, possibly taking up time, space, expertise or other resource, which produces some outcome. A process may be identified by the changes it creates in the properties of one or more objects under its influence. [67]

A business process is a recipe for achieving a commercial result. Each business process has inputs, method and outputs. The inputs are a pre-requisite that must be in place before the method can be put into practice. When the method is applied to the inputs, then certain outputs will be created.It is collection of related structural activities that produce something of value to the organization, its stake holders or its customers. It is, for example, the process through which an organization realizes its product or services to its customers.A business process can be part of a larger, encompassing process and can include other business processes that have to be included in its method. In that context a business process can be viewed at various levels of granularity. The linkage of business process with value generation leads some practitioners to view business processes as the workflows which realize an organization's use cases.Business processes can be thought of as a cookbook for running a business and reaching business goals defined in organization's business strategy.

There are two types of business processes:

1. Core processes : These are the processes that create value for customers, and are a part of the core business.
2. Supporting processes: These processes support the core processes. Examples include "Accounting", "Human Resource", "IT support".

Business process consists of subprocesses, decisions and activities. Subprocess is a part of higher level process which has its own goal, owner, inputs and outputs. Activities on the other hand, are parts of the business process that do not include any decision making and thus are not worth decomposing (although decomposition would be possible), such as "Answer the phone", "produce an invoice".[67]

*"The **Actual Process** is what you do, with all its omission, mistakes, and oversights. The **Official Process** is what books say you are supposed to do" (*Watts Humphrey, 1997). So there are two challenges that a software development firm faces. First, to come up with reliable, efficient and pragmatic *Official processes;* and the second, to make these processes a part of the company's culture i.e. to make the *Official process* the same as the *Actual Process*.

Capability Maturity Model Integration (CMMI) is set of rules, guidelines that describe the requirements to bring about improvement in different processes in the organization and ability to manage the development, acquisition and maintenance of product and services. This is one of the leading software models independent assessment can be used to grade the organization on how well they create software according to how they define and execute the processes. ISO 9000 describes standard of formally organizing processes with documentation.CMMI is a collection of instructions an organization can follow with the purpose to gain better control over its software development processes.

Although small in size at present as compared to other regional powers, software industry in Pakistan is developing at a rapid pace. In 2004, the software and IT enabled services business was worth $300 million. The hardware industry added another $300 million. However exports and outsourcing made up for just $33 million. By comparison, India logged $12.8 billion in software and services exports in 2004. Pakistan Software Export Board, forecasts that the business will grow by at least 45 per cent annually for the next five years.

Software development is a complex process and is very sensitive to deviation and negligence. Software companies can not only depend on competence of individuals who may in their own right may be extremely important resource. The standardized process needs to be in place if a software business wishes to grow above a certain size. This also protects the business from being taken away by a few disgruntled staff. The standardize processes also allow the medium level achievers to be productive and efficient allowing the company to have a diverse staff base. In organizations which are deficient in standardize processes the competent individuals create their own processes in trying to

manage their own parts of the business/units. While some maybe very successful the organization is left at risk if the individual decides to move out of the company.

Another dimension of the problem is that in a country like Pakistan the situation is further aggravated. Pakistanis are basically a conservative society where elders, parents and teachers are considered reverent. Being brought up in such a society an individual looks up to the boss with utmost revere. While such attitude brings a certain discipline to a company, it is the major hindrance in popularizing the *official process.* Employees look at the *official process* as a set of rules that are supposed to be followed and never questioned. "*The process is something that is done because the boss wants us to do*" is the notion that most Pakistani employees believe in.

The present study was designed to provide a baseline for software development processes and procedures to enable a software business, Cyber Rapid Integrated Software Solutions (Pvt) Ltd (CRISS), to implement CMMI.

1.1 Objective of the Study

Objectives of this study/thesis were to:

1. Conduct a gap analysis of CRISS to establish a baseline for continuous process improvement
2. Develop a road map for implementation of CMMI level to improve the software development process at CRISS following research methodology and variables on the pattern that Software Engineering Institute has established.

1.1.1 Scope and the Limitations of the Study

1. The scope of the project will only be limited to the gap analysis and development of implementation plan of one maturity level which has been identified after the gap analysis
2. The scope of the project will only be limited to the specific practices of the process areas.

3. The scope of the thesis will be limited to optimization of development activities at CRISS but it is not designed to implement or evaluate implementation of CMMI maturity levels.
4. The constraint is the insufficient information available or unwillingness to share this information by the organizations which have implemented CMMI.

1.2 Research Questions

The research questions relevant to the scope of this thesis are:

1. Is there a gap between the prevalent systems at CRISS with respect to CMMI standards?
2. What processes CRISS needs to follow to be compliant to CMMI standards?

1.3 Methodology

- The literature review was conducted on CMMI standards and practices using the information tools available on the internet or in the public and private sector organizations as follows:
    - Pakistan Software Export Board (PSEB).
    - Digital Processing System (pvt) Ltd.
    - Innumerable websites available on the internet.
    - Articles from books and journals.
    - Interview with six software industry professionals.
    - Information from research papers.
- A checklist was developed to collect information from seven professionals managing (Project Managers, Business Analyst, Software Developers and Quality Assurance experts). A study visit to Karachi was done to gather the information on the above developed checklist from the CRISS staff. This was also followed up through e-mails and telephonic conversation.
- The data was analyzed using standard methods provided by Software Engineering Institute (www.sei.com), and also adopted by Pakistan Software Export Board.

CHAPTER 2 LITERATURE REVIEW

A software development process is a structure imposed on the development of a software product. Synonyms include software life cycle and software process. There are several models for such processes, each describing approaches to a variety of tasks or activities that take place during the process.A growing body of software development organizations implement process methodologies. Many of them are in the defense industry, which in the U.S. requires a 'Rating' based on 'Process models' to obtain contracts. ISO 12207 is a standard for describing the method of selecting, implementing and monitoring a lifecycle for a project.

The Capability Maturity Model Integration (CMM) is one of the leading models. Independent assessments can be used to grade organizations on how well they create software according to how they define and execute their processes. ISO 9000 describes standards for formally organizing processes with documentation.Capability Maturity Model (CMM) is a collection of instructions an organization can follow with the purpose to gain better control over its software development process.

The CMM ranks software development organizations in a hierarchy of five levels, each with a progressively greater capability of producing quality software. Each level is described as a level of maturity. Those 5 levels are equipped with different number of instructions to follow. If an organization is on level 1 (currently an estimated 75% of software development organizations exist at this level, which can be best described as chaotic), it only follows few of the instructions in CMM, if on level 5 it follows everything from CMM.

The CMMI was developed by the Software Engineering Institute (SEI) at Carnegie Mellon University in Pittsburgh. It has been used extensively for avionics software and for government projects since it was created in the mid-1980s.The Capability Maturity Model Integration (CMMI) is a way to develop and refine an organization's software development process. A maturity model is a structured collection of elements that describe characteristics of effective processes. A maturity model provides:

- A place to start
- The benefit of a community's prior experiences
- A common language and a shared vision
- A framework for prioritizing actions
- A way to define what improvement means for your organization
- A maturity model can be used as a benchmark for assessing different organizations for equivalent comparison.

The SEI has subsequently released a revised version known as the Capability Maturity Model Integration (CMMI).In the 1970s, technological improvements made computers more widespread, flexible, and inexpensive. Organizations began to adopt more and more computerized information systems and the field of software development grew significantly. This led to an increased demand for developers-and managers-which was satisfied with less experienced professionals.

Unfortunately, there were growing pains: project failure became more commonplace not only because the field of computer science was still in its infancy, but also because projects became more ambitious in scale and complexity. In response, individuals such as Edward Yourdon, Larry Constantine, Gerald Weinberg, Tom DeMarco, and David Parnas published articles and books with research results in an attempt to professionalize the software development process.Watts Humphrey's Capability Maturity Model (CMM) was described in the book *Managing the Software Process* (1989). The CMM as conceived by Watts Humphrey was based on the earlier work of Phil Crosby. Active development of the model by the SEI (US Dept. of Defense Software Engineering Institute) began in 1986.

The CMM was originally intended as a tool to evaluate the ability of government contractors to perform a contracted software project. Though it comes from the area of software development, it can be, has been, and continues to be widely applied as a general model of the maturity of *processes* (e.g., ITIL service management processes) in IS/IT (and other) organizations.

The model identifies five levels of process maturity for an organisation:

- Initial (chaotic, ad hoc, heroic) the starting point for use of a new process.
- Repeatable (project management, process discipline) the process is used repeatedly.
- Defined (institutionalised) the process is defined/confirmed as a standard business process.
- Managed (quantified) process management and measurement takes place.
- Optimising (process improvement) process management includes deliberate process optimisation/improvement.

Within each of these maturity levels are KPAs (Key Process Areas) which characterise that level, and for each KPA there are five definitions identified:

- Goals
- Commitment
- Ability
- Measurement
- Verification

The KPAs are not necessarily unique to CMM, representing - as they do - the stages that organisations must go through on the way to becoming mature.The SEI has defined a rigorous process assessment method to appraise how well a software development organisation meets the criteria for each level.The assessment is supposed to be led by an authorised lead assessor. One way in which companies are supposed to use the model is first to assess their maturity level and then form a specific plan to get to the next level. Skipping levels is not allowed.The CMM was originally intended as a tool to evaluate the ability of government contractors to perform a contracted software project. It may be suited for that purpose. When it became a general model for software process improvement, there were many critics.

Shrinkwrap companies, which have also been called commercial offtheshelf firms or software package firms, included Borland, Claris, Apple, Symantec, Microsoft, and Lotus, amongst others. Many such companies rarely if ever managed their requirements

documents as formally as the CMM described. This is a requirement to achieve level 2, and so all of these companies would probably fall into level 1 of the model. [69]

2.1 CMMI Controversial aspects

The software industry is diverse and volatile. All methodologies for creating software have supporters and critics, and the CMM is no exception.

Praises:

- The CMM was developed to give Defense organizations a yardstick to assess and describe the capability of software contractors to provide software on time, within budget, and to acceptable standards. It has arguably been successful in this role, even reputedly causing some software sales people to clamour for their organizations' software engineers/developers to "implement CMM."
- The CMM is intended to enable an assessment of an organization's maturity for software development. It is an important tool for outsourcing and exporting software development work. Economic development agencies in India, Ireland, Egypt, and elsewhere have praised the CMM for enabling them to be able to compete for US outsourcing contracts on an even footing.
- The CMM provides a good framework for organizational improvement. It allows companies to prioritize their process improvement initiatives.

Criticisms:

- CMM has failed to take over the world. It's hard to tell exactly how wide spread it is as the SEI only publishes the names and achieved levels of compliance of companies that have requested this information to be listed.
- CMM is well suited for bureaucratic organizations such as government agencies, large corporations and regulated monopolies. If the organizations deploying CMM are large enough, they may employ a team of CMM auditors reporting their results directly to the executive level. (A practice encouraged by SEI.) The use of auditors and executive reports may influence the entire IT organization to focus on perfectly completed forms rather than application development, client needs or the

marketplace. If the project is driven by a due date, CMMs intensive reliance on process and forms may become a hindrance to meeting the due date in cases where time to market with some kind of product is more important than achieving high quality and functionality of the product.

- Suggestions of scientifically managing the software process with metrics only occur beyond the Fourth level. There is little validation of the processes cost savings to business other than a vague reference to empirical evidence. It is expected that a large body of evidence would show that adding all the business overhead demanded by CMM somehow reduces IT headcount, business cost, and time to market without sacrificing client needs.
- No external body actually certifies a software development center as being CMM compliant. It is supposed to be an honest self-assessment.
- The CMM does not describe how to create an effective software development organization. The CMM contains behaviors or best practices that successful projects have demonstrated. Being CMM compliant is not a guarantee that a project will be successful, however being compliant *can* increase a project's chances of being successful.
- The CMM can seem to be overly bureaucratic, promoting process over substance. For example, for emphasizing predictability over service provided to end users. More commercially successful methodologies (for example, the Rational Unified Process) have focused not on the capability of the organization to produce software to satisfy some other organization or a collectively-produced specification, but on the capability of organizations to satisfy specific end user "use cases" as per the Object Management Group's UML (Unified Modeling Language) approach.[70]

2.2 CMMI Introduction

A model is a simplified representation of the world. Capability Maturity Models (CMMs) contain the essential elements of effective processes for one or more bodies of

knowledge. These elements are based on the concepts developed by Crosby, Deming, Juran, and Humphrey [Crosby79, Juran 88, Deming 86, and Humphrey 89].

CMMI models are not processes or process descriptions. The actual processes used in an

Organization depends on many factors, including application domain(s) and organization structure and size. In particular, the process areas of a CMMI model typically do not map one to one with the processes used in the organization. In an increasingly competitive world, software organizations must implement effective processes to deliver useful and reliable software in time and within budget. CMM Integration models define key elements of effective processes and provide guidance for improving organization's processes. CMM Integration (CMMI for short) places proven approaches into a structure that helps an organization appraise its organizational maturity or process area capability, establish priorities for improvement, and implement these improvements.[10]

2.2.1 CMMI A Brief Overview

In an increasingly competitive world, software organizations must implement effective processes to deliver useful and reliable software in time and within budget. IT organizations are adapting CMMI models to help them streamline their software development activities.

CMMI models define several process areas that indicate where an organization should focus to improve its software process. These Process Areas are further classified under four categories, namely Process Management, Project Management, Engineering and Support. The process areas defined by CMMI model is listed below:

For each Process Area, CMMI models define:

a) Specific and general goals to achieve maturity in the process area.

b) A set of specific and generic practices to achieve the goals.

c) A capability level associated with each specific and generic practice.

CMMI models provide guidance to use when developing processes. CMMI models are not processes or process descriptions. The actual processes used in an organization depend on many factors, including

- Application domain(s)
- Organization structure
- Size of the organization

Process Management	Project Management	Engineering	Support
Organizational Process Focus	Project Planning	Requirements Development	Configuration Management
Organizational Process Definition	Project Monitoring and Control	Requirements Management	Process and Product Quality Assurance
Organizational Training	Supplier Agreement Management	Technical Solution	Measurement and Analysis
Organizational Process Performance	Integrated Project Management	Product Integration	Organizational Environment for Integration
Organizational Innovation and Deployment	Risk Management Integrated Teaming	Verification Validation	Decision Analysis and Resolution Causal Analysis and Resolution
	Quantitative Project Management		

2.2.2 About CMMI Models

A process is a leverage point for an organization's sustained improvement. The purpose of CMM Integration is to provide guidance for improving your organization's processes and your ability to manage the development, acquisition, and maintenance of products or services.

CMM Integration places proven approaches into a structure that helps your organization appraise its organizational maturity or process area capability, establish priorities for improvement, and implement these improvements. Company can use a CMMI model to help set process improvement objectives and priorities, improve processes, and provide guidance for ensuring stable, capable, and mature processes. A selected CMMI model can serve as a guide for improvement of Organizational processes. [15]

2.2.3 Overview

Use professional judgment to interpret CMMI specific and generic practices. Although process areas depict behavior that should be exhibited in any organization, all practices must be interpreted using an in-depth knowledge of the CMMI model being used, the organization, the business environment, and the circumstances involved.

2.3 CMMI Model Representation

There are multiple CMMI models available, as generated from the CMMI Framework. Consequently, the team needs to be prepared to decide which CMMI model best fits your organization's process-improvement needs. First of all the company need to select a representation, either continuous or staged, and you must determine the bodies of knowledge company want to include in the model that the organization will use.[15]

2.3.1 Staged Representation:

The staged representation organizes process areas into five maturity levels to support and guide process improvement. The staged representation groups process areas by maturity level, indicating which process areas to implement to achieve each maturity level. Maturity levels (described later in this chapter) represent a process-improvement path illustrating improvement evolution for the entire organization pursuing process improvement. Within each process area, the specific goals and specific practices are

listed first, followed by the generic goals and generic practices. The staged representation uses four common features to organize the generic practices.[15]

2.3.1.1 Structural Overview

A CMMI model with a staged representation is illustrated in Figure 1.

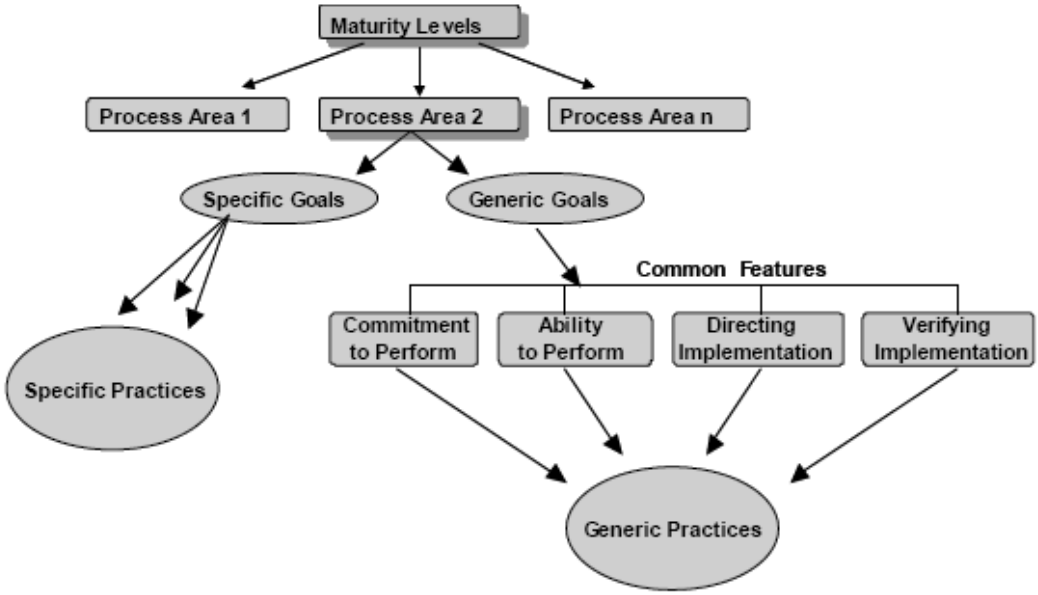

Figure 1: CMMI Model components with staged representation [15]

CMMI models are designed to describe discrete levels of process improvement. In the staged representation, maturity levels provide a recommended order for approaching process improvement in stages. As illustrated in Figure 1, maturity levels organize the process areas. Within the process areas are generic and specific goals as well as generic and specific practices. Common features organize generic practices.

This representation focuses on best practices your organization can use to improve processes in the process areas that are within the maturity level it chooses to achieve. Before you begin using a CMMI model for improving processes, you must map your processes to CMMI process areas. This mapping enables you to control process improvement in your organization by helping you track your organization's level of conformance to the CMMI model you are using. It is not intended that every CMMI process area maps one to one with your organization's processes.

2.3.2 Continuous Representation:

The continuous representation uses six capability levels, capability profiles, target staging, and equivalent staging as organizing principles for the model components. The continuous representation group process areas by affinity categories and designates capability levels for process improvement within each process area.

2.3.2.1 Structural Overview:

A CMMI model with a continuous representation is illustrated in Figure 2

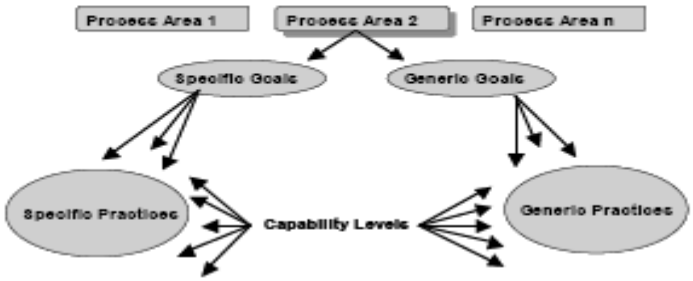

*Figure 2***:** *CMMI Model components with continuous representation [15]*

In continuous representation the specific goals organize specific practices and the generic goals organize generic practices. Each specific and generic practice corresponds to a capability level. Specific goals and specific practices apply to individual process areas. Generic goals and generic practices apply to multiple process areas. The generic goals and generic practices define a sequence of capability levels that represent improvements in the implementation and effectiveness of all the processes you choose to improve. CMMI models are designed to describe discrete levels of process improvement. In the continuous representation, capability levels provide a recommended order for approaching process improvement within each process area. At the same time, the continuous representation allows some flexibility for the order in which the process areas are addressed. This representation focuses on best practices your organization can use to improve processes in the process areas it has chosen to address.

2.3.3 Factors in Selection of Representation Decision

Three categories of factors that may influence your decision when selecting a representation are business, culture, and legacy.

2.3.3.1 Business Factors

An organization with mature knowledge of its own business objectives is likely to have a strong mapping of its processes to its business objectives. Such an organization may find the continuous representation useful to appraise its processes and in determining how well the organization's processes support and meet its business objectives. If an organization with a product lines focus decides to improve processes across the entire organization, it might be served best by the staged representation. The staged representation will help an organization select the critical processes to focus on for improvement.

The same organization may opt to improve processes by product line. In that case, it might select the continuous representation and a different appraised rating of capability might be achieved for each product line. Both approaches are valid. The most important consideration is which business objectives you would like your process improvement program to support and how these business objectives align with the two representations.

2.3.3.2 Cultural Factors

Cultural factors to consider when selecting a representation have to do with an organization's ability to deploy a process improvement program. For instance, an organization might select the continuous representation if the corporate culture is process based and experienced in process improvement or has a specific process that needs to be improved quickly. An organization that has little experience in process improvement may choose the staged representation, which provides additional guidance on the order in which changes should occur.

2.3.3.3 Legacy

If an organization has experience with a staged representation, it may be wise to continue with the staged representation of CMMI, especially if it has invested resources and deployed processes across the organization that are associated with a staged

representation. The same is true for the continuous representation. Both staged and continuous representations were included in CMMI so that the communities that have used them successfully could continue in a manner that is comfortable and familiar as well as successful.

2.3.4 Why Not Both Representations?

Whether used for process improvement or appraisals, both representations are designed to offer essentially equivalent results. More than eighty percent of the CMMI model's content is common to both representations. Therefore, an organization need not select one representation over another.

In fact, an organization may find utility in both representations. It is rare that an organization will implement either representation exactly as prescribed. Organizations that are successful in process improvement often define an improvement plan that focuses on the unique needs of that organization and therefore use the principles of both the staged and continuous representations.

For example, organizations that select the staged representation and are at maturity level 1 often implement the maturity level 2 process areas but also the Organizational Process Focus process area, which is included at maturity level 3. Another example is an organization that chooses the continuous representation for guiding its internal process improvement effort and then chooses the staged representation to conduct an appraisal.

2.3.4.1 Representations for CRISS: Continuous or Staged?

There are many valid reasons to select one representation or the other. Perhaps the organization will choose to use the representation it is most familiar with. Before you begin using a CMMI model for improving processes, you must map your processes to CMMI process areas. This mapping enables you to control process improvement in your organization by helping you track your organization’s level of conformance to the CMMI

Model you are using. It is not intended that every CMMI process area maps one to one with your organization’s processes

CRISS has chosen staged representation for the improvement of its development process there are many advantages of selecting staged representation. This model will give the following advantages to the organization:

- Provide a proven sequence of improvements, beginning with basic management practices and progressing through a predefined and proven path of successive levels, each serving as a foundation for the next
- Permit comparisons across and among organizations by the use of maturity levels
- Provide a single rating that summarizes appraisal results and allows comparisons among organizations whether used for process improvement or appraisals, both representations are designed to offer essentially equivalent results.
- Maturity levels, which belong to the staged representation, apply to an organization’s overall maturity. While Capability levels, which belong to the continuous representation, apply to an organization’s process-improvement achievement for each process area.

The continuous representation offers a flexible approach to process improvement. An organization may choose to improve the performance of a single process-related trouble spot, or it can work on several areas that are closely aligned to the organization's business objectives. The continuous representation also allows an organization to improve different processes at different rates. There are some limitations on an organization's choices because of the dependencies among some process areas. Capability levels are used to measure the improvement path through each process area from an unperformed process to an optimizing process. For example, an organization may wish to strive for reaching capability level 2 in one process area and capability level 4 in another. As the organization's process reaches a capability level, it sets its sights on the next capability level for that same process area or decides to widen its scope and create the same level of capability across a larger number of process areas. If you know the processes that need improvement in your organization and you understand the dependencies among the process areas described in CMMI, the continuous representation would be a good choice for your organization.

For an organization like CRISS continuous representation would not be a good option because company has less experience in process improvement and company doesn't have mature knowledge of its own business objectives and strong mapping of its processes to its business objectives. While for Criss the organization is not clear about the dependency among the process areas and wants to apply organization wide so for Criss staged representation would be the best option.

The staged representation offers a systematic, structured way to approach process improvement one step at a time. Achieving each stage ensures that an adequate improvement has been laid as a foundation for the next stage.

Maturity levels that take much of the guesswork out of process improvement organize process areas. The staged representation prescribes the order for implementing each process area according to maturity levels, which define the improvement path for an organization from the initial level to the optimizing level. Achieving each maturity level ensures that an adequate improvement foundation has been laid for the next maturity level and allows for lasting, incremental improvement.

For CRISS staged representation would be better choice as the company doesn't know where to start and which processes to choose to improve, and the organization don't have mature knowledge of its own business objectives and it will be difficult for CRISS to have a strong mapping of its processes to its business objectives and the company needs to decides to improve processes across the entire organization and secondly there is a limited awareness in the organization about the process improvement, it will be served best by the staged representation The staged representation will help CRISS to select the critical processes to focus on for improvement. As the staged representation is a good choice as it offers a systematic, methodical, structured approach process improvement one at a time, and it will be implemented organization wide, which defines the improvement paths for an organization from the initial level to the optimizing level.

2.4 CMMI Models

The Capability Maturity Model (CMM) of the Software Engineering Institute (SEI) describes the maturity of software development organizations on a scale of 1 to 5. According to the SEI, "Predictability, effectiveness, and control of an organization's software processes are believed to improve as the organization moves up these five levels. While not rigorous, the empirical evidence to date supports this belief ".

2.4.1 Level 1 Initial:

At maturity level 1, processes are usually ad hoc and the organization usually does not provide a stable environment. Success in these organizations depends on the competence and heroics of the people in the organization and not on the use of proven processes. In spite of this ad hoc, chaotic environment, maturity level 1 organizations often produce products and services that work; however, they frequently exceed the budget and schedule of their projects.Maturity level 1 organizations are characterized by a tendency to over commit, abandon processes in the time of crisis, and not be able to repeat their past successes again.

2.4.2 Level 2 Repeatable:

At maturity level 2, software development successes are repeatable. The organization may use some basic project management to track cost and schedule.Process discipline helps ensure that existing practices are retained during times of stress. When these practices are in place, projects are performed and managed according to their documented plans.Project status and the delivery of services are visible to management at defined points (for example, at major milestones and at the completion of major tasks).Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.

2.4.3 Level 3 Defined:

At maturity level 3, processes are well characterized and understood, and are described in standards, procedures, tools, and methods.The organization's set of standard processes, which is the basis for level 3, is established and improved over time. These standard

processes are used to establish consistency across the organization. Projects establish their defined processes by the organization's set of standard processes according to tailoring guidelines.

The organization's management establishes process objectives based on the organization's set of standard processes and ensures that these objectives are appropriately addressed.A critical distinction between level 2 and level 3 is the scope of standards, process descriptions, and procedures. At level 2, the standards, process descriptions, and procedures may be quite different in each specific instance of the process (for example, on a particular project). At level 3, the standards, process descriptions, and procedures for a project are tailored from the organization's set of standard processes to suit a particular project or organizational unit.

2.4.4 Level 4 Managed:

Using precise measurements, management can effectively control the software development effort. In particular, management can identify ways to adjust and adapt the process to particular projects without measurable losses of quality or deviations from specifications.Subprocesses are selected that significantly contribute to overall process performance. These selected subprocesses are controlled using statistical and other quantitative techniques.

A critical distinction between maturity level 3 and maturity level 4 is the predictability of process performance. At maturity level 4, the performance of processes is controlled using statistical and other quantitative techniques, and is quantitatively predictable. At maturity level 3, processes are only qualitatively predictable.

2.4.5 Level 5 Optimizing:

Maturity level 5 focuses on continually improving process performance through both incremental and innovative technological improvements. Quantitative process-improvement objectives for the organization are established, continually revised to reflect changing business objectives, and used as criteria in managing process improvement. The effects of deployed process improvements are measured and evaluated against the

quantitative process-improvement objectives. Both the defined processes and the organization's set of standard processes are targets of measurable improvement activities.

Process improvements to address common causes of process variation and measurably improve the organization's processes are identified, evaluated, and deployed.Optimizing processes that are nimble, adaptable and innovative depends on the participation of an empowered workforce aligned with the business values and objectives of the organization. The organization's ability to rapidly respond to changes and opportunities is enhanced by finding ways to accelerate and share learning.

A critical distinction between maturity level 4 and maturity level 5 is the type of process variation addressed. At maturity level 4, processes are concerned with addressing special causes of process variation and providing statistical predictability of the results. Though processes may produce predictable results, the results may be insufficient to achieve the established objectives. At maturity level 5, processes are concerned with addressing common causes of process variation and changing the process (that is, shifting the mean of the process performance) to improve process performance (while maintaining statistical probability) to achieve the established quantitative process-improvement objectives.[71]

CHAPTER 3: PAKISTAN SOFTWARE INDUSTRY

3.1 Background:

Pakistan's Software Industry has come a long way from its start in 1976 when a company by the name of Systems Pvt. Ltd. opened its offices in Lahore. Over the last three decades or so, the industry has grown from zero to an approximate size of well over a hundred million dollars and employs thousands of professionals. During this time, the industry has seen periods of nascence, hope, euphoria, disillusionment, renewal, and rebuilding. The last decade has in particular not only been a time of great promise, but also a test for the industry that has been through a full cycle of reversals from an inside-out ("domestic first, export later) to an outside in ("export first, domestic later") worldview and back again. In the process, it probably has also been through considerable maturation, not only in terms of its ability to develop good innovative software but also build successful businesses. The IT industry in Pakistan as been growing in fits and starts wit period of high growth in the early nineties followed by the downturn in the market from 2002 to 2003 since then the industry has been in the upturn with exports for the fiscal year 2004-2005 by greater than 45% higher then the previous year and it is expected to grow higher with the time as software industry is getting matured day by day people are investing more in it and business managers are learning new tactics how to manage the IT and the IT professionals are learning how to manage the "business" parts of the IT business. The industry, however, has a long way to go before it can truly realize it's potential.

The number of the IT companies register with the PSEB is nearly about 700 out of which about 300 are actively engaged in providing professional IT services to the clients both domestic and internationally. There are different business model a company can adopt which include sets of features that determine firm's strategic level and competitive dynamics. There are four types of generic software business model. The defining characteristics of these generic business models are the intended market of the software product/service (i.e. domestic or export) and the place of conception of the firm's idea. An export-focused firm is very likely to face an entirely different set of challenges than a domestic focused firm. The second of these factors, namely, the place of conception/origin of the

firm's idea, organizational structure of firm (e.g. the incentives sharing, issues of coordination and control, parent subsidiary relationships etc.) as well as the marketing challenges that it faces (e.g. developing networks, domain expertise, marketing arrangements etc.), whether the firm's primary proponents are based at home (in Pakistan) or the target market of the firm's products/services. There are four different types of models

3.2 Software Business Model

3.2.1 The Export Focused Local Firm

This model is one founded by a predominantly Pakistan based entrepreneurial team (that may or may not have been aided/encouraged by a group of expatriates), but with an explicit purpose of exporting software products or services. Majority of the firms established in pre Dotcom Bubble burst era with an expressed purpose of exporting Services a name given to the dominant Indian model of doing offshore programming and Coding for foreign clients would probably fall within this category. Although there are some that have taken the products route, their numbers are relatively smaller than those focusing on export of services. There are considerable challenges in working under this business model, not only with regards to setting up a software development operation that could deliver the sort of quality product or service demanded by a sophisticated foreign customer but also in terms of putting in place a cost effective marketing front end in a foreign land. Some salient examples of this type of business model in action are: ThreesixtyDegreez, Post Amazers, Advanced Communications, Makabu, Netsol, and Autosoft Dynamics etc.

3.2.2 The Export Focused Foreign (Expatriate) Firm

This model is one founded abroad (or jointly, in Pakistan), by a predominantly foreign (usually an expatriate) entrepreneurial team, with an explicit purpose of using the Pakistan based offshore development facility to deliver a product or service demanded by the foreign market. This type of business model has been adopted by services and product focused companies alike. Within both the services and products domains, this type of

business model has been more valuable than the Export Focused Local Firm model, primarily because of the ability of this firm's expatriate founders to capitalize on their own personal presence and networks in foreign lands. The key challenge for this business model has less to do with not finding domain focus or customers abroad which the expatriate founders often have a very good grasp of and more to do with successfully pulling off the task of setting up a development facility in Pakistan by finding appropriate talent, setting up work systems, and getting over the hill as far as offshore onshore coordination is concerned. Some salient examples of this type of business model in action are: Elixir Technologies, Etilize Inc., Ultimus, MixIT, TechLogix, Prosol, and Xavor etc.

3.2.3 The Domestic Focused Local Firm

The domestic focused local firm model with an exception of a few companies is really one because of circumstances rather than choice. More often than not, and logically so, the domestic focused local firm plans to export its products or services abroad and is merely using the domestic market as a vehicle to gain a track record with real life customers. Whether a firm is in this category by choice ("I'll do domestic first, export later") or by circumstances ("Since the export market doesn't seem very good right now, I'll survive by selling at home") the challenges are quite similar, namely, first, to do enough "large" projects fairly quickly in the local market to build a reputable portfolio of customers but more importantly, to develop a domain expertise, and to migrate effectively from a producer of products/services for a rather unsophisticated domestic customer to a much more sophisticated and quality conscious foreign customer. The more successful of these firms have already begun to look overseas, primarily the Middle Eastern region, Some salient examples of this type of business model in action are: 2B Technologies, ZRG, TPS, Lumensoft, Yevolve, SI3, Softech Systems, AppXS, and Genesis Solutions etc.

3.2.4 Dedicated Offshore Development Center

As the name suggests fairly limited offshore development operation of a foreign company. It is different from the Export Focused Foreign (Expatriate) Firm in the sense that it is often an "add on" to an already existing company whose strategic and managerial processes and controls are quite well established. It, therefore, does not get an

equal say in the long-term vision and strategic direction of its parent. This is true At least from the short to medium term and May change depending on how the parent wants the offshore development operation to evolve over the longer run and on what terms and conditions was the Pakistani subsidiary conceived. The key challenges of this business model, therefore, also differ with reference to the timeframe in question.

In the short to medium run, the challenge is to set up a facility that could deliver quality Products/services in support of the product /service strategy of its foreign parent, to do it in a manner that the local operation is in sync with the foreign parent and its clients, and to transfer the necessary domain expertise and customer experience to the local developers. In the medium to long run, however, as the local operation matures and acquires a life of its own, the key challenge then is to continue to align its interests and requirements with that of the foreign parent. If not managed well, this may give rise to considerable management tension and employee discontent. While most companies established under such an arrangement in Pakistan have not yet reached the “longer run” of their existence, some have, and one can clearly see them navigating through these later stage challenges. Some salient examples of this type of business model in action are: MetaApps, ITIM Associates, Clickmarks, Trivor Systems and Strategic Systems International etc.

PSEB has conducted a survey by taking 50 companies as a sample, which will give the statistical snapshot of Pakistan's software industry, and the results of this survey is defined in Figure 3. In large companies, only 9% of the projects are completed on time and within budget. About 53% of projects will cost 189% of original estimate [14]. According to one estimate, the opportunity cost of poor project management, while not measurable, could easily be in the trillions of dollars. Cost of prevention is much more less than the cost of rework. The issue of technical and process quality arises in at least a couple of contexts, namely, the propensity to seek a certification and the ability to deliver a quality product or service per se, with or without a certification to show for it. That companies use quality certifications, primarily ISO9000 but increasingly CMM, as a means of signaling the quality of their processes is a well-established fact in literature (Arora and Asundi, 1999)[5]. Indian companies have been, by far, the most sophisticated users of quality certification with over half of the total worldwide CMM Level 5

certifications going to Indian companies alone. In Pakistan too, this has had a ripple effect, with an increasing number of Pakistani companies trying to acquire a quality certification. NCR's Teradata division recently announced itself to be the first CMM Level5 Company in Pakistan. Netsol is widely believed to be at CMM Level 4 and Kalsoft claims to be at CMM Level 3.

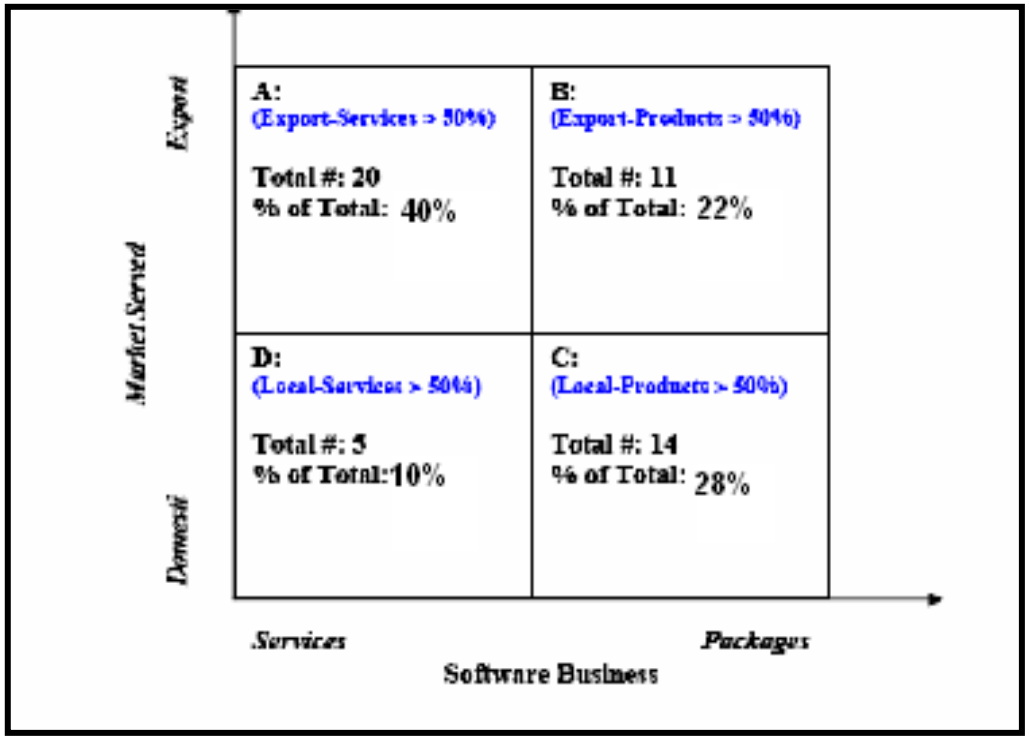

Figure 3: Software Business Model [72]

The cost of certification has thus far been a major, not the only prohibitive factor in an even larger number of companies acquiring a CMM certification. Consequently, the Government, through PSEB, has stepped in to subsidize CMM certification of fairly respectable number of software companies.

To be fair, the importance of quality certification, where it makes sense, cannot be denied. There are, however, clear indications in the sample of various types of companies showing different propensities to seek a quality certification. For example, companies in the exports of services, especially hybrids, are most likely to seek a quality certification. Alternatively, product-focused companies are least likely to seek one probably because the track record of their products serves as an ample signaling mechanism. One of the

often cited and very visible examples neither is that of Microsoft a company that is not CMM neither certified nor does it plans to be. Microsoft's example is also relevant here from another standpoint. When operating at the cutting edge of innovative products, "good enough" quality maybe acceptable to the customer but This is a kind of luxury not available to most Pakistani product focused companies as they focus on less innovative end of the products market, namely, ERPs, accounting software, and run of the mill billing and automation systems. Another empirical regularity is that the dedicated development center operations are considerably less likely to seek certification but much more likely to adopt rigorous technical and process quality approaches. Herein lies the other key element of the quality issue. Many in the industry believe that certification is not the only measure of technical and process quality. People in the industry normally believe that "*The very act of going through a certification process, at times, overshadows the actual software development process itself. We tend to do a lot of things because they are needed by the certification process rather than their value in terms of improving the quality of the process"* often people say that It is always a bad idea for the certification to become an end in itself rather than a means to an end (process quality). Most organizations are, therefore, quite cautious about whether or not they seek a Certification and how they bring up the quality of their technical (software) development processes to get there.

Another issue that has considerable bearing on the quality practices of the local software operations is simply inexperience and lack of adequate amount of work. In the end, process maturity is important regardless of whether it comes with a certification or without. Many entrepreneurs have come to realize that over time, as most point out to the fact that "maturity" comes with gaining experience in doing projects. Ones processes cannot become mature overnight. [73]

Another problem is executives accept schedule commitments when the engineers offer no evidence that they can meet these commitments. Engineers agree to dates when they have no idea how to meet them. Project managers concentrate on the work to be done and pay little or no attention to the disciplines with which the work is done. While disciplined methods are known in the organization but, management does not always ensure their consistent use Motivation declines as professionals gain experience all non-technical

elements of motivation are controllable by the immediate manager Heroic efforts rescue troubled projects and heroes are in short supply To address these issues, it is not enough that we just try harder Executives must personally lead their organization's transformation into the modern world of engineered software .There are many problems that are mostly exist in the Pakistani software industry and which has slowed down the growth and adoption of CMMI standards in the organization. There are two ways the way companies can take CMMI

- Companies may undertake CMMI as a cure to their problems - *the reactive approach*,
- As a mean to improve their current position - *the proactive approach*.

Some companies undertook CMMI as a solution to their declining revenues, unsatisfied customers, and increasing defect rate while in Pakistani companies they have limited resources if they take CMMI initiative at that point of time CMMI will further deplete their resources NCR teradata did not have any such pressing problems to provoke CMMI initiative. NCR implemented CMMI to support its growth, and to better the current processes. The end-result in both the cases was the same namely a much improved company, producing quality software with in time and with in budget. Even the clients were able to appreciate the difference of quality before and after CMMI certification.

CMMI, in Pakistan software industry is best implemented as a preventive cure - *the proactive approach* (like TATA, Boeing, and Motorola). This is because almost all Pakistani software companies are smaller companies with limited resources. If a company is not doing well and it starts its CMMI initiative as a cure to its ailing condition - this would mean further drain on its already depleted finances.

The best time for a Pakistani software company to undertake CMMI, is when things are looking and should start their CMMI initiative as a tool that will not only bring them more foreign projects, but will also help them in the growth. An immature company can never grow above a certain size, as its immaturity would drag it down, only a mature company can sustain growth and CMMI is the best maturity tool at our disposal. There are different problems because of these issues companies hesitate to implement and take initiative to implement CMMI

- Cost for CMMI implementation.
- Management commitments for process improvement.
- Culture.
- Employee’s attitude and opposition.

3.3 Problems Related To Pakistan's Software Industry

3.3.1 COST for CMMI implementation:

CMMI is very expensive to implement. There are different types of costs that are associated with the CMMI implementation costs are

- Consultant Charges
- Auditing charges
- Training Charges
- Staff Salaries
- Operational cost
- Time

Even if the management and the employees are all CMMI aware and are all willing to implement CMMI in the organization the major hindrance could be lack of human as well as financial resources. CMMI cannot be implemented by a group of employees working part-time on CMMI initiative. It requires a dedicated team of three or more people who will be assigned to implementing CMMI. These individuals must all be respected in the company at least one of them (the team leader) should be in a position of authority. Unlike ISO team leadership, which is usually handled in Pakistan by individual with almost no software experience, the CMMI team lead must have solid software development experience. In short a company that puts CMMI as its top priority would assign its very best man to the task. This makes CMMI initiative very expensive. Even after assigning a competent team to overlook CMMI the mere process of inviting the CMMI auditors to audit the company can be a very expensive proposition. There aren't many CMMI auditors around meaning that getting an auditor to audit your company

would require paying him and his team a modest amount. A CMMI auditor may take anywhere between one to two weeks to audit. During this time they would be poking their noses in four to five selected projects. They would require interviewing and surveying the individuals who did those projects. This would require the people to leave their assigned tasks and find enough time to talk to the auditors. So in general the company's day-to-day tasks would be affected. All these factors put into dollar figures may result in a substantial amount. This huge amount may be another deterrent in applying CMMI.

3.3.2 Culture:

Pakistanis are basically a conservative society where elders, parents and teachers are considered reverent. Being brought up in such a society an individual looks up to the boss with utmost revere and it is difficult for anyone in the middle and lower tier to take process improvement initiative and they mostly don't bother about Process improvement and continuous learning. As CMMI has been around for over a decade; it may still be considered new to Pakistan. Remember that Pakistan is a country which has only recently recognized the importance of ISO certification although ISO has been around for much longer than CMMI.And it is only adopted if upper management realizes the importance and employees have been forced to take part in implementing and the top management always don't bother of implementing these standards As in Pakistan most of the companies have been managed by "SEATHS"and they mostly are more concerned with profits and nothing else. Based on this slow response of Pakistani Industry to standardization it is only logical to expect that software industry would not be any different. Hence it won't be for another few years before the Software Industry realizes the importance of CMMI.

CMMI is new not only to Pakistan, but also to many other parts of the world. Official CMMI documents start surfacing around 1992; and although SEI's official documents indicate that four companies applied for certification in as early as 1987; but the same documents also indicate the infancy of CMMI certification and standards. So for all practical purposes CMMI has become better known since 1992. The first reaction to CMMI was that of rejection as is the case with any new methodology. It was only after a

few companies successfully obtained CMMI certifications, and started releasing figures that show the resulting improvements in efficiency and productivity that the software industry started appreciating CMMI Based on the above discussion CMMI may still be considered new to Pakistan. But this should not be an excuse for Pakistan Software Industry to ignore CMMI. Software market is not as forgiving as other industries. If a software company does not improve its processes then it gets left behind. Recent times have seen many Pakistani companies go bellies up lack of CMMI initiative is not the only reason for their debacle but this definitely was a contributing factor.

Another problem is the lack of CMMI example in Pakistan, and the organization which wants to implement CMMI in the organization are not fully aware of what CMMI is they just know it is a certification and all the big and renowned companies have this certification why not try to get it they even don't know what will be the benefits of obtaining the certification. In Pakistan NCR is the first organization, which has achieved SW-CMM level 5, and Netsol Lahore is at level 4. With the government of Pakistan support five more companies have register themselves with the PSEB. As in case of India whose ambition and progress towards becoming a "mini (software) superpower" is no mystery from the world India is in tier 1 of software exporting nations while Pakistan is in tier 3. Indian software companies (Dutta and Sekhar, 2004) and the adoption of standardized quality practices like Six Sigma methodologies (Radhakrishnan, 2004) and CMM certifications. These geographical differences in software development practices, however, maybe attributed to both cultural and type of work related factors. For example, Cusumano et al. (2003) observe that India and Japan significantly lag the American and European software operations in terms of the innovative quality of their work.

Indian companies have been, by far, the most sophisticated users of quality certification with over half of the total worldwide CMMLevel5 certifications going to Indian companies alone. India has many software companies with CMMI certifications, so an Indian software company can look at Wipro, TCS, etc. and actually see the benefits (both tangible and intangible) of CMMI. In Pakistan, very few companies have CMMI certification one is NCR and other is NetSol and now five more companies have register themselves with PSEB for getting the CMMI certifications but most of the companies don't know what is CMMI and this lack of example in the industry gives the upper

management enough of an excuse not to undertake CMMI. The *"they are not certified and they are doing just fine"* syndrome stops the management from taking CMMI seriously.

3.3.3 Management commitments for process improvement:

One of the major obstacles in implementation of CMMI in Pakistani organization is the lack of CMMI understanding in the upper management of Pakistani software companies. CMMI and other process improvement initiatives can only be successful only if management realize the importance of process improvement and improvement of quality and meet the international standards prevailing in the industry around the globe and management want them to be implemented in the organization. CMMI initiative depends heavily on top Management support and commitments. Without visible and enthusiastic and passionate management support a CMMI initiative is bound to fail. The upper management of some of the Pakistani software companies is totally unaware of CMMI and its importance. CMMI is an overwhelming standard and it streamline all the processes of the company but it cannot be implemented in the organization until or unless top management fully support it as this is very demanding process this requires time, resources and understanding of software processes.

The top management of majority of Pakistanis software companies knows about CMMI-unfortunately this knowledge is simply limited to knowing that CMMI stands for Capability Maturity Model Integration and that it is something similar to ISO and to obtain the CMMI certification will improve the company image. It is this mere smattering of knowledge of CMMI that is more dangerous than total ignorance.

While a CMMI-Unaware manger would completely dismiss the idea of CMMI a manager who has *partial* knowledge of CMMI can prove to be more detrimental to CMMI initiatives. The only thing worst than not attempting to implement CMMI is a superficial attempt towards implementing CMMI. In Pakistan Software Industry one would come across many managers who are *partially aware* of CMMI. These managers read the success stories of CMMI and tend to get carried away. They self-delegate themselves to implement CMMI in their company. Without consulted others, without considering their company's unique needs and employee’s conditions - these managers take it upon

themselves to follow the success stories of CMMI. While a CMMI initiative cannot succeed without management support the management usually does not have enough time to lead the CMMI initiative themselves. The management role should be that of a sponsor and not of a CMMI team lead.

Every software company is unique in its needs, projects, people, culture and resources. While CMMI makes sense for a majority of software firms there may still be software companies that need not follow CMMI for example Microsoft has shown no interest to achieve CMMI certification. They have their own ways of doing things - and it seem to work fine for them. Before managers get all pumped up by the very idea of their company getting the CMMI certification they need to thoroughly study their company's culture, and make an educated and mutually agreed decision whether to pursue CMMI or not.

This is perhaps one of the biggest excuses being used by the management. Apparently it makes perfect sense. Many high profile companies have chosen not to pursue CMMI certification because they were satisfied with the way things were being done at their companies. After all if a system has been working successfully for so long there’s no point in changing it. Microsoft, for example, has chosen not to pursue CMMI since they seem to be happy with their own ways of managing themselves. Since 1960s people have been coming up with software methodologies, practices, and standards etc. that claim to be the solution of all the software industry's problems. A new one has superseded every such solution, with time. It's only logical to believe that CMMI would suffer the same fate. As a matter of fact CMMI has already gone through many revisions to better itself. For example *People-CMM* came as an answer to *Software-CMM*'s indifference towards people of a software company. While there is nothing wrong with a company sticking with the status quo, this approach is not advisable to Pakistani companies.

Almost all the Software companies in Pakistan may be considered small they do not have well developed processes like Microsoft, and hence cannot choose to dismiss CMMI. The only reason why a majority of Pakistani software firms are doing well despite having no certification is because these companies rely heavily on Heroes *these are extremely motivated, talented, and well paid individuals who will almost always produce quality*

software, with in time, and within cost. It is these heroes that run most of Pakistani Software companies. However it is when these *heroes* choose to leave the company that the real fragility of the company is exposed. CMMI is based on a philosophy in which the company's success does not depend solely on these heroes - rather it depends on the processes that the company follows.

Another reason is most of the companies have ambitions to grow to a size of above 500-1000 employees. A smaller company may survive solely on heroes but as the company size grows there aren't enough heroes to go around and that is when stable, predictable processes can make the difference. If the company grows in size it cannot survive without implementing CMMI, or any equivalent process improvement initiatives.

In most of the organization in which managers are aware of the CMMI but it's really amazing and strange the way they choose to implement CMMI process areas. Most of the top management chooses that CMMI Key Process Lack Areas (key process area) that require lot of work from developers and very little from the managers. CMMI is a hierarchical standard. A lower CMMI Level lays ground for a higher level. Although a company may choose to implement any key process area from any Level, but it is suggested that due to the dependency of Higher Level key process areas on lower Level key process areas a company must address all the key process areas in a lower level before moving on to the higher Level; although this is more of a suggestion rather than a rule. For example "Peer Reviews" is a Level-3 key process area, and does not depend on any of Level-2 key process area on the other hand Level-4 key process area "Software Quality Management" depends on Level-2 key process area "Software Quality Assurance". If Management decides to work on key process areas belonging to more than one level - they must use discretion and must keep in view the inter-dependencies of key process areas.

Many managers choose to start with key process areas that require too much work from developers and too little from managers this presents CMMI as a formidable standard to the employees and this negative first impression may hinder rest of the CMMI implementation. The management must start with the key process areas that require more work from the management and less from the developers this gives a good first

impression to the developers and also allows the managers to lead by example. In short, extreme care should be taken in choosing which key process areas to start from. Remember that to satisfy a certain CMMI Level, all the key process areas of that level and the preceding levels must be satisfied.

Every task being done in a company needs to have a motivation behind it - CMMI is no exception. To follow CMMI practices, an employee needs to put in extra effort. A software developer, who has been developing code without proper commenting - if asked to follow a documented commenting policy to put comments in his code would need to put more effort, Therefore there needs to be some incentive for the employees to follow CMMI.

Many managers fail to see this simple point. Some managers argue that employees should automatically learn to appreciate that following CMMI practices is in their own benefit. What they fail to see is that it won't be for another few months before the benefits of CMMI become evident; therefore the employees need to be given incentives to keep them motivated until the CMMI benefits become evident. These incentives could be salary raise, a word of praise in a company meeting, an employee of the month award, or even a simple pat on the back. The employees need to know that the extra effort they are putting in is being noted and duly appreciated. Therefore before the CMMI initiative in undertaken the managers need to give some incentives to the employees. A common incentive being used successfully by many companies is to give a bonus salary to all the employees on successful attainment of a CMMI certification.

3.3.4 Employees Issues

One of the major problems one would come across while implementing CMMI is unaware and unconcerned employees and this is single factor that is the biggest hindrance in implementing CMMI this would have to be Employees unawareness of CMMI and less commitment to implement CMMI. A software developer is too busy coping up with the ever-approaching deadlines he usually does not have enough time to educate himself about CMMI. It is for this reason that CMMI to a developer seems like an adversary something that is waiting to engulf him in the quicksand of documentation. As if the tremendous amount of work wasn't enough, now he also has to follow the

CMMI practices. Unfortunately many introductory texts on CMMI further strengthen this negative view. CMMI should be presented to a developer as a standard that is here to help and not something that is meant to overload the developer. It is the duty of the management to inculcate this view through out the company. This is something that management fails to understand. For a successful implementation of CMMI the whole company needs to understand the essence of CMMI and needs to be willing to follow CMMI practices; otherwise the company may still get CMMI certification but the company's culture would not change which would defy the whole purpose of CMMI. The few Pakistani software companies that have ISO certifications face the same dilemma. Although they have achieved ISO certification the employees still see ISO requirements as something that is to be done because the management has told them to. This is the classical case of a process improvement initiative bringing the company the certification but not changing the company's culture. Such companies are worst than the companies with no certification, since these companies live by the illusion of having a mature process but in fact they have very fragile processes that are waiting to collapse under tough projects. Such companies have processes that heavily depend on individuals, if a few individuals suddenly decide to leave the company - the whole system becomes susceptible to a collapse.

Every task being done in a company needs to have a motivation behind it CMMI is no exception. To follow CMMI practices, an employee needs to put in extra effort. A software developer, who has been developing code without proper commenting - if asked to follow a documented commenting policy to put comments in his code would need to put more effort. Therefore they demand some thing in return as they are putting extra efforts. [7]

CHAPTER 4 CRISS GAP ANALYSIS

4.1 Company Background:

CRISS, Cyber Rapid Integrated Software Solutions (Pvt.) Limited, a Lakson Group company is organized as a separate business entity to better leverage its intellectual resources. CRISS provides turnkey software & web development solutions including development of new applications or new functions for existing software applications, software maintenance and software re-engineering services through its dedicated state of the art facility located in Karachi, Pakistan.

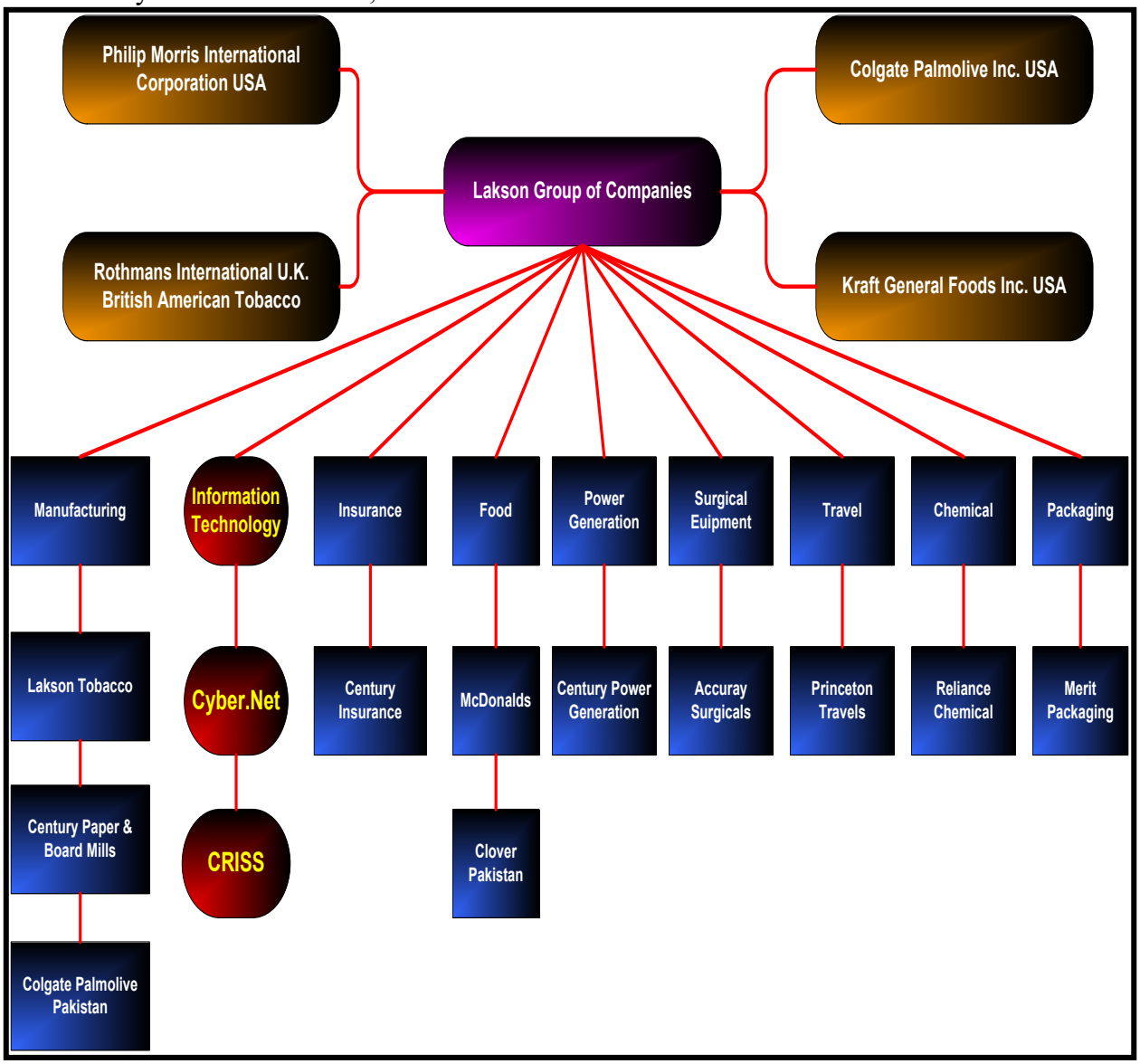

Figure 4: Lakson Group of Companies Organization Structure

4.2 CRISS Vision

Engaging technology for business process transformation and Innovation Company's main focus is on innovative and high quality software and web development, competitively providing solutions with best ROI. CRISS wants to emerge as a global technology integration source, recognized as pre-eminent by our employees, customers, competitors and the public. Focus would be to effectively, responsibly and competitively engage in software and web development business for promotion of both new and old economy concerns. CRISS's hallmark is innovation, initiative, and teamwork of the people and the ability of not merely responding to changes but also to create them as well. Company wants to provide innovative and high quality solutions to their customers accompanied with dependable and real-time support. Lastly, objective of continuous learning would serve the purpose of better adaptability to market needs through constant up-gradation of offerings [74].

With a customer-centric approach coupled with thorough understanding of the market, CRISS puts together solutions for providing sustained business advantage to the clients. The strategy team works in close liaison with the clients to identify and interpret their business objectives and rapidly develop and deploy solutions in line with the objectives. CRISS core competence lies in:

- Online marketing communications and E-commerce solutions.
- Supply chain integration-extranets Intranets.
- Customized software development.

4.3 Company's Objectives:

The objectives of CRISS are as follows:

1. To provide products and services that consistently fulfills client's needs and requirements.
2. To deliver complex, high-quality software products on time, within budget, and to the complete satisfaction of the clients.
3. To establish bidirectional traceability for updating clients of the status of their project from problem analysis to integrated testing and product deployment.
4. To establish a long lasting business relationship with the clients.

4.4 CRISS's Clientele:

CRISS's portfolio of clients is diversified including organizations dealing with food industry, consumer goods, agriculture, telecommunication, civil aviation, finance, insurance, travel and medicine. It has focused primarily on multinational companies for securing their part of market share. It has clients which are unwilling to compromise on quality and efficiency and therefore, require strong commitment by CRISS to provide innovative and quality products and services meeting the international standards. A sample of key clients is given in Figure 5.

4.5 CRISS Organizational Structure

CRISS is a contributory organization of one of the leading group of Pakistan, The Lakson Group of Companies. The structure that company follows is given in figure 6. It appears to be a mechanistic structure. As with mechanistic structure it is traditional or classical design, which is common in many medium- and large-size organizations. It is somewhat rigid in that they consist of very clearly defined jobs, have a well-defined hierarchical structure, and rely heavily on the formal chain of command for control. CRISS's tall structure encourages people to become relatively confined to their own area of specialization. The managers tend to provide considerable direction and have considerable control over others. There is a sharp division of labor and work specialization. CRISS is organized in a functional manner and according to technological disciplines. Senior functional managers are responsible for allocating resources. The responsibility for the total product is not allocated to a specified person and therefore, there is lack of accountability. Coordination occurs through rules and procedures, detailed specifications, shared traditions among engineers and meetings. Although structured meetings are objective but a lot of ad hoc practices prevail at almost all levels sometimes rendering the processes chaotic. CRISS benefits from its tall structure most of the times it is able to deliver the products and services which need high level of specialized knowledge. It also helps CRISS to deliver more than 45% of its product and services within time and budget. Apparently, this may seem very inefficient but when compared to the prevalent industry standards where the figure does not exceed 25% (As reported by PSEB www.pseb.org.pk) CRISS seems fairly efficient and productive.

Figure 5: CRISS Clientele

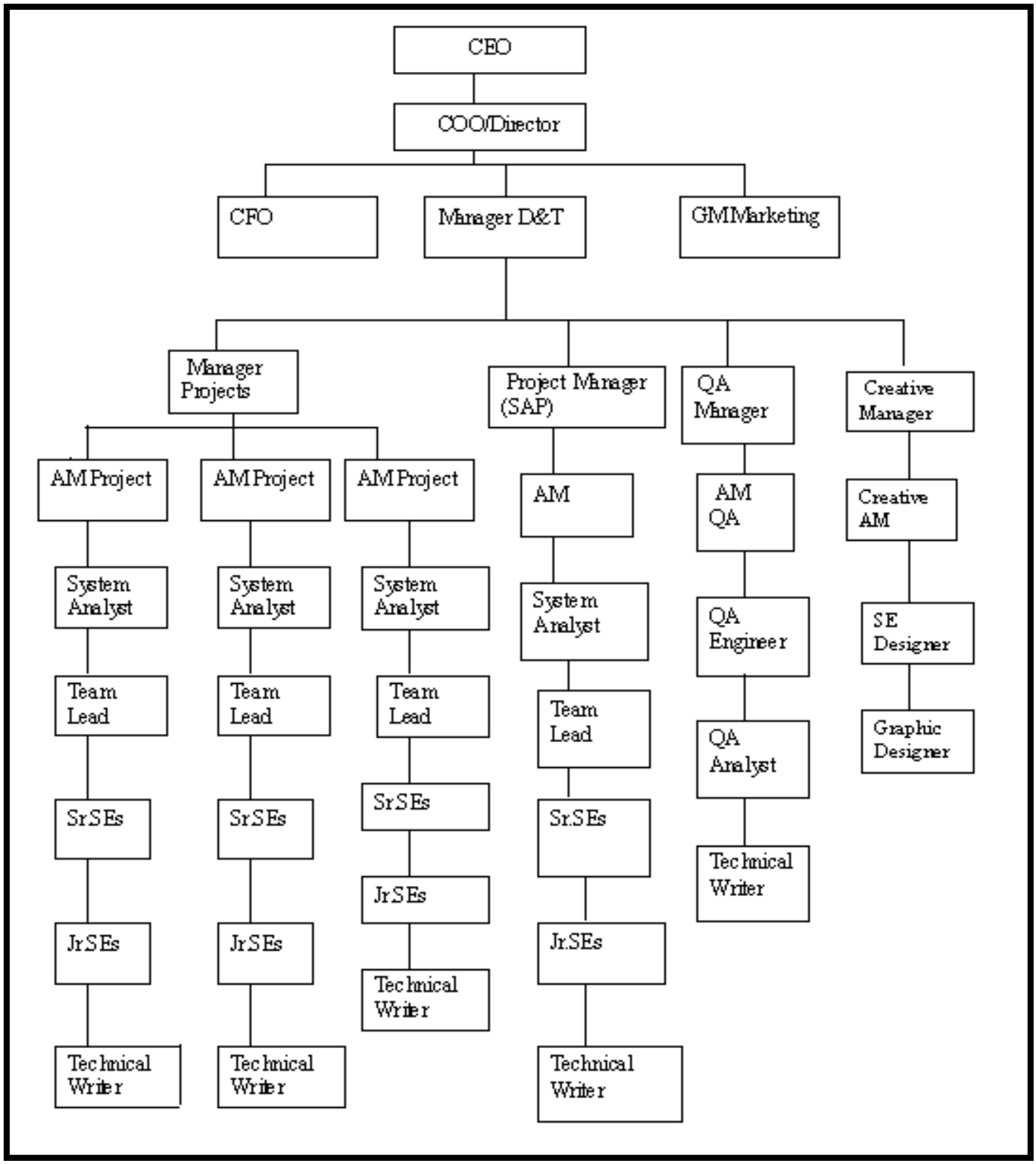

Figure6: CRISS Organizational Structure

4.6 Company Culture:

Basically, organizational culture is the personality of the organization. Culture is comprised of the assumptions, values, norms and tangible signs (artifacts) of organization members and their behaviors. Members of an organization soon come to sense the particular culture of an organization. Culture is one of those terms that are difficult to express distinctly, but everyone knows it when they sense it. For example, the culture of a large, for-profit corporation is quite different than that of a hospital which is quite different that that of a university. You can tell the culture of an organization by looking at the arrangement of furniture, what they brag about, what members wear, etc. Similar to what you can use to get a feeling about someone's personality.

There are different types of culture just like there are different types of personality. There are different types of cultures CRISS follows the *Academy Culture.* In the academy culture *e*mployees are highly skilled and tend to stay in the organization, while working their way up the ranks. The organization provides environments in which employees can develop and exercise their skills. There are many learning and growth opportunity for the employees of the CRISS.

4.7 Process Improvement and CMMI and Business Objectives

The improvement information in CMMI models includes the creation of a viable process infrastructure. CMMI help CRISS to focus more on defining and following its processes. This can be done by provide training and actively involve people so that they know their roles and help them to execute the roles in the processes. CMMI will help CRISS to use and collect the measurement data to improve the processes performance, innovate when processes need to evolve, and ensure the ability to meet changing needs.

To initiate a process improvement at CRISS Manager (D & T) is designated for managing CMMI project, evaluating the progress of CMMI implementation in the company, responsible for allocating resource for process improvement initiative and responsible for objectively evaluating that the process is being followed. It is estimated by keeping in mind organization’s size and the current condition of the organization processes it is estimated that project will be finish with in 6 months and the timeframe allocated for this project is June, 2007 to November, 2007. To start CMMI

implementation in the organization first of all baseline will be established to develop a base line gap analysis has been carried out and after identifying the weaknesses develop the road map of the process areas of CMMI level to improve the organizations processes.
The business objectives for CRISS for implementation of CMMI are:

- ***Produce quality products or services:*** CMMI has a strong focus on quality-related activities including requirements management, quality assurance, verification, and validation, quality products are a result of quality processes. This will help CRISS to provide quality products and services within time and budget and up to customer's expectations.
- ***Create value for the stakeholders:*** As the company's processes mature organizations are more likely to produce quality products, predictable schedules, and effective measurement to support management in making accurate and defensible forecasts, make better cost and revenue estimates than those with less maturity, and then performs in line with those estimates. This will help organization to make more profits and eventually share these profits with employees which act as a motivational tool for the employees. Further, it will reduce the cost of the product or services for the customers.
- ***Be an employer of choice****:* Watts Humphrey has said, "Quality work is not done by accident; it is done only by skilled and motivated people." CRISS can benefit from CMMI as it has strong emphasis on training, both in disciplines and in process. This helps people to learn new processes easily. Software development process is a complex process and engineers in particular are more comfortable where there is a sense of cohesion and standardization. Experience has shown that organizations with mature processes have far less turnover than immature organizations.
- ***Enhance customer satisfaction:*** CMMI will help CRISS in meeting cost and schedule targets with high-quality products that are validated against customer needs. As *CMMI* addresses all of these ingredients through its emphasis on planning, monitoring, and measuring, and the improved predictability that comes with more capable processes.
- ***Increase market share:*** Market share is a result of many factors, including quality products and services, name identification, pricing, and image. Clearly, customer

satisfaction is a central factor, and in a marketplace, having satisfied customers can be contagious. *CMMI* improves estimation and lowers process variability to enable better, more accurate bids that are demonstrably achievable. It also contributes to meeting essential quality goals.

- ***Implement cost savings and best practices:*** *CMMI* encourages measurement as a managerial tool. By using the historical data collected to support schedule estimation, CRISS can identify and widely deploy practices that work, and eliminate those that don't. Processes that are documented, measured, and continuously improved are perfect candidates for becoming best practices, resulting in cost savings for the organization.
- ***Gain an industry-wide recognition for excellence****.* The best way to develop a reputation for excellence is to consistently perform well on projects, delivering quality products within cost and schedule parameters. CRISS can advertise their *CMMI*-defined maturity rating that will definitely help CRISS in building its brand name and this will definitely enhance that reputation.

4.8 CRISS Workflow

CRISS provides turnkey software & web development solutions including development of new applications or new functions for existing software applications, software maintenance and software re-engineering services. Development process that CRISS follows is explained in Figure 7. The development process starts with the customer query. This query may have been initiated either by the customer or by supplying quotations to the customer or winning the tender in a bid. There are three ways how a customer can generate a query:

1. Customer asks for quotation.
2. Tender is invited through newspapers or other media.
3. Contacts by marketing personnel of CRISS.

After initial discussion a detailed meeting is held between the client, the marketing department personnel, and the Project Manager. In case the project size is relatively large the Chief Executive Officer and/or the Chief Operating Officer and/or Manager

Development and Technology may also attend this meeting. This meeting is held to negotiate and agree on the following:

- Project and payment terms and conditions.
- Pricing.
- Project duration.
- Scope of work.
- Warranty.
- Maintenance terms.

When all the terms and conditions are properly defined and agreed, the project is handed over to the Project Manager. The Project Manager selects a project team. The size of the team varies from project to project depending upon the scope of work, expertise required, project duration and availability of resources. While selecting the team the Project Manager consults all stakeholders to ensure their ownership of the project and designates the team leaders of each unit. A meeting of the team is held in which the Project Manager explains the project outputs and roles to the team members to ensure clarity.

Preparation of Analysis and Design Documents:

After the internal project team meetings a few team members meet the client to capture the requirement of the project. This is a formal meeting with the client in which all required data is obtained from the client on a CRISS requirement specification format. After this meeting a requirement specification document is prepared and signed-off by the CRISS (System Analyst or Project Manager) and the client. This document serves as a formal agreement between CRISS and the client and forms the baseline for project activities. Sometimes, the requirement analysis is done by client's IT department and requirement specification document so prepared is then signed by CRISS and the client. After the requirement specification agreement, CRISS prepares another internal functional specification document for the project. In this document screen shots and system flow diagrams are provided. The client reviews this document and either may agree to the proposed design or suggest modifications. In some cases, the modifications suggested by the client may alter the requirement specifications. However, these specifications are not usually incorporated in the already agreed requirement specification document. It remains a verbal commitment and sometimes results in disagreements

between the parties on deliverables. This completes the analysis and design documentation.

The design document is then handed over to the development team. The Team Leader divides this design document into different modules and assigns these to different Software Engineers according to their expertise. When development team members finish the modules, the Team Leader integrates these into a system resulting in an operational software. At this stage the development team also develops user manuals/ set of instructions for operation of the software. Once the modules are integrated into one system it is handed over to the quality assurance (QA) department. The QA department plans its mandatory quality testing in which it is ensured that the system is tested properly using either white or black box models. In the white box model, QA department prepares test cases and runs the software against these cases. In case, time is a constraint usually the black box testing is done. In black box model testing is done only by registering wrong entry results. The whole QA process must take at least 33% of the length of time it takes to develop the software. After testing, the QA department confirms the source code accuracy and then sends this source code back to the development team for rectification of bugs identified during testing. After bugs have been removed, the development team sends this source code back to the QA department. The software is again tested. After successful testing the QA department prepares an executable file through which software can be executed on clients systems. The development team makes necessary changes in the user manual/set of instructions if required. The Project Manager then delivers this executable file along with user manuals to the marketing team personnel and to the client.

4.9 Work Breakdown Structure

CMMI implementation in CRISS is treated as a project and all of the project management methodologies have been followed ,First of all work breakdown structre of the project has been identified.This is standard workbreak down structure that has been defined by Software Engineering Institute.

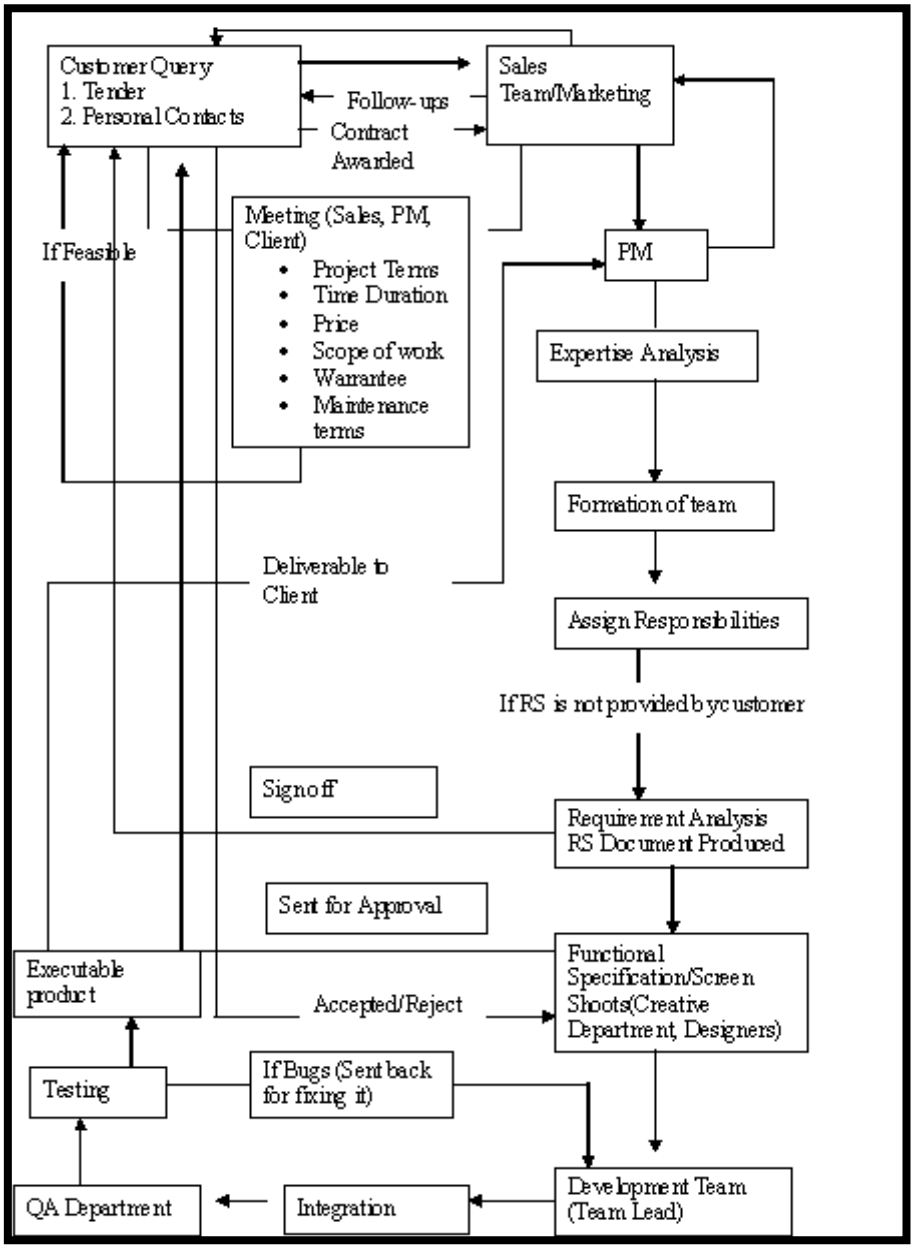

Figure 7: Software development workflow at CRISS

1. Secure Sponsorship and Funding:

Before begin the process improvement efforts in CRISS, First step is to ensure that process improvement program has a senior management sponsor and funding. Manager D& T will be the head of this project and ensures that sponsorship and funding is available for this project. First primary objective is to educate senior management about CMMI by presenting the CMMI overview or CMMI overview for executive's presentations and business case of CMMI implementation

2. Take Core Training:

PSEB will arrange a basic course of CMMI for all of the companies which are registered with PSEB and willing to adopt CMMI, this training ensures that management knows the basic concept of CMMI.

3. Select Representation for Process Improvement Program:

At this stage company will select the model representation for the organization. There are two types of representations staged /continuous, at this stage CRISS will select the representation that best suit its business objectives

4. Prepare CRISS for Change:

At this stage consultant and Manager D & T establish the business reasons and the business goals for the effort and create a compelling case for change, including the rationale for the undertaking and the expected benefits and costs for the people affected. Develop a persuasive presentation of the problems and opportunities.

5. Form Engineering Process Group (EPG):

At this stage EPG group formed purpose of this group is to coordinates process improvement activities across the organization and this group exists for the duration of the process improvement activity. Members of the group serve as process improvement mentors.

6. Know Where You Are:

At this stage map CMMI best practices to the organization's existing processes and do an informal gap analysis to determine how the existing processes compare to CMMI model

practices. To build a detailed picture information has been gathered from almost all of the departments and from different levels.

7. Know Where You Are Going:

At this stage process areas have been selected by keeping in view the picture where company wants to go and company's business. Prioritize the process areas to address and build the improvement plan and track the progress against the plan.

8. Communicate and Coordinate:

Create a culture of honest and open communication. Share the plan with everyone who will be affected and listen to their comments.

9. Track Progress:

Compare the picture of where you are to the one of where you want to be. The difference between the two is the focus of the process improvement program. Create a periodic (e.g., monthly, weekly) report that demonstrates the program's progress in reaching its (and the organization's) goals. After the completion of the process SEI-authorized lead appraiser conducts an appraisal, this will provide an objective evaluation of the organization using the SCAMPI method and a CMMI model [9].

4.10 Company's Current Scenario:

"On time, under budget" is a dream. But most software projects cost more and take longer than planned. Most people have given up; assuming this is the norm rather than the exception.

In 2005, CRISS developed 22 projects of varying sizes and durations all falling in one of the following three categories:

Category 1: E-Commerce and web development

Category 2: Customize solutions

Category 3: Supply chain integration

The relative resource cost of the projects is given in Table 1. Considering a fixed operational cost of Rs 10,000 for each project irrespective of the category, the projects related to supply chain integration cost more than the other two categories. Category 2 projects cost 19% more than the category 1 projects. Similarly category 3 projects cost

50.75% more than the category 1. The costlier input is primarily the time spent by the team leader who is responsible for the total operation of the development. While Technical Writer is a part time resource works only for two hours a day on one project. In addition one more staff is required in category 2 than in category 1. Similarly 2 more staff members are required in category 3 as compare to category 1.

Resource	Category 1	Category 2	Category 3
	Cost per day in Pak Rupees		
Team Lead (Rs35,000 /month)	1,592	1,592	1,592
Senior Software Engineer 1 (Rs 25,000/month)	1,136	1,136	1,136
Senior Software Engineer 2(Rs 25,000/month)	Not required	Not required	1,136
Junior Software Engineer 1 (Rs 15,000/month)	680	680	680
Junior Software Engineer 2 (Rs 15,000/month)	Not required	680	680
Technical Writer (Rs 25,000/month)	170	170	170
Total Cost per day	**3,578**	**4,258**	**5,394**

Table 1: Resource cost

According to the data provided by CRISS less than 50% of its projects are completed in time and budget. The estimated cost of the delayed projects in each category is described in Table 2. On average, 5 projects out of 11 which were delayed are of category 1. The agreed project completion time ranged between 5 and 6 months. On average, delay time of these projects was 28 working days. On an average, 4 out of 11 of category 2 projects were delayed. Time duration of these projects varied from project to project but ranged between 8 months to one year. Some projects in this category, especially those requiring only addition to the existing systems could easily be completed within 2 months. Average delay time of these projects was however, 40 working days. On an average, 2 out of 11 projects of category 3 were delayed. Estimated completion time of these types of projects was 1 year to 1-1/2 years. Average delay time of these projects was 60 working days.

Although the number of projects delayed in the category 1 is highest, the total cost of the delay is lower than that of category 2 or category 3. On average delay in category 3

projects costs 21.12% more than category 1. Similarly, delay in category 2 projects costs 30.92% higher than the category 1.

Type of Project	Number of projects	Number of days	*Cost per project	Total Cost
			Cost in Pak Rupees	
Category 1	5	28	1,10,184	5,50,920
Category 2	4	40	1,80,320	7,21,280
Category 3	2	60	3,33,640	6,67,280
Total Cost	**11**	**128**	**6,69,424**	**20,43,680**

Table 2: Cost of delay for the projects in CRISS

*8Cost per project= (Category cost (table 1)*Number of days delayed) +other expenses*

After calculations it has been analyzed that company's huge sum money ($ 34,061) is wasted each year on bad or delayed software. There are several reasons for delays such as incomplete or ambiguous requirement, lack of agreement by stakeholders, uncontrolled requirement changes as evolved, no assessment of interim deliverables, no basis of evaluations, lack of workmanship standards, quality to be tested in insufficient time allotted to quality assurance department, testing diminished /eliminated due to time constraint.

It has been often argued at different levels in CRISS that implementation of CMMI will increase the cost of the projects further, making it unprofitable for the organization. However, it can be argued that the delay is primarily caused by lack of standardize processes in the organization which hinders decision making and harmony within the team. Further, the project development process and project planning requires a careful scrutiny and standardization so that the marketing team is able to negotiate projects in different categories keeping some minimum standards.

4.11 CRISS Gap Analysis Results

The purpose of the gap analysis is to identify the gaps that exist between the CMMI standards and the CRISS's actual processes. Once the organization know where their gaps are, they can take steps to fill them. To conduct gap analysis 7 employees from different departments of the organization which includes Account Manager, Project Manager,

Business Analyst, System Analyst, QA, Software Engineers has been taken as sample. By studying this sample the results can be fairly generalize. They have to fill up the checklist of CMMI level 2 key process areas. These checklists are designed in such a way that it includes all the specific goals of each of the key process area and the specific practices of each specific goal. Each question has three possible answers:

- Fully implemented-------I
- Partially Implemented---P
- Not implemented--------N

"*I"* answer means that organization has already met one of CMMI requirements, an "*N"* answer points to a gap, while "*P"* answer means that these practices are partially followed in the organization. "*N"* answers reveal gaps that exist between the organization's actual processes with respect to CMMI standard, whenever sample participants answer "*N"* to a question, it means that at least one of the organization's processes fails to meet CMMI requirement. A "*N"* answer tells that a process needs further development. It tells that a process needs to be modified, improved, or created. Therefore, whenever answer is *"N"* to a question, this process must be considered and decide which ones need to be changed. For CMMI gap analysis 47 specific goals have been identified of CMMI level 2 key process areas. Taken together, these 47 specific goals make up a complete CMMI level 2. This checklist is attached in Annexure 2.

Process Area	**I**	**P**	**N**
Requirement Management			
Obtain an Understanding of Requirements	60%	14%	26%
Obtain Commitment to Requirements	50%	50%	0
Manage Requirements Changes	9%	43%	49%
Maintain Bidirectional Traceability of Requirements	23%	23%	52%
Identify Inconsistencies between Project Work and Requirements	17%	14%	69%
Project Planning			

Estimate the Scope of the Project	20%	16%	64%
Establish Estimates of Work Product and Task Attributes	30%	35%	35%
Define Project Life Cycle	13%	26%	61%
Determine Estimates of Effort and Cost	15%	17%	68%
Establish the Budget and Schedule	23%	29%	48%
Identify Project Risks	9%	12%	79%
Plan for Data Management	12%	15%	73%
Plan for Project Resources	32%	14%	54%
Plan for Needed Knowledge and Skills	5%	3%	92%
Plan Stakeholder Involvement	8%	12%	80%
Establish the Project Plan	25%	20%	55%
Review Plans that Affect the Project	12%	8%	80%
Reconcile Work and Resource Levels	17%	11%	72%
Obtain Plan Commitment	14%	11%	75%
Project Monitoring and Control			
Monitor Project Planning Parameters	18%	19%	63%
Monitor Commitments	5%	9%	86%
Monitor Project Risks	10%	11%	79%
Monitor Data Management	9%	15%	76%
Monitor Stakeholder Involvement	5%	15%	80%
Conduct Progress Reviews	5%	25%	70%
Conduct Milestone Reviews	15%	19%	66%
Analyze Issues	2%	9%	89%
Take Corrective Action	25%	35%	40%
Manage Corrective Action	15%	18%	67%
Measurement and Analysis			
Establish Measurement Objectives	3%	4%	93%
Specify Measures	3%	2%	95%
Specify Data Collection and Storage Procedures	0	1%	99%
Specify Analysis Procedures	0	1%	99%

Collect Measurement Data	0	4%	96%
Analyze Measurement Data	0	1%	99%
Process and Product Quality Assurance			
Objectively Evaluate Processes	4%	67%	28%
Objectively Evaluate Work Products and Services	7%	49%	44%
Communicate and Ensure Resolution of Noncompliance Issues	5%	9%	86%
Establish Records	48%	29%	23%
Configuration Management			
Identify Configuration Items	5%	8%	87%
Establish a Configuration Management System	3%	9%	88%
Create or Release Baselines	22%	13%	65%
Track Change Requests	2%	7%	91%
Control Configuration Items	7%	13%	80%
Establish Configuration Management Records	27%	14%	59%
Perform Configuration Audits	6%	9%	85%

Table 3: Gap analysis results

4.12 Finding and Analysis of CRISS Gap analysis

Maturity levels consist of predefined set of process areas. The maturity levels are measured by the achievement of the specific and generic goals that apply to each predefined set of process areas. Gap analysis was conducted to find out the maturity level of the CRISS development processes. Company is following these practices in one way or another but there is not as such set procedures and it entirely depends on the individual's efforts. There are weaknesses in the organization's actual processes. The result of the Gap analysis is as follows:

CRISS, Cyber Rapid Integrated Software Solutions (Pvt.) Limited	**Shazia Ashraf**

	GAP Analysis
	Requirement Analysis a. Criteria for Acceptance of requirements are established while it is difficult for the organization to distinguish requirement provider. Most of the time company prefers to get requirement analysis done by the customer's IT department. b. Communication Gap with customers to establish requirements in all projects c. Projects plan is reviewed for consistency with requirements in all projects while for some of the projects work products are not being reviewed for consistency .There is not any set criteria in the organization. d. Change Management procedure is not at all defined for the projects e. Bi-directional traceability among requirements and plans and work products is not maintained f. The reviews of plan and work products are not documented g. Policies are not defined at organization level to perform projects engineering, management and support processes h. Most of process activities are not planned e.g. CM, MA, and PP etc. i. Adequate resources are not provided to perform process related activities e.g. Traceability Matrix, Bug tracking tools, change management etc. j. Not all responsibilities are assigned for all activities performed k. Adequate training is not provided to perform process related activities l. Designated work products are not maintained properly. m. Not all relevant stakeholders are identified and involved in most of the processes n. Not all processes are being monitored and controlled in all projects o. As processes are not adequately defined it is not possible to objectively evaluate adherence to standard processes p. Not all process activities are reviewed with Sr. management

	q. All processes are required to be defined as per CMMI requirements r. No process related measurements are identified and collected s. Estimates of attributes related to work products are not documented e.g. size and complexity etc.
	Project Planning
	a. Top level WBS is establish for all projects but it is not detailed b. Milestones, Assumptions, constraints, critical dependencies and critical paths are not documented for most of the projects c. Schedule are documented for all projects but it has not been followed seriously d. Risks are not identified for most of the projects e. Data management is not plan adequately f. Staffing requirements are determined for all projects but sometimes useful resource is so much occupied g. Process requirements, critical facilities, equipments and components requirements are not documented h. Inventory of skills is not maintained i. Review of Project Plan is not documented j. Not all relevant stakeholders are identified and consulted for obtaining commitments k. Project activities are not defined properly
3.	**Process and Product Quality Assurance**
	a. Criteria to objectively evaluating Processes are not establish b. Criteria to objectively evaluating work products are not establish c. Work Product evaluation is not documented. d. Criteria to objectively evaluating work products are not establish e. Adequate records against Process and product quality assurance are not maintained

4	**Configuration Management**
	a. Change requests are not being tracked in most of the projects b. Configuration items are not identified for all projects c. Adequate configuration management system is not in-place d. Baselines are not established for all projects e. Change request management process is not established f. Not all configuration items are controlled g. Configuration management records are not establish h. Configuration audits are not performed
5	**Project Monitoring and Control**
	a. Commitments identified in the plan are not monitored b. Plan and actual performance is not monitored in most of the project c. Stake holder's involvement are not being monitored against plan d. Significant deviation are not documented for all projects e. Project Risks are not monitored in all projects f. Data management is not monitored adequately g. Not all project reviews are documented h. Milestone reviews are not performed i. Not all issues are being analyzed e.g. issue related to effort and cost j. Corrective actions are not formally negotiated and documented k. Corrective actions are not managed to monitor the results
6	**Measurement Analysis**
	a. Measurement objectives are not maintained according to needs and objectives. b. Information needs and objectives are not document. c. Information needs and objectives are not prioritize d. Measurement objectives are not Documented , reviewed, and updated e. No feedback is provided for refining and clarifying information needs and objectives.

	f. Traceability has not been maintained of the measurement objectives to the identified information needs and objectives g. Candidate measures are not documented according to measurement objectives. h. Operationally measures have not been defined properly. i. There is not at all any method as how measurement data will be obtained and stored. j. Difficult to identify which data are needed k. It is not specified as how to collect and store the data for each required measure.

Table 4: Weakness in the CRISS's actual processes

The summary of the gap analysis is explained in Figure. 8. After the gap analysis it is analyze that CRISS is at initial level. It is evident from the figure 8 that company's processes are not compliant to the CMMI standards and most of these practices are not followed in the organization. Almost 40% of the requirement management practices are not followed in the organization development processes. Similarly 95% of measurement analysis practices are not followed or implemented in the organization. The results of the gap analysis clearly shows that CRISS is at maturity level 1, processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment. Success of the project entirely depends on the competence and heroics of a few highly paid individuals and not on the use of proven processes. In spite of this ad hoc, chaotic environment, CRISS often produces products and services that work. However, half of these projects exceed the budget and schedule. Company reported that 50% of the projects are completed in time and budget, while remaining projects exceed time and budget.

According to PSEB repeated studies have confirmed that less than 25% of software development projects ever meet their objectives. Apparently it looks that CRISS's development process is much better as compared to other companies, but results of the gap analysis is different and shows that company does not follow the processes. The reason for these successful projects is that the success of projects is largely dependent on

few highly paid individuals. This is not a problem for the company in the current scenario but as the size of the company of the company grows it will be difficult for the organization to sustain and produce successful projects.

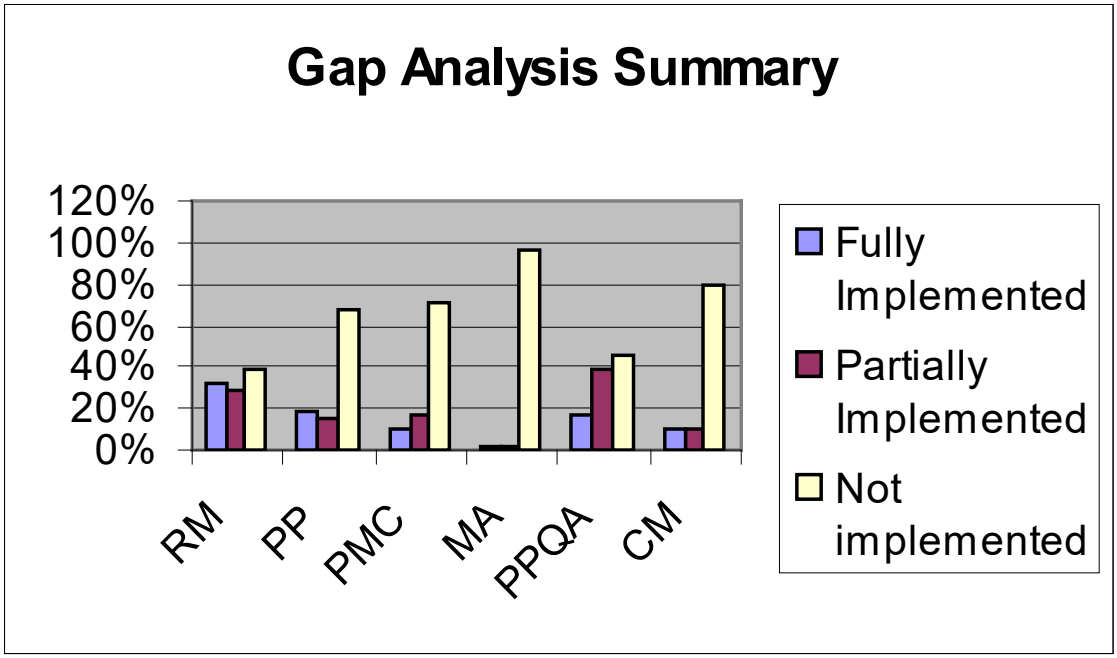

Figure 8: Gap analysis summary

4.13 Organizing for Process Improvement:

Process improvement is a long-term effort. The working relationships between the process group and the rest of the organization must be ongoing, and management oversight and direction must continue over the long term.

Software Engineering Process Group (SEPG):

SPEG is top management group the main function of this group is to reviews the results of assessments, charter working groups to prepare plans, approves those plans in priority order, monitors the progress of the working groups the team leader of SEPG for CRISS is Manager D&T and another person would be hired for assisting in implementation of CMMI. The reason for selecting Manager D& T is that he is an experienced IT professional, and respected amongst the company and will be fully devoted to the task of CMMI. The main characteristic of the SEPG Team-Lead is a person who should be someone who has been working in the company for a few years who should have a solid

academic background and should have earned respect from the company's employees. The SEPG in CRISS will have top management as part-time members, includes CEO, COO, Manager D& T, Manager Projects, An individual from SQA/QA will also be included in SEPG, either as a full time or part-time member.

Engineering Process Group (EPG):

This group coordinates process improvement activities across the enterprise and exists for the duration of the process improvement activity. Members of the group can serve as process improvement mentors. As there is no process improvement group in CRISS so it is new wave in the organization so the members should consider taking the Defining Software Processes or Mastering Process Improvement courses.

EPG is a middle management group the main function of this group to develop the implementation plan and help the organization to implement CMMI in the organization

This is the groups who is responsible for the development of process guides and artifacts of each process area and get it approved from the top management.

Process Action Group (PAG):

This group is of software engineer and technical writer and work on full time or part-time basis depending upon the availability. This group is chartered to work on a wide range of issues reviewing the process guides and helps the EPG implementing the specific process area in the department The members of process action group, engineers from a number of project types and application domains, benefit for the same reason their managers benefit from having a steering committee, that is, cross-fertilization. This group will assist EPG for implementing the process area in their specific departments

4.14 Schedules for CMMI Implementation at CRISS:

The time frame of this project is 6 months. To address this road map has been developed and the whole project is divided into five cycles, on the basis of process definition, procedure, templates, standards, and process implementation indicator. Detailed implementation road map is attached in Annexture-1. For CRISS this has been divided into five different cycles:

- **Cycle 1:** Cycle 1 is to create an initial baseline for the company. This will identify perceived gaps and gain an understanding of the company's products, organizational structure and the corporate culture.
- **Cycle 2:** Cycle 2 will identify the common process areas for which specific training will be required. A schedule will be established and agreed by all the stakeholders.
- **Cycle 3:** Cycle 3 is to formally asses the progress and establishes a new baseline. PSEB will provide the on-site and off-site support prior to this checkpoint.
- **Cycle 4:** Cycle 4 is to perform a class B appraisal for one project. Based upon the updated baseline. A revised schedule will be established to reflect the time and resources to close any gaps identified.
- **Cycle 5**: Cycle 5 is the formal review off all the issues raised during the start of the CMMI project and to ensure their closure and PSEB will determine the readiness for pre appraisal. PSEB will provide the pre appraisal training and provide both on-site and off-site support.

CRISS will start the project in June, 2007 when PSEB announce for the selection of companies for CMMI implementation Phase 3 .It is expected to finish this project in 6 months and formal assessment will be done in November 2007. Time frame of CMMI level 2 project is defined in Table 5:

Task Name	**Start Date**	**Finish Date**
CMMI Level 2 Project	June 1st, 2007	November 23, 2007
Planning & Software Process Improvement Team Development	June 1st, 2007	June 8th ,2007
Detailed Planning	June 11 ,2007	June 15, 2007
CMMI Process planning Complete-Milestone-1	**June 15, 2007**	**June 15, 2007**
CMMI Process Training & Understanding	June 18, 2007	June 18, 2007
Detailed Training on PA's	June 19, 2007	June 22 ,2007
Requirement Management Training	June 19, 2007	June 19, 2007
Project Planning Training	June 19, 2007	June 20, 2007
PPQA Training	June 20, 2007	June 20 ,2007
PMC Training	June 21, 2007	June 21, 2007

MA Training	June 21, 2007	June 21, 2007
CM Training	June 22, 2007	June 22, 2007
CMMI Process Training Complete-Milestone-2	**June 22, 2007**	**June 22, 2007**
Process Definition	June 25, 2007	June 25, 2007
PA _Requirement Management	June 25, 2007	July 6, 2007
PA_Project Planning	July 9, 2007	July 20, 2007
PA_Process and Product Quality Assurance	July 23, 2007	August 3, 2007
PA_Configuration Management	August 6, 2007	August 17, 2007
PA_Measurement Analysis	August 20, 2007	August 31, 2007
PA_PMC	September 3 ,2007	September 14, 2007
CMMI Process definition Complete-Milestone-3	**September 14, 2007**	**September 14, 2007**
Organization Process Training	September 17, 2007	September 17, 2007
Training Kick-off	September 18, 2007	September 21, 2007
CMMI Process Training Complete-Milestone-4	**September 21, 2007**	**September 21, 2007**
Implementation Planning	September 24, 2007	September 25, 2007
Implementation Kick-Off	September 26, 2007	October 26, 2007
Pre-Appraisal & Incorporation of findings	October 29, 2007	November 2, 2007
SCAMPI Appraisal –Milestone-5	**November 5, 2007**	**November 23, 2007**

Table 5: Time schedule of CMMI implementation

4.15 CMMI Implementation Cost:

The major contributory factors in CMMI implementation cost are as follows:

- External assessment team (both fees & costs)
- Internal assessment participants
- Training expenses

The major portion of this cost comprises of external assessment which is done by SEI registered consultant, and training cost of different teams.

Cost Element	Current State
SEPG	2 – 10% of software staff
External Assessment Team	$40,000 – 100,000 per event
Assessment Participants	400 hours per event
Training	4 – 8 hours per KPA per person

Figure 8: CMMI implementation cost estimate for Non- registered companies

(http://www.dtic.mil/ndia/2002cmmi/walden2a3.pdf)

In Pakistan there are two scenarios companies can either go for assessment independently or through PSEB. The cost indicated in Figure. 8 above represent a situation in which a company opts for assessment without PSEB support. The major cost in this process is of external assessment team which varies between $40,000 - $100,000. While in case of PSEB registered companies this amount is reduce to $14,000 which includes consultancy charges, audit charges and initial training charges. The Company that wishes to be assessed for any of the CMMI maturity level has to pay only 20% of the total cost to PSEB. The rest of the 80% will be paid by PSEB to the consultant on five cycle of completion of project activities.

There are other costs that company has to bear. This includes operational expenses and training expenses. Operational expenses also include the salary of the EPG team. Training expenses are approximately $2000 or Rs 120,000. In short the cost is summarized as follows:

Cost to CRISS for external assessment = $ 2800

Operational Expenses = $5000

Training Expenses = $ 2000

Total CMMI Implementation cost for CRISS=$ 9,800

There are also indirect costs to the company due to non implementation of CMMI which include the following:

- Loss of Market share
- Lost opportunity
- Loss of repeat customer business
- Penalties

The software companies which have implemented CMMI such as Motorola, Boeing, and TATA etc have reported a return on investment (ROI) of 6:1. CMMI implementation seeks to improve processes rather than products. The processes involve technologies and human resources with varied expertise backgrounds, ethnicities, values and commitments. The improvement in the processes requires discipline and happens over a long period of time with repetitive activities. On the other hand the managers like to see immediate return on investment. They also like to see tangible improvements in products or profitability. There is no doubt that processes improvement will result in quality of products and more profitability but some time its direct relationship is not visible in short time. For example, in CRISS, keeping the present portfolio of projects constant, the yearly cost of delay exceeds Rs 2 million a year. The total cost of implementation of CMMI may not exceed Rs 0.58 million which is only 27% of the cost of delay.

4.16 Training Plan:

Training is one of the most important elements of business process improvement initiative. As organization undertake process improvement program, new skills and concepts are required. Therefore, the content and methodology is critical for the training course to be effective in changing behaviors and outcomes. With significant investment of time and money, it is very important that the design and delivery of the training class is done right.

If organizations want to survive and prosper in the modern world of rapid change, they need to be more flexible, faster-moving and faster-learning than before. Their ability to do this rests upon the abilities of their workforce to have these characteristics hence the value of training cant be denied. If individuals are able to learn, develop and change, then so can the organizations. Providing training for employees not only helps them develop

their skills and knowledge, but it is also motivational and a building block to organizational success it is important for any organization, large or small, to plan the training that its people may need. While there can be enormous benefits in developing the capabilities of the workforce, training don't come cheaply. Training needs to be for the right people, it needs to be the right type of training and it needs to be at the right time. Training needs aligned to the business goal/process vision and designed to be customized to meet specific needs. Training is an investment in time, money, company strategy and the employees's skill level. If the training is done well, it will have a significant impact on the organization and the return on the investment will be incalculable.For CMMI implementation CRISS needs to conduct the following trainings:

- Secure Sponsorship and Funding
- Introduction Training
- Process Guide Training
- Implementation Training

Secure Sponsorship and Funding:

First primary objective of this training session is to educate senior management about CMMI by presenting the CMMI overview or CMMI overview for executive's presentations. Objective of this training is "Secure Sponsorship and Funding". In this training session trainers are:

- Consultant.
- CMMI Project Manager.

This is one day training and the purpose of this training is to ensure that process improvement program has a senior management sponsor and funding. Such sponsorship and funding is critical to ensuring the program's success. Training participants are:

- Chief Executive Officer.
- Chief Operating Officer.
- Chief Financial Officer.
- GM Marketing
- Manager D&T
- Manager Projects

- Project Manager SAP
- QA Manager
- Creative Manager

This training session will include a presentation provides a brief overview of CMMI to top management. This session includes

- Introduction to CMMI
- Concluding Sessions & Feedback

Introduction Training:

This is one-week training which introduces systems and software engineering managers and practitioners, appraisal team members, and engineering process group (e.g., SEPG, EPG ,PAG) members to software process improvement benefits, approaches and implementation challenges. The program would also give an insight into models and highlight how CRISS can effectively implement these to achieve maximum business benefits. Objectives of this training session are:

- Present and facilitate the Introduction to CMMI courses using common guidelines for interpreting CMMI models.
- Demonstrate an in-depth understanding of model content

Trainers of this session are consultant and Project Manager CMMI. Participants of this training session are:

- Senior management of CRISS
- Manager D&T
- Project Manager (SAP), Manager Projects
- QA Manager
- Creative Manager
- Project Coordinator CMMI
- Technical Writer CMMI

Modules of this training session are

- Introduction to CMMI
- Using CMMI for Process Improvement
- An approach and Overview

- Model-based process improvement
- Overview of CMMI model
- Maturity levels and Process areas of the models
- Insight into selective process areas of the model

After attending this training, participants will be able to understand how models can be applied to CRISS's process improvement program and demonstrate the practical applicability of models.

Process Guide Training:

This is one of the important training sessions in this training session all of the key process areas are being discussed. Identify the specific goals and the specific practices. Trainers of these training sessions are Consultant and Manager EPG and the training participants are:

- Software engineering process group
- Engineering process group.
- Process action group

The purpose of this training session is to introduce the participants about the process guide procedures. This training also includes the discussion of all of the level 2 key process areas and development of implementation plan of these process areas in the organization. Modules of this training session are:

CMMI key Process Area concepts

- Requirements Management.
- Project Planning.
- Project Monitoring and Control.
- Measurement and Analysis.
- Process and Product Quality Assurance.
- Configuration Management.

Implementation Training:

This is one of the crucial training sessions, and the purpose of this training session is "Defining organizational implementation scope and implementation objective,

strategies". Trainers of this session are EPG Manager and consultant and the training participants are:

- Engineering Process Group.
- Process Action Group.

Modules of this training are identification of CMMI key process area implementation strategies and implementation of process guides in different departments.

Scampi pre Appraisal Training:

Objective of these training sessions is "Practice the skills and abilities critical to success of a SCAMPI appraisal and to build proficiency with the methods used for SCAMPI appraisal ". Consultant is the trainer and the training participants are:

- Engineering process group.
- Process action group.
- Software engineering process group.

4.17 Advantages of Implementing CMMI Level 2:

As the software process becomes repeatable (CMM Level 2) and in general independent of individuals engaged in heroic efforts, the necessary personnel resources can be assigned and the completion dates forecast with known reasonable accuracy. With this software process in place, successful software projects are not dependent on individuals, and software developers can be more easily exchanged with minimal project impact. CMMI implementation in the organization, matures the software development process, new drivers of business value emerge, and consequently a more efficient, productive and responsive organization arises, and this will definitely increases the revenues. Other benefits of CMMI implementation in an organization is as follows:

- Improved management visibility into technical status and progress
- Higher customer satisfaction due to project control and communication
- Increased ability to manage and control schedule and cost
- Successful avoidance or reduction of risks through risk identification and risk management

- Improved management insight into process and policy compliance through quality assurance activities
- Improve delivery of promised performance, cost, and schedule.
- Collaborate with external stakeholders and manage their expectations.
- Provide competitive world-class products and services.
- Implement an integrated, enterprise business and engineering perspective.
- Master system-of-systems evolutionary development complexity.
- Use common, integrated, and improving processes for systems and software.
- Implement proactive program management techniques.
- Develop project leaders who look ahead and not over their shoulder.
- Develop a staff that uses best practices to cope with changing development, technology, and customer environments.
- Enable staff members to move between projects and still use the same processes.
- Create and improve processes that adapt to a changing business environment.
- Eliminating inconsistencies.
- Reducing duplication.
- Increasing clarity and understanding.
- Providing common terminology.
- Providing consistent style.
- Establishing uniform construction rules.
- Maintaining common components.
- Assuring consistency with ISO/IEC 15504.
- Being sensitive to the implications for legacy efforts.

REFRENCES

1. Watts Humphrey, Introduction to the Personal Software Process Addison-Wesley 1997.
2. Naween A. Mangi, BPO Sector fights for Global Market Share Dawn, 2005
3. D.R. Goldenson, J. Jarzombek, and T. Rout,"Measurement and Analysis in Capability Maturity Model Integration Models and Software Process Improvement," Crosstalk: The Journal of Defense Software Engineering, July 2003
4. M.C. Paulk, B. Curtis, Bill, M.B. Chrissis, and C. Weber, Capability Maturity Model for Software, Version 1.1, Software Engineering Institute, CMU/SEI-93-TR-24, February 1993.
5. Sanjay K. Pillai The quality matter IT firms gloss over Chennai Business Standard ICE World -April 21, 2004
6. Priscilla Fowler Stan Rifkin "Software Engineering Process Group Guide" September 1990
7. W. Decker, J. Haskell, F. Mcgarry Experiences with CMM and ISO 9001 benchmarks. Whitepaper by Computer Sciences Corporation (CSC)
8. Kashif Manzoor "The Challenge of Implementing Capability Maturity Model (CMM)"
9. www.sei.cmu.edu/cmmi/
10. www.sei.cmu.edu/pub/documents/ 02.reports/pdf/02tr011.pdf
11. www.sei.cmu.edu/cmm/cmms/cmms.integration.html
12. www.sei.cmu.edu/publications/ documents/02.reports/02tr007.html
13. www.sei.cmu.edu/sema/profile.html
14. http://www-128.ibm.com/developerworks/rational/library/4166.html
15. http://www.dtic.mil/ndia/2002cmmi/mchale2a3.pdf
16. http://www.dtic.mil/ndia/2003CMMI/2003CMMI.html
17. http://www.dtic.mil/ndia/2003CMMI/Marks.ppt
18. swassurance.gsfc.nasa.gov/disciplines/quality/checklists/pdf/requirements_management.pdf

19. sw-assurance.gsfc.nasa.gov/disciplines/
quality/checklists/pdf/configuration_management.pdf
20. sw-assurance.gsfc.nasa.gov/disciplines/
quality/checklists/pdf/measurement_analysis.pdf
21. sw-assurance.gsfc.nasa.gov/disciplines/
quality/checklists/pdf/project_planning.pdf
22. sw-assurance.gsfc.nasa.gov/disciplines/
quality/checklists/pdf/monitoring_control.pdf
23. sw-assurance.gsfc.nasa.gov/disciplines/
quality/checklists/pdf/software_quality_assurance_plan.pdf
24. www.dtic.mil/ndia/2003CMMI/ferg.ppt
25. www.dtic.mil/ndia/2003CMMI/wolf.ppt
26. www.dtic.mil/ndia/2003CMMI/william.ppt
27. www.dtic.mil/ndia/2003CMMI/weinberg.ppt
28. www.dtic.mil/ndia/2003CMMI/walden.ppt
29. www.dtic.mil/ndia/2003CMMI/voight.ppt
30. www.dtic.mil/ndia/2003CMMI/ terry.ppt
31. www.dtic.mil/ndia/2003CMMI/sweeney.ppt
32. www.dtic.mil/ndia/2003CMMI/struble.ppt
33. www.dtic.mil/ndia/2003CMMI/schaff.ppt
34. www.dtic.mil/ndia/2003CMMI/over.ppt
35. www.dtic.mil/ndia/2003CMMI/olson2.ppt
36. www.dtic.mil/ndia/2003CMMI/marks.ppt
37. www.dtic.mil/ndia/2003CMMI/kovar.ppt
38. www.dtic.mil/ndia/2003CMMI/kit.ppt
39. www.dtic.mil/ndia/2003CMMI/judy.ppt
40. www.dtic.mil/ndia/2003CMMI/irion.ppt
41. www.dtic.mil/ndia/2003CMMI/holt.ppt
42. www.dtic.mil/ndia/2003CMMI/hern.ppt
43. www.dtic.mil/ndia/2003CMMI/hefner.ppt
44. www.dtic.mil/ndia/2003CMMI/hef2.ppt

45. www.dtic.mil/ndia/2003CMMI/gum.ppt
46. www.dtic.mil/ndia/2003CMMI/groarke2.ppt
47. www.dtic.mil/ndia/2003CMMI/bern.ppt
48. www.dtic.mil/ndia/2003CMMI/byr.ppt
49. www.dtic.mil/ndia/2003CMMI/chris.ppt
50. www.dtic.mil/ndia/2003CMMI/croll.ppt
51. www.dtic.mil/ndia/2003CMMI/dutt.ppt
52. www.dtic.mil/ndia/2003CMMI/evers.ppt
53. www.dtic.mil/ndia/2003CMMI/ferg.ppt
54. www.dtic.mil/ndia/2003CMMI/freed.ppt
55. www.dtic.mil/ndia/2003CMMI/groarke.ppt
56. www.sei.cmu.edu/ttp/publications/are-you-ready.pdf
57. www.sei.cmu.edu/cmmi/adoption/pdf/byrnes.pdf
58. www.pseb.org.pk/admin/images/ Fiscal%20Year%202004-2005.pdf
59. www.hkcs.org.hk/hkspin_cmm_gap_analysis.pdf
60. http://www.dtic.mil/ndia/2002cmmi/walden2a3.pdf
61. http://homepages.com.pk/kashman/cmm.pdf
62. www.awprofessional.com/content/ images/0321154967/samplechapter/chrissisch01.pdf -
63. www.sei.cmu.edu/cmmi/models/
64. http://www.awprofessional.com/articles/article.asp?p=169102&rl=1
65. http://qualityconsulting.wipro.com/knowledge.php
66. http://www.bizmanualz.com/biznewz/ezine18/index.html
67. http://www.bizmanualz.com/articles/11-14-05_Most_value_out_of_training_course.html
68. www.pakistan.gov.pk/.../planninganddevelopment-division/ MTDF/32 Quality%20Matters/32-Quality%20Matters.pdf
69. en.wikipedia.org/wiki/Business_process
70. www.iei.ie/uploads/files/sectors/ %7B66C19450-A292-41FB-88E6 AB1555BBAC01%7D_India_Emerging_Superpower.pdf
71. en.wikipedia.org/wiki/Software_development_process

72. en.wikipedia.org/wiki/CMMI
73. www.pseb.org.pk
74. www.criss.com.pk