Impact of CMMI Based Process Improvement on high maturity software houses in Pakistan

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Of

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By

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FINAL APPROVAL

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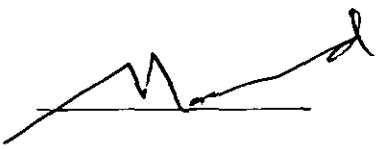

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Abstract

Software products are often behind schedule, over budget, non-conforming to requirements and of poor quality. Controlling and improving the processes used to develop software has been proposed as a primary remedy to these problems. The Software Engineering Institute at Carnegie Mellon University has published the Capability Maturity Integration Model (CMMI) for use as a set of criteria to evaluate an organization's Process Maturity. Organizations can use this model as a roadmap to improve software development process's maturity.

Software houses around the world and in Pakistan have used CMMI for internal software process improvement. SEI has published report of CMMI based Process improvement results for various companies. This report shows that companies have tremendously improved in Cost, Schedule, quality and other performance categories using CMMI based process improvement.

This research examines the impacts of CMMI based process improvement on High maturity software houses in Pakistan. This research provides the performance results and analysis of result's variation for Cost, Schedule, Quality and other performance categories.

Currently there are two companies in Pakistan at Higher maturity Level. Performance results from these two companies show that process improvement ratio for most of the performance categories were competitive to SEI results. However in comparison Company A improvement ratio was higher than Company B for most of the performance categories. Company A average improvement for all performance categories was 27% as compared to Company B's 22%. Major reasons for variation were the dedicated quality engineering team, frequency of audits; use of control charts for process stability in Company A. Process compliance percentage was higher in both companies near and right after CMMI appraisals.

Although Performance improvement ratio was lower in Company B than Company A, however closing performance baselines for most of the performance categories were higher in Company B, the major reason for this was Company B started high maturity level implementation with higher performance baseline values than Company A.

Acknowledgment

I would like to thank **Dr.Naveed Ikram** for his continued support and guidance for the completion of this work. He was always available to help and resolve the research issues. His leadership skills helped me to complete the work which was pending since long.

I express my gratitude to the colleagues in both companies whose unprecedented support helped me understanding the complex metrics and generating comparable results. I am especially very thankful to Mumtaz Awan principal Quality Engineer for his personal effort for the completion of my thesis work.

I am very thankful to my research group members, Abdul Basit, Murtaza, Kamran, although they are working on separate topics but their moral support was commendable.

Last but not the least my family whose continued moral and financial support helped me completing this long journey.

Declaration

I hereby declare and affirm that this thesis neither as a whole nor as part thereof has been copied out from any source. It is further declared that I have completed this thesis entirely on the basis of my personal effort, made under the sincere guidance of our supervisor. If any part of this report is proven to be copied out or found to be a reproduction of some other, we shall stand by the consequences. No portion of the work presented in this report has been submitted in support of an application for other degree or qualification of this or any other University or Institute of learning.

Muhammad Arshad Farooq
74-FAS/MSSE/F-05

Dedication

I would like to dedicate my work to

ALMIGHTY ALLAH,

Who has always showered His endless blessings upon me;
I also dedicate this work to my

FAMILY AND FRIENDS

Whose sincere prayers and love were a source of strength for me
and made this project successful.

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1 – Introduction

In the twenty first century every organization wants to deliver products and services better, faster and cheaper. In the high technology environment solutions are becoming more and more complex. To build these complex solutions organizations are working collaboratively to deliver the competitive solutions. Usually to develop big solutions companies develop some components in-house and some are acquired to integrate the final solution. Organizations must have mature processes to manage and control these complex development solutions. To achieve the business objectives and to better solve the problems these organizations have to adopt integrated approach.

Currently lot of process models and guidelines are available in the market to help the organizations to improve their processes. However most of them address partial areas in the organizations. These models and guidelines do not provide systematic approach to address the problems at enterprise level [1]. [2], [3].

Capability Maturity Model® Integration (CMMI®) is a process improvement model that provides organizations a systematic approach to improve their processes and solve business problems at enterprise level [16].

Software Engineering Institute (SEI) has found several dimensions that an organization can focus on to improve its business [26]. Figure 1 illustrates the three critical dimensions that organizations typically focus on: people, procedures and methods, and tools and equipment.

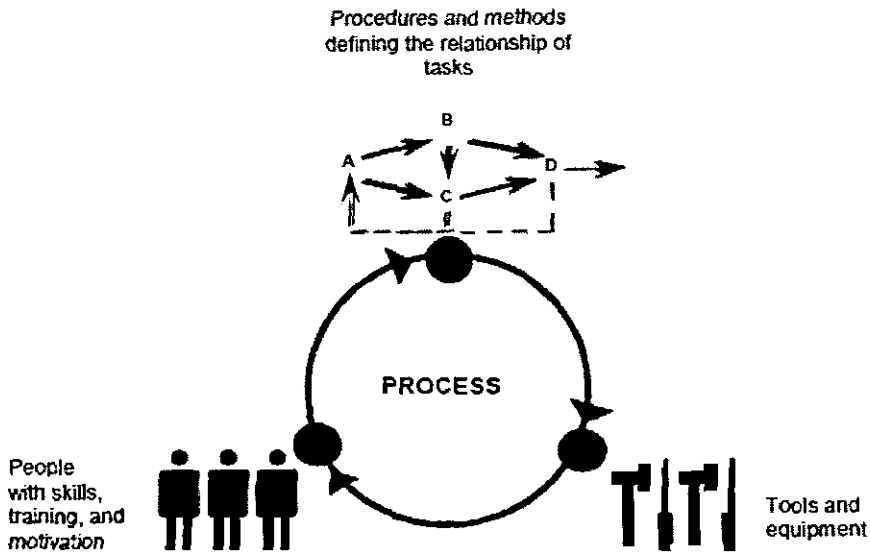

Figure 1: The three critical dimensions [26]

But this is the "process" which holds everything together. Processes allow organizations to address scalability and provide a way to incorporate knowledge of how to do things better. Processes help the organizations to leverage the resources and examine business trends.

By saying this, we can not ignore the importance of People, tools & technologies. However as we are living in the dynamic world, people have to pursue their careers and technology changes rapidly. A focus on process provides the infrastructure necessary to deal with an ever-changing world, and to maximize the productivity of people and the use of technology to be more competitive [26].

1.1 History of CMMI

Following picture published by Software Engineering Institute at Carnegie Mellon University shows the history of CMM/CMMI development.

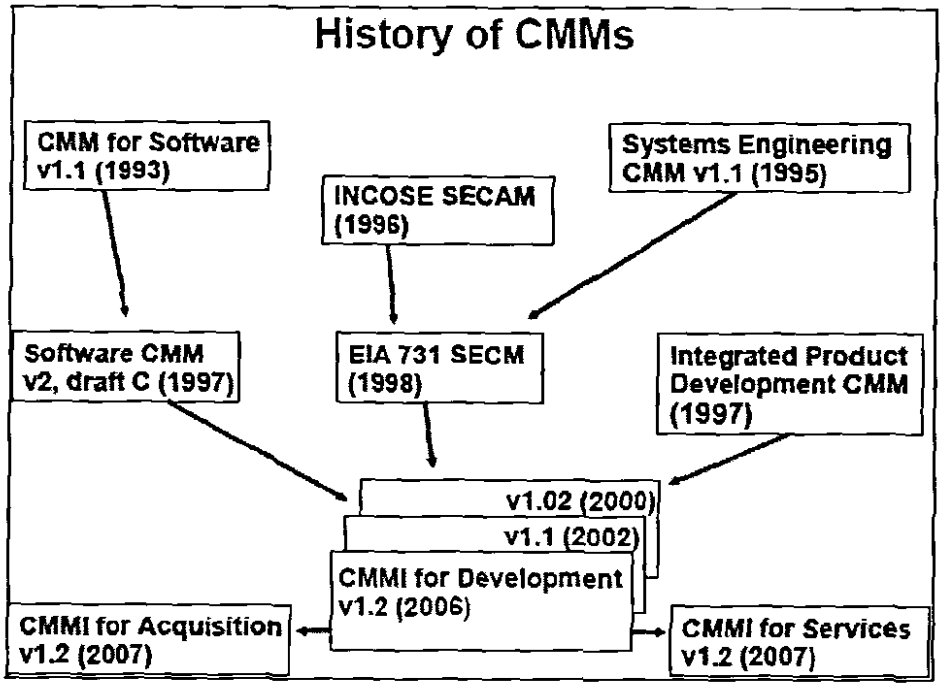

Figure 2: History of CMMs [26]

1.2 Structure of CMMI

Following section describes structure of CMMI and high level description of each maturity level.

1.2.1 Maturity Levels Description

CMMI consist of five maturity levels, each a layer in the foundation for ongoing process improvement, designated by the numbers 1 through 5:

Maturity Level 1: Initial

Processes are usually ad hoc and chaotic at maturity Level 1. The organization usually does not have a stable environment to support the processes. Success in these organizations depends on the competence and heroics of the people in the organization and not on the use of proven processes. [26]

Maturity Level 2: Managed

At maturity level 2, the projects of the organization have ensured that processes are planned and executed in accordance with policy; the projects employ skilled people who have adequate resources to produce controlled outputs; involve relevant stakeholders; are monitored, controlled, and reviewed; and are evaluated for adherence to their process descriptions. [26]

Maturity 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 maturity level 3, is established and improved over time. These standard processes are used to establish consistency across the organization. [26]

Maturity Level 4: Quantitatively Managed

At maturity level 4, the organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managing processes. Quantitative objectives are based on the needs of the customer, end users, organization,

and process implementers. Quality and process performance is understood in statistical terms and is managed throughout the life of the processes [SEI 2001], [26].

Maturity Level 5: Optimizing

At maturity level 5, an organization continually improves its processes based on a quantitative understanding of the common causes of variation inherent in processes. Maturity level 5 focuses on continually improving process performance through incremental and innovative process and 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. A critical distinction between maturity levels 4 and 5 is the type of process variation addressed. At maturity level 4, the organization is concerned with addressing special causes of process variation and providing statistical predictability of the results. Although processes may produce predictable results, the results may be insufficient to achieve the established objectives. [26]

1.2.2 Selection of implementation approach

CMMI offers two representations for process improvement. Each representation has advantage over the other; some organizations use both to address their particular needs.

1 - Continues Representation

This representation type provides maximum flexible way to select improvement path for the organization. Using this representation, organizations usually can address selected pain areas. The continuous representation also allows an organization to improve different processes at different rates i.e. at different capability levels. However there are also some limitations while selecting certain process area for improvement, because some process areas are dependent on each other.

2 - Staged Representation

This representation provides a systematic, structured way to approach model-based process improvement one stage at a time. Completion of each stage ensures that an adequate process infrastructure has been laid as a foundation for the next stage. The staged representation prescribes an order for implementing process areas 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.[26]

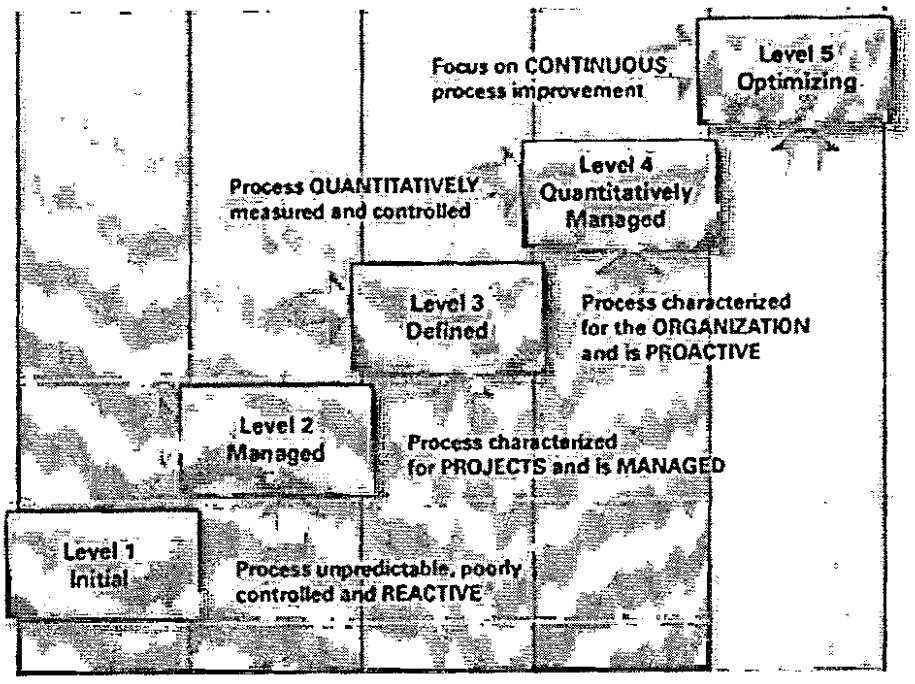

Figure 3: CMMI Staged representation [26]

There are 22 process areas in the CMMI process model. In staged approach, process areas are grouped according to the following table.

Maturity Level	Process Area name
Maturity Level 1	None
Maturity Level 2	CM - Configuration Management MA - Measurement and Analysis PMC - Project Monitoring and Control PP - Project Planning PPQA - Process and Product Quality Assurance REQM - Requirements Management SAM - Supplier Agreement Management
Maturity Level 3	DAR - Decision Analysis and Resolution IPM - Integrated Project Management +IPPD OPD - Organizational Process Definition +IPPD OPF - Organizational Process Focus OT - Organizational Training PI - Product Integration RD - Requirements Development RSKM - Risk Management TS - Technical Solution VAL - Validation VER – Verification

Maturity Level 4	QPM - Quantitative Project Management OPP - Organizational Process Performance
Maturity Level 5	CAR - Causal Analysis and Resolution OID - Organizational Innovation and Deployment

Table 1: Key process areas in CMMI [26]

1.3 CMMI worldwide adaptability

SEI publishes appraisal results twice every year. Figure 4.0 shows CMMI adoptability trend year wise [27].

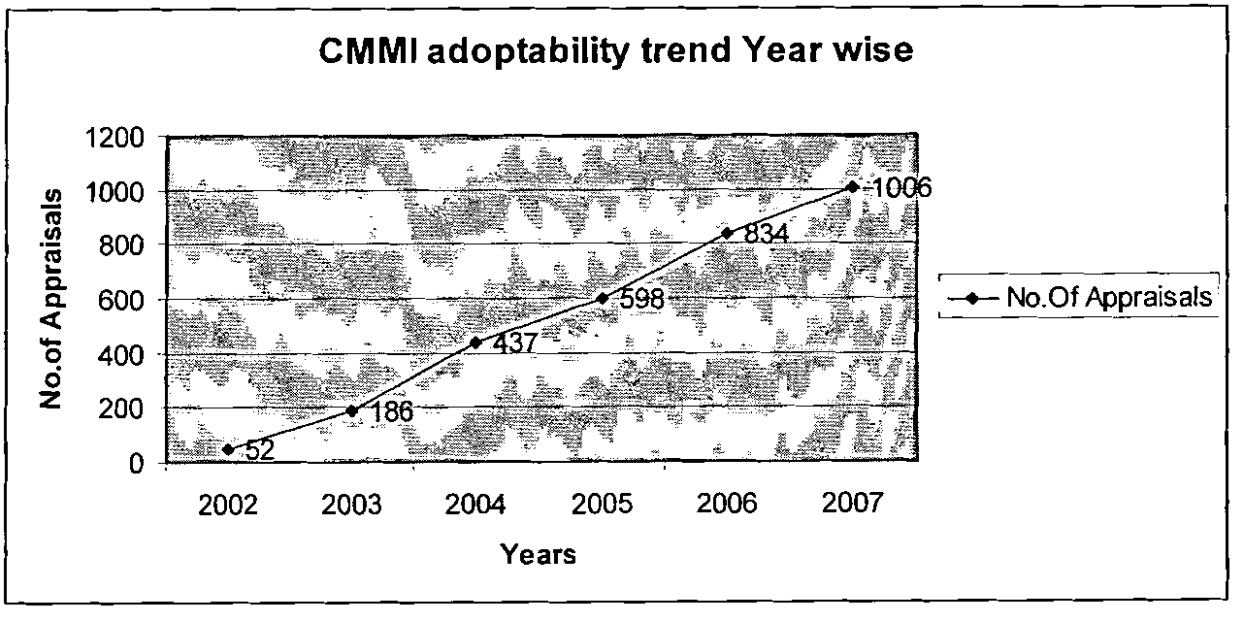

Table 2: CMMI adaptability trend year wise (values taken from SEI January 2008 report)

Following table shows the adoptability of CMMI continent wise [27].

Continent	No. Of appraisal conducted
Africa	38
Asia	1354
Europe	403
North America	1080
Oceania	30
South America	208

Table 3: Continent wise CMMI adaptability (SEI January 2008 report)

Following table shows the rate of maturity levels achieved world wide for all appraised companies [27],

CMMI Level	**No. Of organizations (%age of 2674 organizations)**
CMMI L1	1.5 %
CMMI L2	32.9 %
CMMI L3	41.9 %
CMMI L4	3.3 %
CMMI L5	12.3 %

Table 4: Maturity Level wise implementation (SEI January 2008 report)

As we can see in the table 4, only few companies went for higher maturity levels i.e. CMMI L4 and CMMI L5. It's due to the complexity of these maturity levels. A high maturity organization is expected to use metrics heavily for process and project management [28].

1.4 CMMI Initiative in Pakistan Software Industry

Pakistan software industry has also embraced the CMMI implementation. Pakistan software export board (PSEB) took initiative and launched a comprehensive program to cater the global needs of software quality.

This program aims to provide technical and financial assistance to:

- 110 IT companies in achieving ISO 9001:2000 certification
- 25 IT companies in achieving various levels of CMMI
- 10 IT companies achieving ISO 27001 certification

PSEB started CMMI program in May 2004. Till now 21 companies have achieved different levels of CMM/CMMI levels [15]. Following is the current CMMI Level of Pakistan software companies:

CMMI Level	No. of Organizations
CMMI L1	0
CMMI L2	16
CMMI L3	3
CMMI L4	0
CMM/CMMI L5	2

Table 5: Current Status of CMMI Level in Pakistan Software houses [15]

1.5 Research Question

The purpose of this research is to find out

1. How much high maturity software houses in Pakistan have improved in terms of Cost, Schedule and Quality with the implementation of CMMI based process improvement?
2. What are the reasons for variations in the results of performance categories (i.e. Cost, Schedule and quality) for High maturity software houses in Pakistan?

1.6 Expected Outcome

There will be following results from this research:

- CMMI based process improvement performance results from high maturity software companies.
- Analysis of variation in the results of performance categories.
- Compilation of feedback and recommendations to get more benefits from CMMI based process improvement.

2 – Literature Review

2.1 Literature analysis

Process improvement within software organizations is gaining momentum. More organizations today are initiating software process improvement efforts [3]. One indication of this trend is the number of assessments performed each year; this number has increased tremendously every year [6].

But for those organizations that have had active software process improvement efforts for several years, management is asking for quantitative evidence regarding the value returned for the investments made [1], [2], [3].

To fulfill this need, SEI took an initiative in 1993 and conducted a survey of 20 companies out of which 13 companies responded and an initial report was published [3]. Second report of SEI was published in 2003 and third in 2006 to demonstrate the impact of CMMI based process improvement [1], [2]. All these reports have shown excessive benefits from CMMI based process improvement.

The literature review has shown that Software Process Improvement (SPI) is the current popular approach to software quality and that many companies are taking formal and informal SPI programs [7],[14].

Many organizations have published technical and experience reports to demonstrate the value added by CMMI .These organizations have reported the gains in productivity, quality, time to delivery, and accuracy of Cost and Schedule estimates as well as product quality [8], [9], [10], [12], [31], [32], [33].

While organizations in their process improvement journey move from one maturity level to next, the range of benefits from its improvement activities increased substantially. Organizations at Level 2 were able to meeting schedule, and reduced turnover resulting from less overtime. Organizations at Level 3 reported meeting cost and functionality targets as well as Improved Quality, At level 4 organization reported predictable results, knowledge of factors causing variance and reuse and at L5 they were able to continuously target improvements required to meet business objectives [1],[2],[3],[38].

During Process Improvement Journey, Raytheon have increased productivity and a return ratio of 7.7 to 1 on its improvement expenditures. The company saved $4.48 Million savings in 1990 from $0.58 Million investment. In Four and half year effort in Process improvement programs, the company reduced $15.8 Million in rework cost [41].

At Boeing, when improvements were compared to baselines established at earlier levels the following results was declared [38]:

Criteria	Level 1->2	Level 2->3	Level 3->4
Reduced Defects	12%	40%	85%
Reduced Cycle Times	10%	38%	63%
Reduced Cost	8%	35%	75%
Schedule Variance	145%	24%	15%

Table 6 Boeing Improvement Results

As reported earlier, organizations at different maturity levels gain different benefits from process improvement programs using CMMI. High maturity organizations tend to have more ability to target specific problems, identify root causes and make improvements with predictable efforts. For example, Tata Consultancy Services Level 5 Company in India analyzed root causes for variation in the accuracy of their efforts predictions for work packages. TATA reported that organization saved $58 K in Defect prevention, reduced Rework effort and saved $59K in this category, using use case estimation and guidelines save $1.6K, using conversion Tools saved $314K [38],[40].

Similarly Northrop Grumman & Lockheed Martin reported that achieving high maturity level have helped the companies in prioritizing the projects and better management of resources. It helped in early detection of problems, improved planning and tracking and process verification [36], [39].

Some companies conducted Business case to validate business goals from financial perspective. One effort regarding this was conducted by GDAIS partnered with the SPC to produce the business Case for General Dynamics (Advance Information Systems).The business case output was reported in terms of financial return based on cost and benefits converted into series of annual cash flows containing Annual rate on investment, Net present

value and internal rate of interest. The business case proved successful as all the key questions were answered, showed positive results and was accepted by senior leadership. The business case showed substantial improvements in Sales and Marketing Share, Customer Satisfaction, productivity, Quality, Cycle Time and Learning and Growth [41].

While talking about improvements organizations have different perspectives. Studies have shown that government organizations tend to characterize investments in process improvement in terms of costs, whereas industry tend to characterize it in terms of effort expended on SPI activities. In some cases, cost measures such as calendar months have also been used [42].

However all above reported benefits have some cost associated with it. A number of companies have published the cost details of their process improvement efforts based on the CMM. A study conducted by the SEI determined the amount of time it takes organizations to increased their maturity levels on the CMM for the first three levels [4], [44].

In this study two groups of organizations were identified: those that moved from level 1 to level 2, and those that moved from level 2 to level 3. On average, it takes organizations 30 months to move from level 1 to level 2. Those organizations, however, varied quite dramatically in the amount of time it takes to move up one maturity level [44].Organization size can impact the number of months required to move from one maturity level to another.

In another study of US Companies, It was found that organizations at level 2 spend between 12 to 36 months at level 1 with an average of 21 months, and organizations at level 3 had spent 22-24 months at level 1 with an average of 23 months. Organizations at level 3 spent from 12 to 20 months at level 2 with an average of 17.5 months. This data was corroborated with the results of improvement efforts at AlliedSignal [45] where advancement from Level 1 to 2 and from Level 2 to Level 3 took 12-14 months across different sites.

However many problems related to people, ,communication ,change management, culture, goals and politics have also been reported by the focus groups of companies in the literature who took formal SPI programs [14].

This study will find out the performance results of CMMI based process improvement from High maturity software companies in Pakistan. Variation in the results will be analyzed and lessons learned will be documented.

2.2 Related Work

Since 1991, CMMs have been developed for a myriad of disciplines. Some of the most notable include models for systems engineering, software engineering, software acquisition, workforce management and development, and Integrated Product and Process Development [16].

Looking on the obvious benefits of process improvement, many organizations throughout the world have invested in CMMI-based process improvement [1] to reduce the cost, reduce the schedule slippage and improve the quality of the software products.

Although much has been written discussing the short-term and long-term benefits of increasing maturity levels [1], [2], [3] [5], [7], [13], [17].However, there has been widespread demand of factual information about the impact and benefits of process improvement based on CMMI models [1], [3]. Executives want to know what exactly they company will get after implementation of this model.

To provide a quantitative view of performance results to the executives, SEI collected data from various organizations in the world and published different performance reports.
SEI has published following performance results on the basis of data collected from various companies in the world.

Performance Category	Median Improvement
Cost	34%
Schedule	50%
Quality	48%
Productivity	61%
Customer Satisfaction	14%
Return on Investment	4.0 : 1

Table 7: CMMI based process improvement performance results

Pakistan Software Export Board (PSEB) realizes the benefits of Process improvement programs and took an initiative in May 2004 to launch CMMI implementation program for Software houses in Pakistan. In first step five companies were selected to bring up to CMMI L3 or above. In the second phase 30 companies were selected for CMMI L2 [15].

It has also been reported in the literature that their are cultural, people, politics and other issues associated while Software Process Improvement program is started in a company [14].

Some work has been done in Pakistan to explore the implementation status and adoption trend of CMM/CMMI in Pakistan [29], [30].However no study has been conducted in Pakistan to assess the benefits of CMMI based process improvement.

This study will examine the performance results of CMMI based process improvement from High maturity software houses. Variation in the results will be analyzed and lessons learned will be documented.

2.3 Research Limitations

The focus is this research is only High maturity software houses in Pakistan. There are only two High maturity software houses in Pakistan.

3 - Research Methodology

As this research is intended to analyze the impact of CMMI based process improvement. Case Study research is an ideal methodology when a holistic and in depth analysis is required for such situation. In my study I want to analyze the Case of Process Improvement Project for two CMMI L5 companies in Pakistan. I want to analyze in depth what was the impact on performance of these companies after successful implementation of this model.

3.1 What is Case Study?

Yin defined Case study as
"A case study is a story about something unique, special, or interesting—stories can be about individuals, organizations, processes, programs, neighborhoods, institutions, and even events".

The case study gives the story behind the result by capturing what happened to bring it about, and can be a good opportunity to highlight a project's success, or to bring attention to a particular challenge or difficulty in a project. [19]

3.2 Proposed methodology and Case study design

3.2.1 Overview

The research design basically provides the researcher the blue print for getting from beginning to the end of a study. The beginning is usually an initial set of questions, initial study and the end is results and conclusion.

Research design is the string of logic that ultimately links the data to be collected and the conclusions to be drawn to the initial questions of the study. Typically, research designs deal with at least four problems:

- What questions to study?
- What data are relevant?
- What data to collect?
- How to analyze that data?

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- What questions to study?
- What data are relevant?
- What data to collect?
- How to analyze that data?

In other words, a research design is basically a blueprint for getting from the beginning to the end of a study. The beginning is an initial set of questions to be answered, and the end is some set of conclusions about those questions.

Robert K. Yin does offer five basic components of a research design:

- A study's questions.
- A study's propositions (if any).
- A study's units of analysis.
- The logic linking of the data to the propositions.
- The criteria for interpreting the findings.

3.2.2 Case Study Design

"CMMI based process improvement in Pakistan "case study will be conducted in two CMMI L5 companies of Pakistan. Following is the graphical overview of Case Study design which will be followed during the Case study.

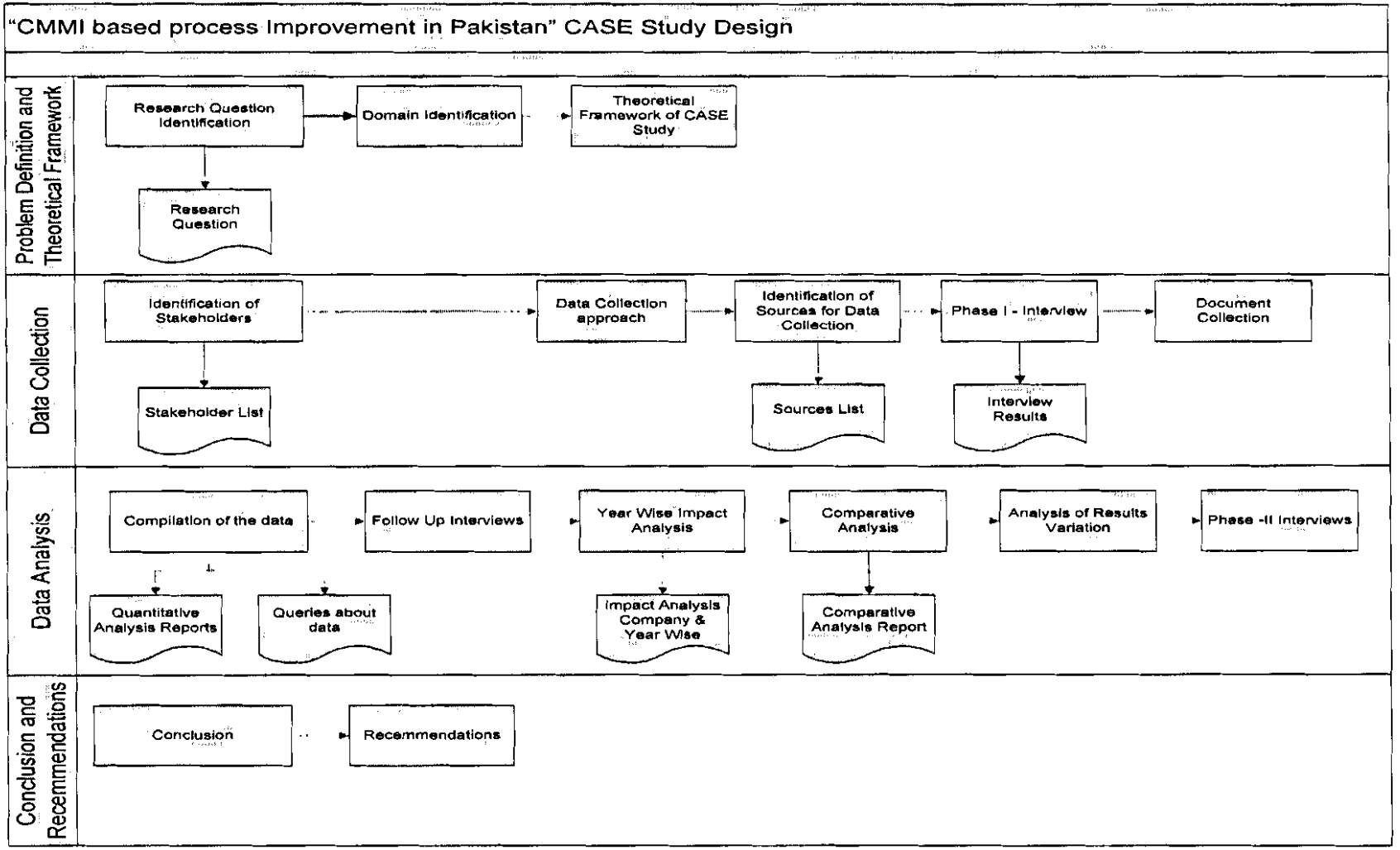


Figure 4: Case Study Design

3.2.3 Domain of the problem

This study will be conducted in the high maturity software houses of Pakistan. There are currently two high maturity software companies in Pakistan. Unit of analysis is organization in this research.

3.2.4 Interview and Data Collection approach

3.2.4.1 Identification of Stake holders

Stakeholders will be defined at two levels:

- For phase – I interviews stakeholders will be defined according to the criteria given at section 3.2.4.3.
- For phase – II interviews stakeholders will be defined on the basis of observations and analysis results obtained against the section 4.5.6.2 (Analysis of the data) activity.

3.2.4.2 Sources of Data Collection

Following six sources will be used for the collection of data

a. Documents ,
b. Archival records ,
c. Interviews ,
d. Direct observation ,
e. Participant observation , and
f. Physical artifacts

3.2.4.3 Phase I - Interview

The purpose of this interview is to get an understanding of

a. Engineering Process Group (EGP) structure
b. Process Definition , review and approval process
c. Process Improvement methods being used in the company

d. To get an overall understanding of quality culture of the company.
e. High level benefits, major issues faced during process improvement.
f. Identification of potential documents for review like Project Plans, quality reports, analysis reports, bug reports etc.

This interview will be limited to EPG or quality engineering (QE) department of the company. Questionnaire for interview is attached at appendix A.

3.2.5 Document Collection

Collection of documents identified during Phase I interview.

3.2.6 Data Analysis approach

3.2.6.1 Compilation of the Data

a. Identification of key metrics associated with Cost, Schedule, Quality and other performance categories.
b. Compilation of data for each identified metric to generate analysis reports. Following table format will be used for the compilation of data against each metric.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Company A performance Data from Mar 2004 to Dec 2006												
2	Sl No.	Metrics	UAL/LAL	Mar-04	Jun-04	Sep-04	Dec-04	Mar-05	Jun-05	Sep-05	Dec-05	Mar-06	Jun-06
3	1	SVP	±15%	12.12%	11.48%	-7.96%	9.96%	9.12%	8.15%	6.97%	5.58%	5.98%	5.10%
4	2	Effort Estimation Accuracy (EEA)	0.85 ≤ EEA ≤ 1.15	1.19	1.17	0.86	1.11	1.09	1.07	1.05	1.03	1.04	1.08
5	3	IRP	IRP = 100%	91.95%	95.10%	93.73%	97.15%	97.99%	98.13%	99.10%	99.15%	99.88%	99.25%
6	4	Employee Turnover (ETO)	ETO ≤ 8%	10.48%	11.18%	12.60%	8.15%	8.07%	6.07%	8.15%	7.11%	8.08%	5.08%
7	5	Service Efficency	SE >= 90%	80%	70%	75%	82.14%	86.71%	81.98%	83.98%	89.19%	90.26%	92.15%
8	6	OSSP Compliance Percentage	>=95%	85.65%	86.18%	90.19%	98.18%	80.18%	90.16%	87.00%	80.11%	87.00%	89.16%
9	7	Defect Removal Efficency (DRE)	Must be greater than 95%	80.18%	82.98%	81.12%	91.87%	94.75%	93.75%	94.83%	92.12%	94.94%	95.23%
10	8	Mean Time to Complete Job (MTC)	Must be less than 4	8.45	9.15	8.98	6.15	6.76	7.98	7.10	7.19	6.15	6.10
11	9	Cost of Quality (COQ)	16% ≤ COQ ≤ 22%	26.18%	23.19%	19.19%	18.98%	20.18%	21.34%	20.15%	20.36%	20.98%	17.19%
12	10	Cost of Poor Quality (COPQ)	2% ≤ COPQ ≤ 5%	8.19%	8.16%	6.98%	5.14%	5.98%	6.16%	5.98%	5.10%	5.16%	4.98%
13	11	Defect Density	< 8 defects/kloc	10.85	10.15	10.76	9.15	9.01	8.85	8.01	7.50	6.50	6.01
14	12	Productive Hours Percentage (PHP)	100%	63.82%	62.98%	65.71%	68.71%	70.17%	71.67%	73.65%	75.98%	79.15%	80.15%

Figure 5: Sample Data Compilation table for metrics

c. Follow up Interviews with the QE department to sort out any queries regarding documents, metrics, analysis methods used etc.

3.2.6.2 Analysis of the Data

a. Summary analysis for major performance Categories i.e. Cost, Schedule and Quality showing median improvement for all associated metrics over the Process improvement period.
b. There are multiple metrics associated with each major performance category as described in section 4.2.2.1 (Interpretation of metrics).

Following table and graph shows the sample SVP improved over time due to CMMI based process improvement in Company A.

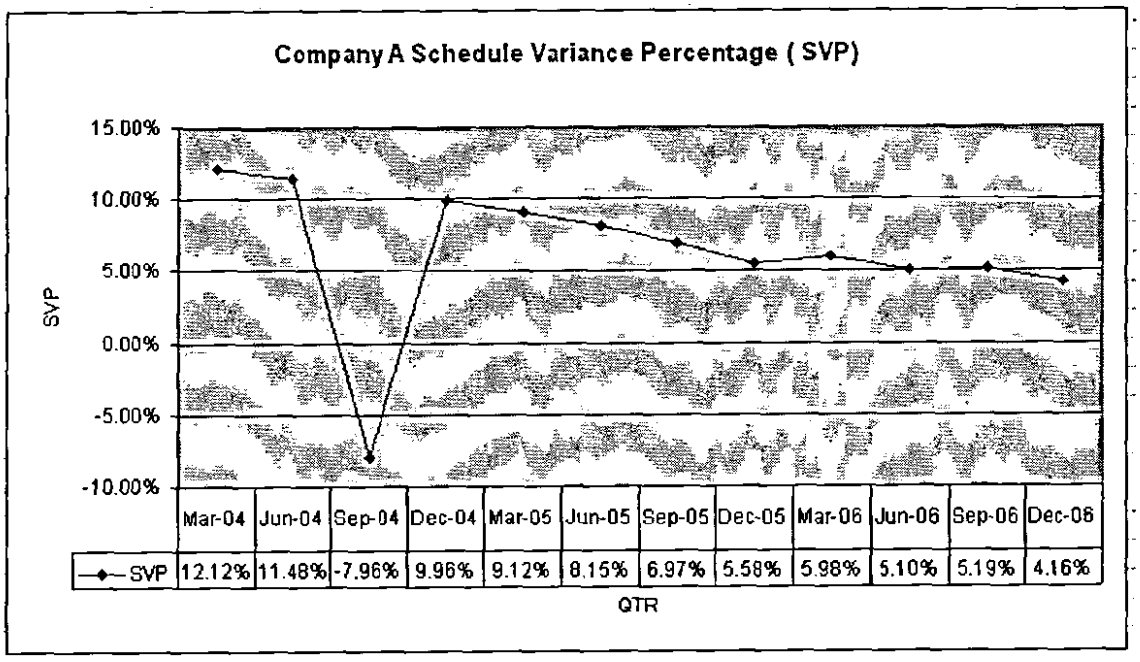


Figure 6: Sample SVP analysis of Company A

c. Comparative analysis of major performance categories for both companies.
d. Comparative analysis of major performance categories with SEI results.
e. Detailed Comparative analysis of each metric for both companies to review the volume of impact. Following table and graph show OSSP improvement Comparative analysis for Company 1 and Company 2.

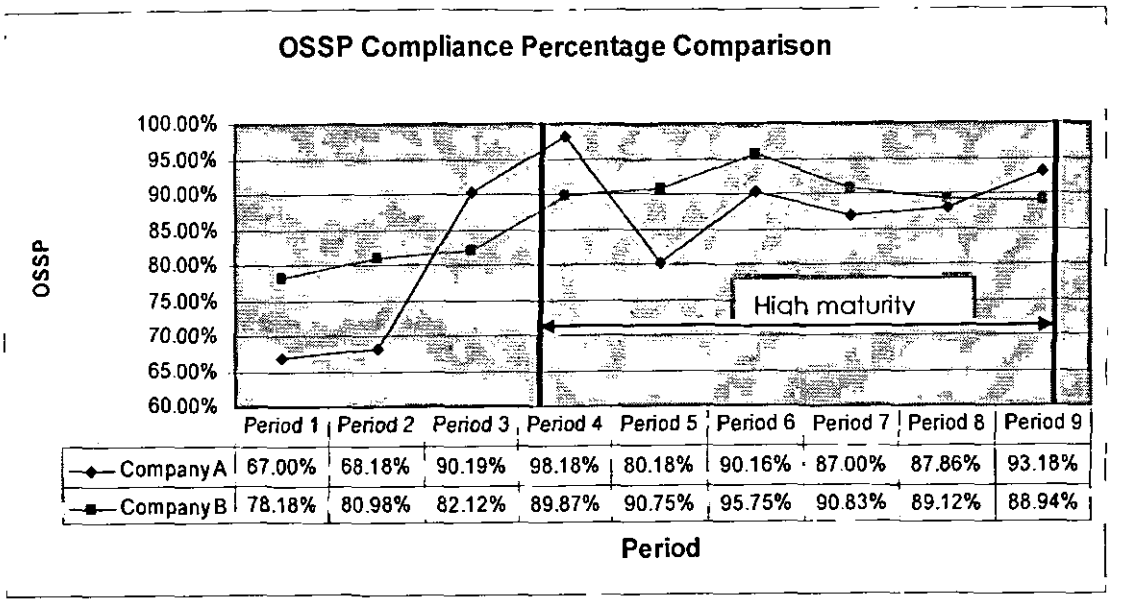


Figure 7: Comparative analysis of OSSP for company A And Company B (Sample)

f. Once Individual and comparative analysis are generated for cost, schedule, quality and all associated metrics for both companies. This information will help to analyze
   I. Volume of CMMI based process improvement for both companies.
   II. Any variations in improvement for cost, schedule, quality and other performance categories.

3.2.7 Phase II - Interviews

These interviews will be more detailed to discuss the variation reasons. On need basis other strategies will also be developed to find out the reasons. (e.g. Distribution of questionnaire , site visits , review of products , review of Process improvement methodology).

3.2.8 Conclusion and Recommendations

Conclusion and recommendations list will be generated on the basis of comparative analysis and Phase II interviews results.

3.2.9 Research Plan

The proposed timelines of high level activities are given as under:

S No.	Major Milestones	Timelines
1	Research proposal finalization	3 Week
2	Research design completion	2 Week
3	Phase I interviews	1 Week
4	Data Collection and compilation	1 Week
5	Individual and comparative data analysis	1 Week
6	Analysis of results variation	3 days
7	Interviews with the companies to corroborate the results.	1 Week
8	Compilation of conclusion and Recommendations	3 days
9	Completion of Thesis report	1 Week

Note: These timelines are subject to the availability of company's representatives for interviews and provision of data for analysis.

4 – Demonstrating impact on performance

4.1 Company Introduction

Following section describe the Company Process improvement history, Engineering process group structure, Roles and responsibilities, QMS structure. This description will finally help in the comparative analysis section.

4.1.1 About Company A

4.1.1.1 Process Improvement History

Company A took imitative for Process improvement in 1998 and selected ISO for their internal process improvement. Company A did ISO certification at the end of 1998. Looking on the advantages of Process improvement Company A planned for long term objectives and developed a roadmap for overall process improvement. They were interested in selecting a model which could specifically help the company in improving the processes regarding software development.

After thorough R&D Company A selected SEI *Carnegie Mellon* University's CMMI model for internal process improvement. Company A selected staged representation of CMMI for SPI roadmap and built initial required infrastructure.

Efforts continued for process improvement and Company A was finally appraised successfully for CMM L2 in March 2002. It was the first ever CBA-IPI reported for any Pakistani company on SEI website. With the successful completion of CMMI L2 Company A management defined a long journey of process improvement for employees to achieve CMMI L5. In the start, it was very big milestone for employees to achieve. However the obvious benefits of CMM L2 energize the employees to accept this milestone.

As CMM L2 is mostly focused on Project level. Company A took advantage of SEI lead appraiser presence in the company and conducted the GAP analysis for CMMI L3 and redefined the SPI structure and approach for higher maturity levels.

CMMI L3 is focused at organization level. Keeping in mind the long term objective to achieve the CMMI L5, Company A took following initiatives

- Redefine and improve Engineering Process Group (EPG) structure
- Clearly define roles and responsibilities for SPI.
- TO maintain CMMI staged representation for process improvement.

Company A was appraised successfully at CMMI L3 in May 2003.

4.1.1.2 EPG Roles and Responsibilities:

Sr No	Roles	Responsibilities
1.	Top Management	1. To provide sponsorship for Process Improvement activities in COMPANY A. 2. To develop, review and update as necessary the COMPANY A Vision , Mission, Goals and Objectives document reflecting process needs and process improvement objectives through the Process Engineering Group. 3. To develop and provide sponsorship by develop Policies for all major processes at COMPANY A. 4. To review and approve the Resource Allocation, Process Improvement Initiatives Project Schedule and Project Plan. 5. To monitor progress of Process Improvement Initiatives 6. To review and approve Process Documents and Process Assets for use in COMPANY A
2.	EPG	1. Identifies process needs of COMPANY A that would satisfy the process related Objectives. 2. Along with Consultants develops the GAP Analysis Checklists. 3. Along with Consultants develops the Detailed GAP Analysis Activity Schedule and obtain buy in from participants. 4. Along with consultants and GAP Analysis participants Conducts the GAP Analysis as per the Schedule and record findings in the GAP Checklists. 5. Along with Consultant prepare the Draft Findings

		Presentations and Draft GAP Analysis Report. And presents the findings to all the participants. 6. And consultants Change Findings as per comments and prepare GAP Analysis report. 7. Defines the project Scope and Technical Approach or the Road map for the selected Process Improvement Initiative. 8. Develops the High level Work Breakdown Structure and estimates for work product size, resources, effort and cost. 9. Aand Process Groups develop project team structure and assign responsibilities for process leads, process action group members and lead authors. 10. Does the detailed planning and develops the project Improvement Plan and Process Improvement Initiative Project Schedule with other planning documents. 11. Manager identifies the training needs and Trainers for different training needs along with the source of training. 12. Along with PG Identify and Nominate training participants for different identified trainings. 13. Manager along with Trainers/ Training Participants/RD Manager determine effectiveness of training and report to the PG and Top Management. 14. And PG Approves training delivery and take further actions on the basis of training effectiveness as appropriate. 15. Manager EPG and PG establish and update the Tailoring Guidelines as appropriate. 16. Manager EPG Review the Tailoring/Waivers Requests and take appropriate actions. 17. Reviews the Processes and Process Assets. Conducts Usability Survey , Other Process Feedback Updtaes and

		transitions.
3.	Process Groups	1. Along with EPG develop project team structure and assign responsibilities for process leads, process action group members and lead authors. 2. Reviews and approves all planning documents along with relevant stakeholders. 3. And EPG Identify and Nominate training participants for different identified trainings. 4. And EPG Approves training delivery and take further actions on the basis of training effectiveness as appropriate. 5. And Manager EPG establish and update the Tailoring Guidelines as appropriate. 6. Review of Processes & Process Assets
4.	Project Teams	1. Along with EPG,PG and Top Management do the detailed Process Implementation and Deployment planning in process improvement schedule and process improvement schedule 2. Along with EPG,PG and Top Management conduct the implementation kick off meeting and initiate process implementation and deployment. 3. Along with EPG,PG and Top Management take necessary actions on areas of improvements identified by ISR

Table 8 :Company A Roles & Responsibilites

4.1.1.3 Company A QMS Structure:

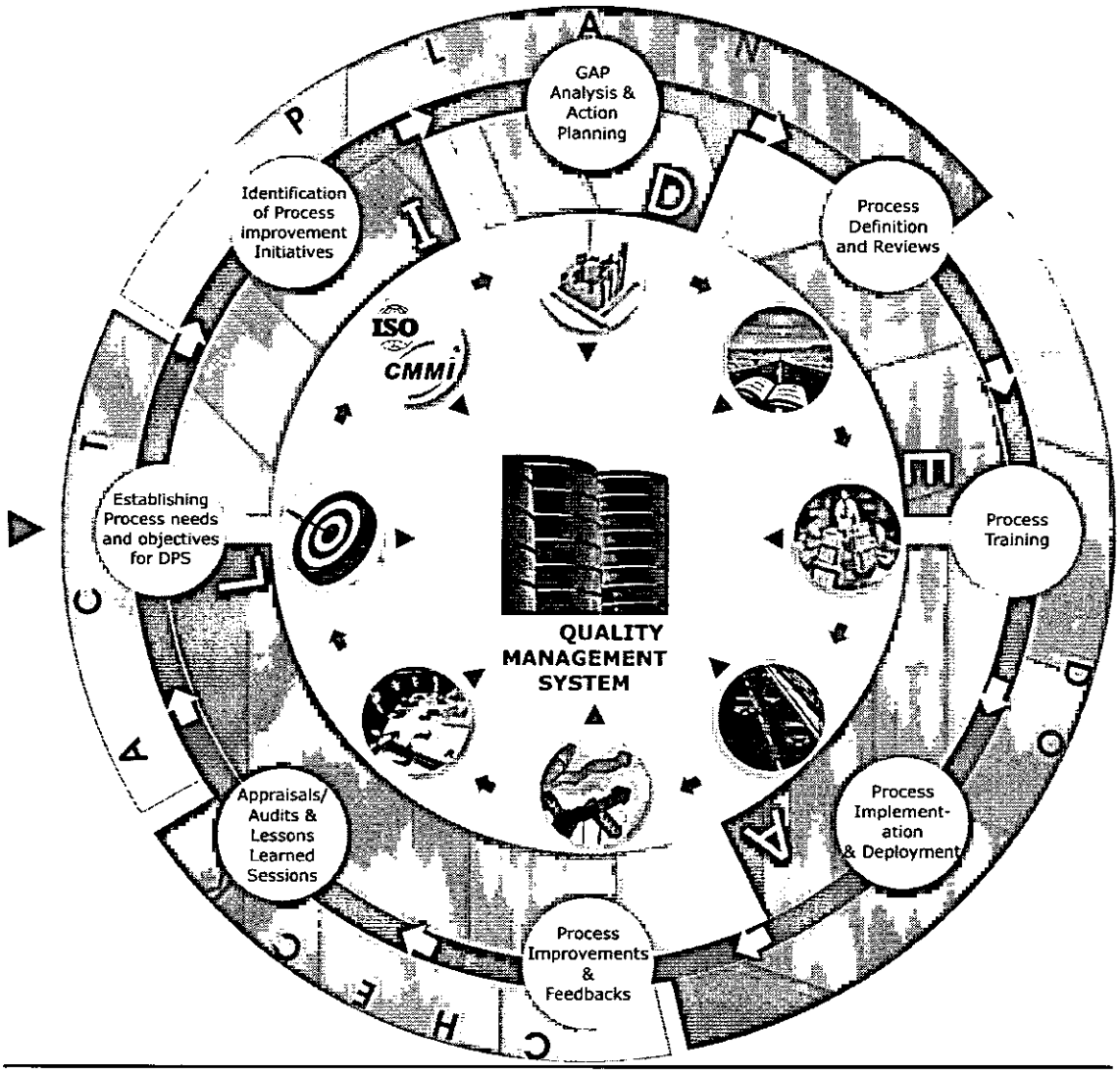


Figure 8: Company A QMS Structure

4.1.1.4 High Maturity Levels achievement

High maturity levels (CMMI L4 & L5) are termed as Advanced Process Management processes in SEI CMMI V1.2. Organizations consider higher level maturity levels when they want to establish a quantitative understanding of the performance of the organization's set of standard processes. When they want to work on process performance data, baselines, and models to quantitatively manage the organization's project.

As high maturity levels are more focused on Quantitative project management and statistical process control, comprehensive measurement program was defined at organization level.

Company A defined measurement program (Fig 9) to achieve high maturity levels for the organization.

Company A achieved CMMI L4 in December 2004. CMMI L5 helps companies for continual process improvement. To maintain the pace of continuous process improvement, Company A achieved CMMI L5 in August 2006.

4.1.1.5 Company A Measurement program structure

To achieve the measurement objectives for High maturity levels, Company A devised a comprehensive measurement programs for metric collection and compilation. Following diagram shows the details of the measurement program in the company.

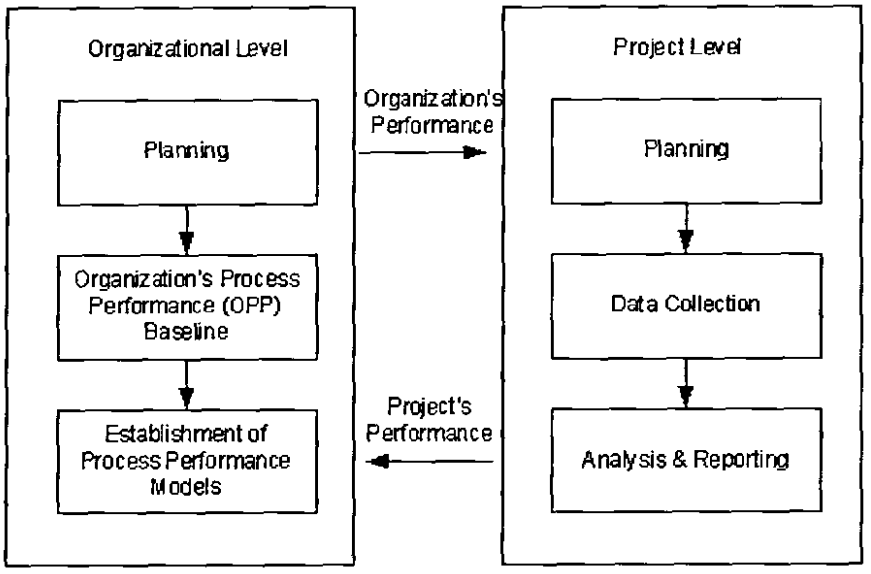


Figure 9: Company A Software Measurement Program

4.1.2 About Company B

4.1.2.1 Process Improvement Approach

To successfully implement the process improvement program. It is very necessary to devise the comprehensive Process improvement program at organization level. COMPANY B adopted following approach to implement the SPI program in the company. Following diagram shows the details of each step:

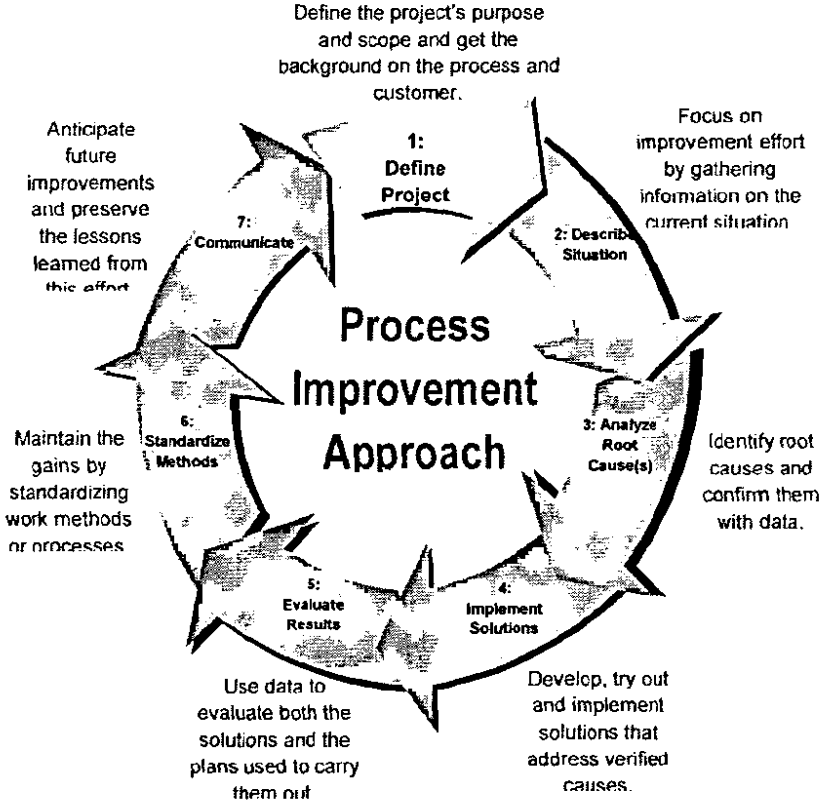


Figure 10: COMPANY B Process Improvement Approach

4.1.2.2 Data collection and analysis framework

Although data collection and analysis framework is required for all levels of CMMI. To guide the companies to develop comprehensive measurement programs and data collection & analysis framework, SEI has included a complete process area Measurement & Analysis at CMMI L2 to build the foundation for measurement programs.

High maturity levels require more rigor in data collection and analysis. COMPANY B developed following data collection and analysis framework to fulfill the data analysis needs of High maturity levels.

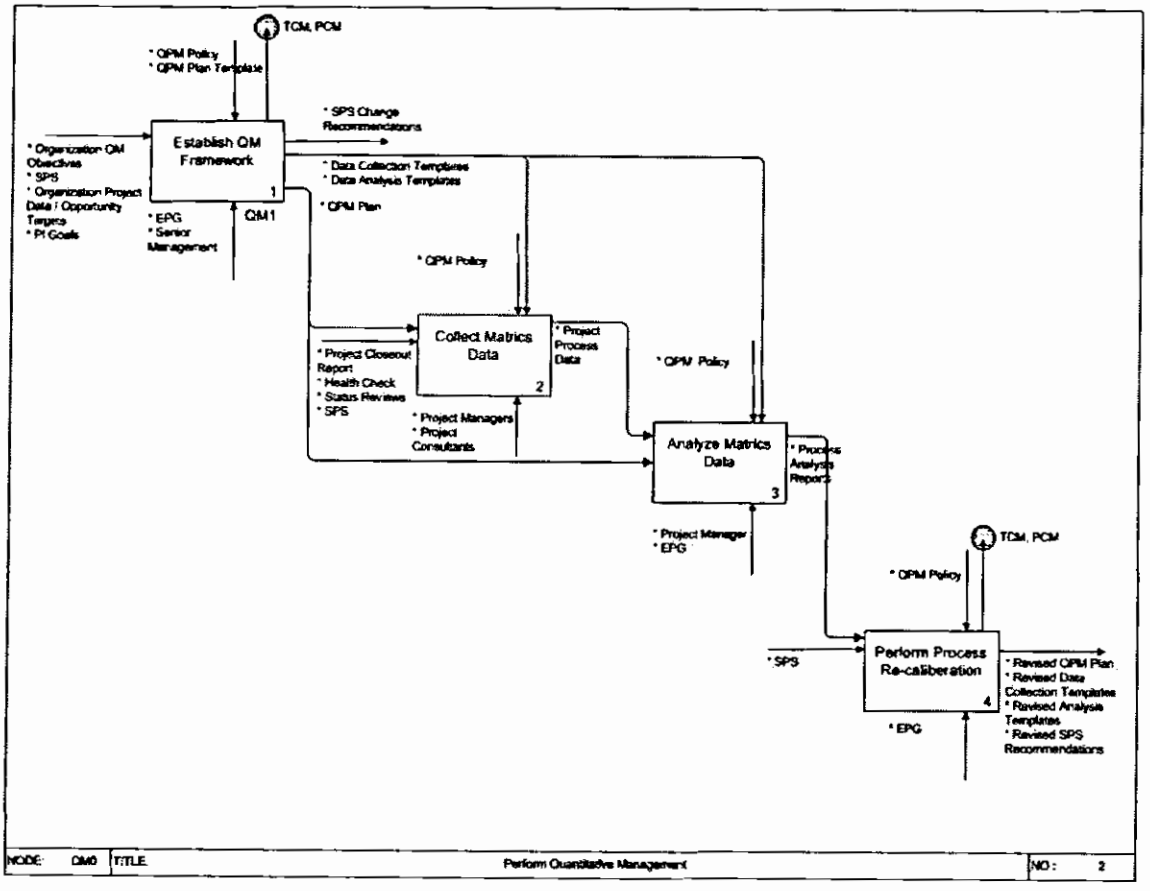


Figure 11: COMPANY B Data collection and analysis framework

4.2 Data Collection and Compilation

4.2.1 Data Collection

Company A:

During Phase –I Interview it was revealed that metrics database is compiled in Company A at the end of each quarter. After the completion of phase-I interviews following documents were collected.

1. Quality Management System (QMS) structure (Described at section 5.1.3.2)
2. List of artifacts being used at different levels of SDLC.
3. SEPG Structure and roles and responsibilities described at section 5.1.3.1
4. Measurement Program structure described at Section 5.2.4
5. Measurement repositories (From March 2004 to December 2006)
6. Metrics definition files

COMPANY B:

During Phase –I Interview it was revealed that metrics database is compiled in COMPANY B at different intervals to fulfill the needs of the management.

After the completion of phase-I interviews following documents were collected.

1. Process improvement structure
2. List of artifacts being used at different levels of SDLC.
3. Data collection and analysis framework
4. Measurement repositories (From November 2002 to September 2005)
5. Metrics definition files

4.2.2 Data Compilation

The main purpose of t his activity is to establish interpretation of metrics to understand impact of CMMI based process improvement on Cost, Schedule and Quality. Table 9 describes the details of metrics associated with Cost, Schedule and quality. These metrics will help to understand the overall impact of CMMI based process improvement on the companies.

During data collection stage companies reported some metrics which are not directly impacting the cost, schedule and quality but in the wider context these metrics helped the organizations to improve ROI, Customer Satisfaction and Productivity. As these improvements are also the result of Process improvement program therefore they were also included in the study.

4.2.2.1 Interpretation of metrics

Following table shows the detail of all metrics associated with each performance category. At some points companies were using different terminologies to represent results. For comparison and analysis purpose, these measurements are conformed to generate the comparable results.

Major Category	Metric Name	Description	Formula
Quality			
	Defect Removal Efficiency (DRE)	This measure describes that what was the origin of defects in SDLC phase	DRE= D(N)/((D(N)+D(C)) D=Defect, N= Company Name, C=Customers Note= These metrics are up to UAT Phase
	Defect Density	This metric describes that what is the Defect per unit size.	Defect Density = Total Defects/Total Size
Schedule			
	SVP	This metric describes that how much project is delayed against plans.	Schedule Variance Percentage (SVP)= ((Actual Duration– Plan Duration) / Plan Duration) * 100)
	Effort Estimation Accuracy (EEA)	This metric describes that how much project effort deviates against plans	EEA = Actual Effort / Planned Effort
Cost			
	Cost of Quality (COQ)		COP = (Review Effort+Rework Effort+Testing Effort+Training

			Effort)/Total Effort
	Cost of Poor Quality (COPQ)	This metric describes that what is re-work effort percentage against all project activities	
Productivity			
	Productive Hour Percentage (PHP)	This metric describes that what is the productivity of projects members	Productive Hours Percentage (PHP) = ((No. of hours for productive activities / Total man hours) * 100)
ROI			
	OSSP Compliance %age	This measure describes that what is average compliance of projects against Key practices of CMM	Compliance Percentage = Weighted Key Practices Satisfied / Total Weighted Key Practices (as per OSSP Implementation Report)
	Employee Turnover (ET) for Company A Only.	This metric describes that, what is the employee turnover in Company A	Employee Turnover (ETO) = ((No. of resigned employee / (Total No. of employee – No. of new employee) * 100)
	Implementation Requirement Percentage (IRP)	This metric describes that, how many requirements are implemented in project	Implemented Requirements Percentage (IRP) = ((No. of implemented requirements / Total No. of signed off requirements)*100)
Customer Satisfaction			

	Service Efficiency	This metric describes that, what is the efficiency of services that company is providing to customers	Service Efficiency (SE) = (No. of Critical/Major bug request serviced / No. of Critical/Major bug request received) * 100

Table 9 (Interpretation of Metrics 1)

4.3 Data Analysis

Every organization has different business goals and strategic objectives. They offer different products and services to their clients. They differ in how they implement CMMI-based process improvement program and in the ways they measure their resulting progress and performance.

Process improvement based on CMMI models may be demonstrated in several ways. Some organizations have established new processes or changed existing processes as a result of guidance found in the CMMI Product Suite. Others have broadened the organizational scope of their improvement efforts, through the integration of systems, software, hardware, and related disciplines. It depends upon the information needs of the company.

4.3.1 Data Analysis Approach

Following steps will be followed for the analysis of data:

1. Selection of performance category from Metric definition table described in Table 9.
2. Selection of associate metric for the performance category. For this analysis there are following performance categories
    - Cost
    - Schedule
    - Quality
    - ROI
    - Customer Satisfaction
    - Productivity
3. Compilation of summary impact for each metric. This summary will include
    a. median improvement before implementation of High Maturity Levels
    b. median improvement after implementation of High Maturity Levels
    c. Lowest improvement during the analysis period
    d. Highest improvement during the analysis period
    e. Detailed analysis of each metric based on the data described in data collection sheet (Section 5.3.4).

4.3.2 Data Analysis Results

Following section shows the performance results of Company A and COMPANY B for following categories:

- Schedule
- Cost
- Quality
- ROI
- Customer Satisfaction
- Productivity

4.3.2.1 Schedule

This category covers improvements in Schedule variance percentage and reductions in time to complete the work. In this category I have analyzed two major metrics Schedule Variance Percentage (SVP) and Effort Estimation Accuracy (EEA). Following summary table shows the improvement in these performance categories after implementation of High maturity level.

Summary of Impacts on Schedule:

Company Name	Metric Name	UAL/ LAL	Before High maturity level implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvement
Schedule						
Company A	SVP	±15%	11.48%	5.98%	18.56%	3.19%
	Effort Estimation Accuracy (EEA)	0.85 ≤ EEA ≤ 1.15	1.17	1.05	1.19	1.02
Company B	SVP	±20%	14.26%	7.73%	15.89%	6.14%
	Effort Estimation Accuracy (EEA)	0.80 ≤ EEA ≤ 1.20	1.15	1.08	1.16	1.05

Table 10 Summary of Impact on Schedule

* UAL/LAL denotes Upper acceptable limit/ Lower Acceptable limit for any metric.

Detail Metric Analysis

Details of each metric associated with this schedule are described below in details.

4.3.2.1.1 Company A Schedule Variance Percentage (SVP)

Major Category	Metric Name	Description	Formula
Schedule	Schedule Variance Percentage (SVP)	This metric describes that how much project is delayed against plans.	Schedule Variance Percentage (SVP)= ((Actual Duration– Plan Duration) / Plan Duration) * 100)

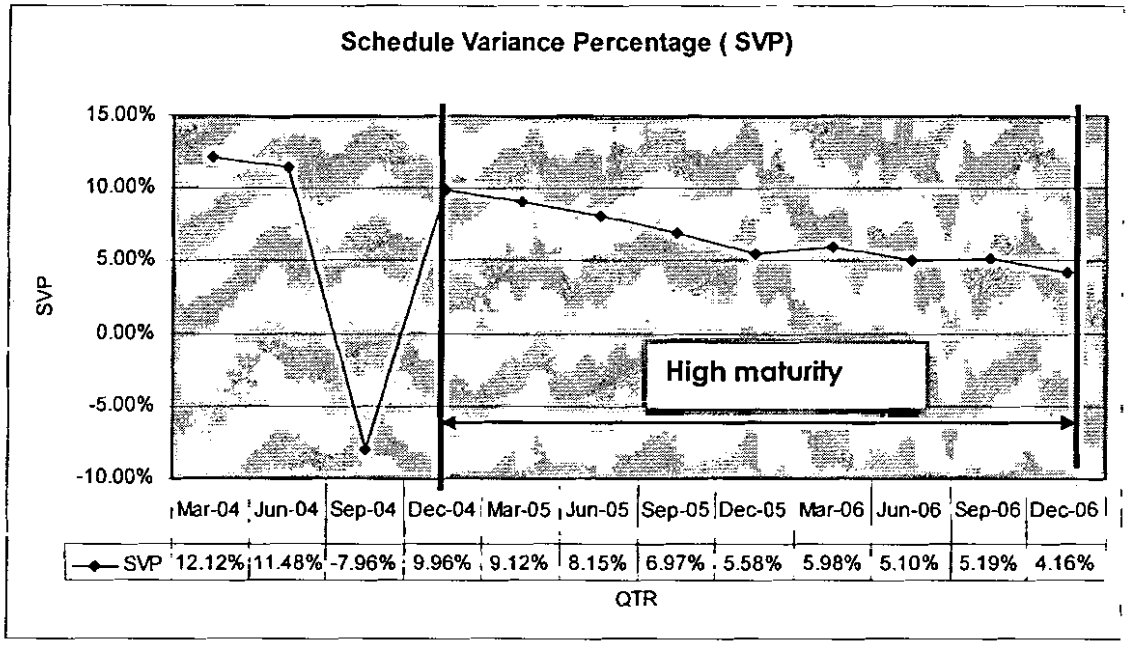


Figure 12: Company A SVP

4.3.2.1.2 Company B Schedule Variance Percentage (SVP)

Major Category	Metric Name	Description	Formula
Schedule	Schedule Variance Percentage (SVP)	This metric describes that how much project is delayed against plans.	SVP=(BCWP – BCWS) / BCWP

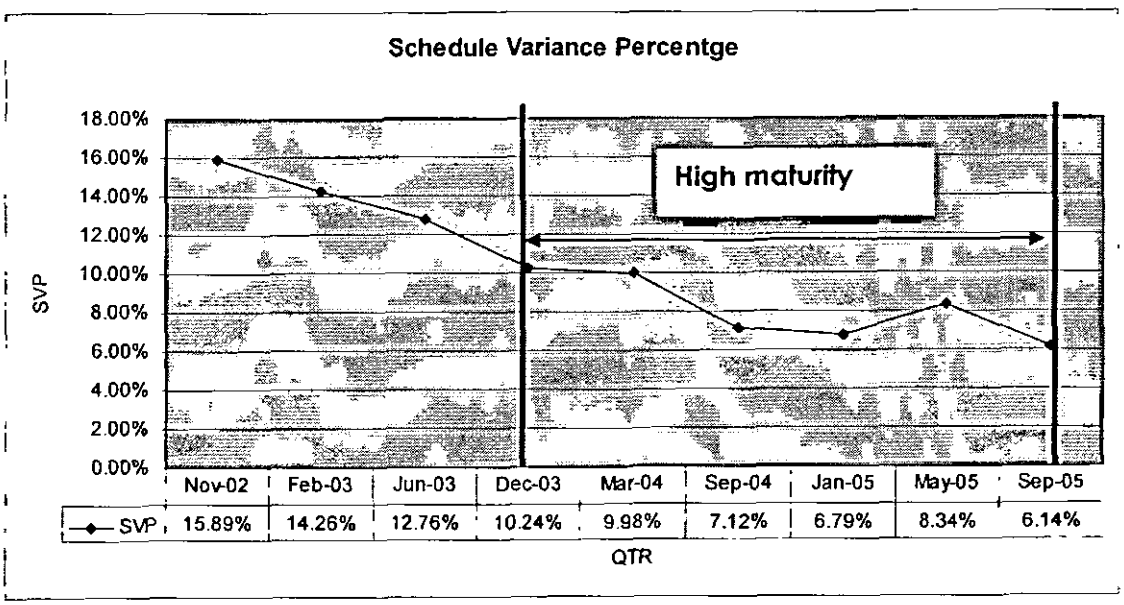


Figure 13: Company B SVP

4.3.2.1.3 Company A Effort Estimation Accuracy (EEA)

Major Category	Metric Name	Description	Formula
Schedule	Effort Estimation Accuracy (EEA)	This metric describes that how much project effort deviates against plans	EEA = Actual Effort / Planned Effort

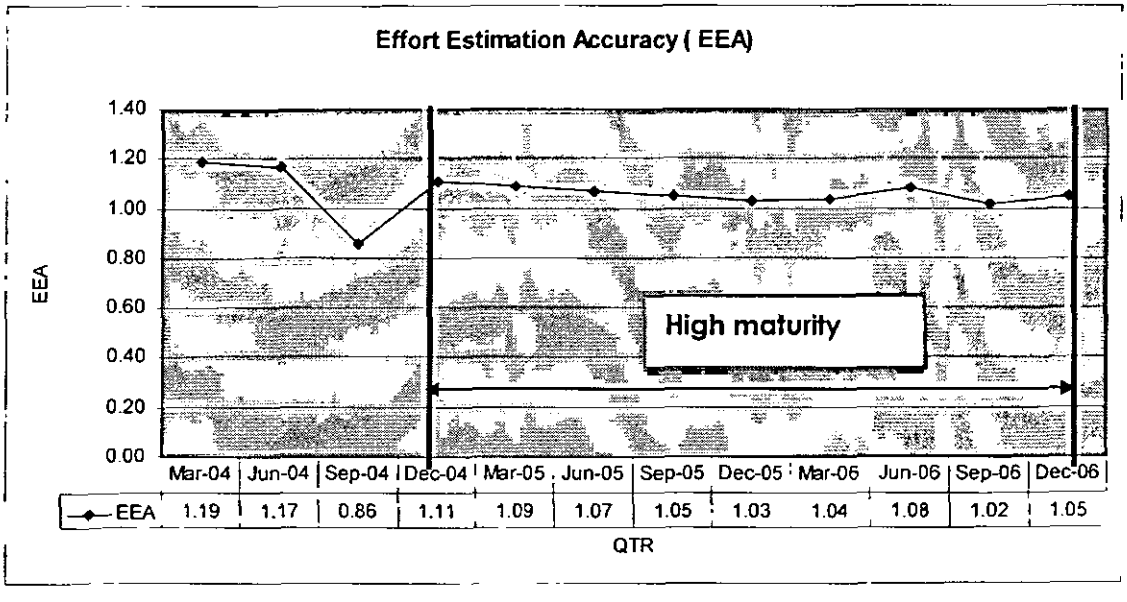


Figure 14: Company A: Effort Estimation Accuracy

4.3.2.1.4 Company B Effort Estimation Accuracy (EEA)

Major Category	Metric Name	Description	Formula
Schedule	Effort Estimation Accuracy (EEA)	This metric describes that how much project effort deviates against plans	EEA = Actual Effort / Planned Effort

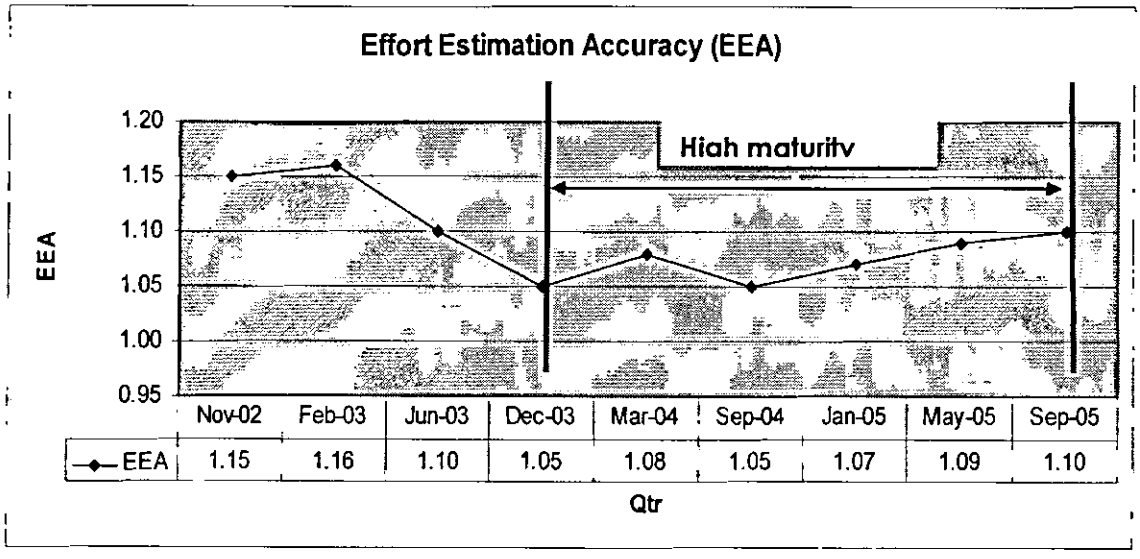


Figure 15: Company B EEA

4.3.2.2 Quality

Improvement in product quality is most frequently measured with reductions in number of defects. To analyze the impact of CMMI based process improvement on quality, Defect Removal efficiency and Defect density are included.

Summary of Impact on Quality

Company Name	Metric Name	UAL/LAL	Before High maturity level implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvement
Quality						
Company A	Defect Removal Efficiency (DRE)	Must be greater than 95%	81.12%	94.25%	81.12%	98.16%
	Defect Density	< 8 defects/KLOC	10.76	7.5	10.85	5.11
Company B	Defect Removal Efficiency (DRE)	>99%	87.45%	94.54%	87.45%	96.99%
	Defect Density	< 6 defects/KLOC	8.43	5.72	8.58	5.02

Table 11: Summary of Quality on Company A and Company B

Detail Metric Analysis

Details of each metric associated with this Quality are described below in details.

4.3.2.2.1 Company A: Defect Removal Efficiency (DRE)

Major Category	Metric Name	Description	Formula
Quality	Defect Removal Efficiency (DRE)	This measure describes that what was the origin of defects in SDLC phase	DRE= D(N)/((D(N)+D(C)) D=Defect, N= Company A, C=Customers Note= These metrics are up to UAT Phase

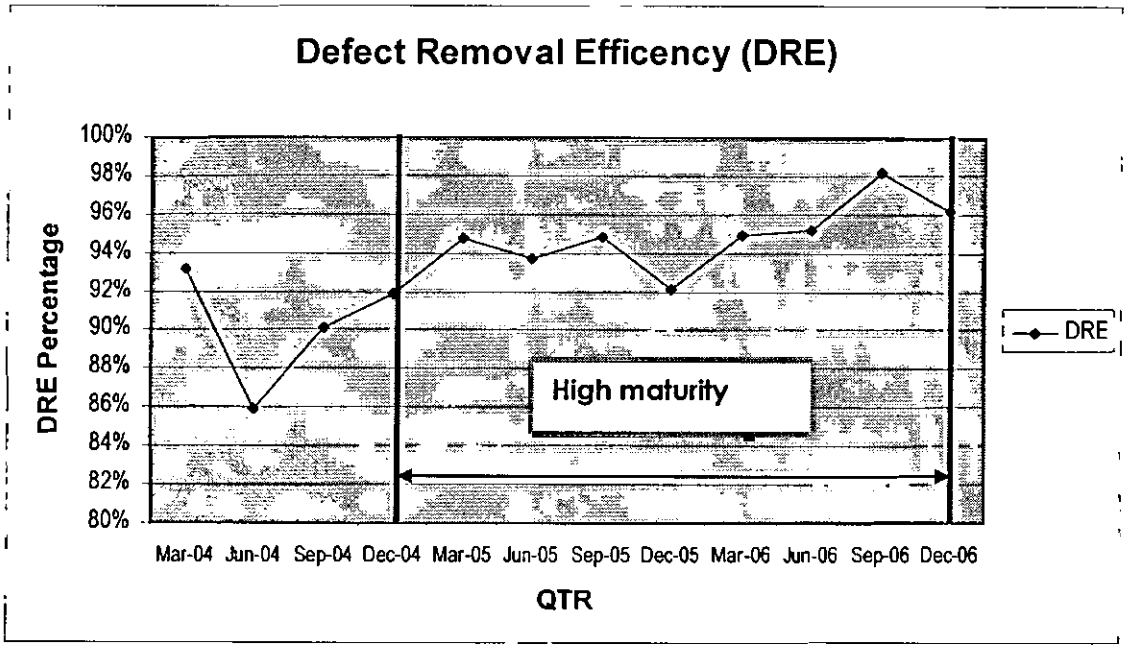


Figure 16: Company A: Defect Removal Efficiency

4.3.2.2.2 Company B: Defect Removal Efficiency (DRE)

Major Category	Metric Name	Description	Formula
Quality	Defect Removal Efficiency (DRE)	This measure describes that what was the origin of defects in SDLC phase	DRE= D(N)/((D(N)+D(C)) D=Defect, N= Company A, C=Customers Note= These metrics are up to UAT Phase

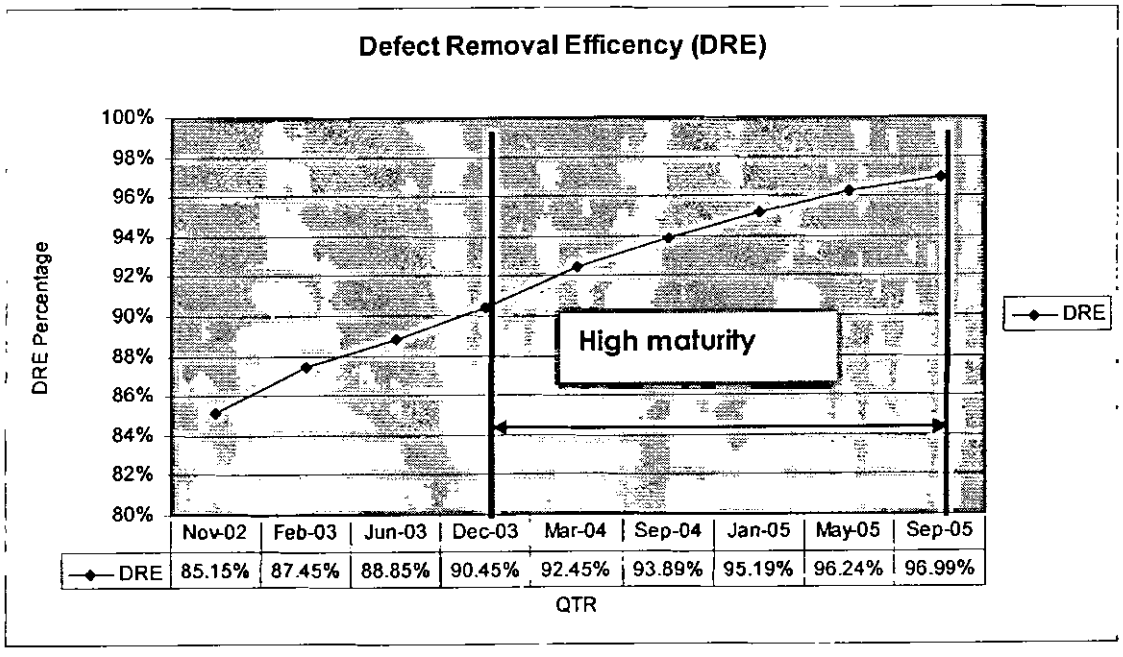


Figure 17: Company B: Defect Removal Efficiency

4.3.2.2.3 Company A: Defect Density (DD)

Major Category	Metric Name	Description	Formula
Quality	Defect Density(DD)	This metric describes that what the Defect per unit size is.	Defect Density = Total Defects/Total Size

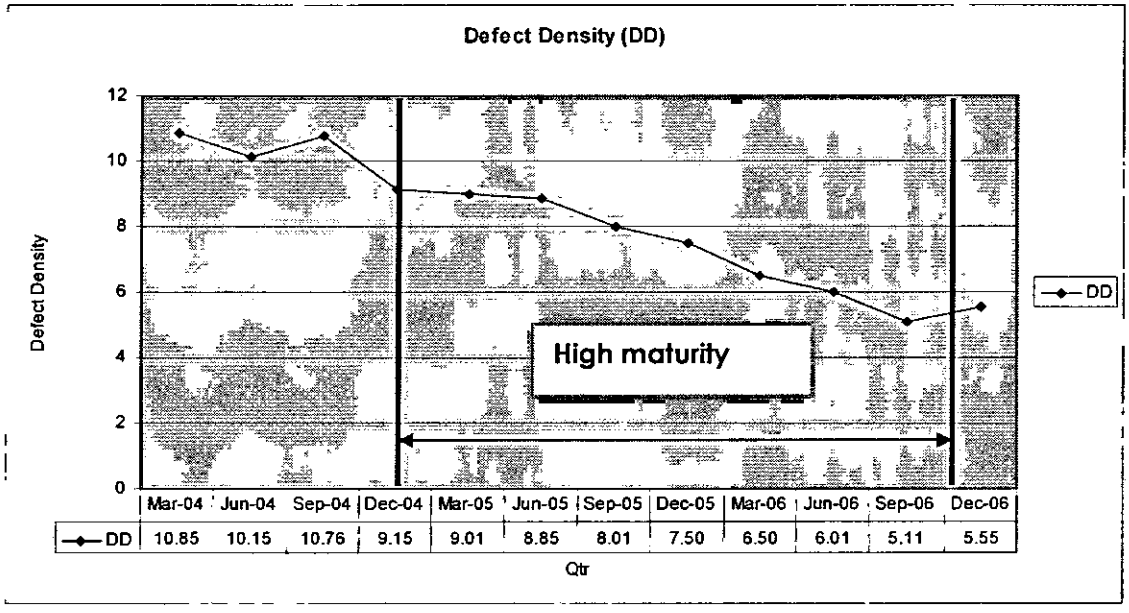


Figure 18: Company A: Defect Density

4.3.2.2.4 Company B: Defect Density (DD)

Major Category	Metric Name	Description	Formula
Quality	Defect Density(DD)	This metric describes that what the Defect per unit size is.	Defect Density = Total Defects/Total Size

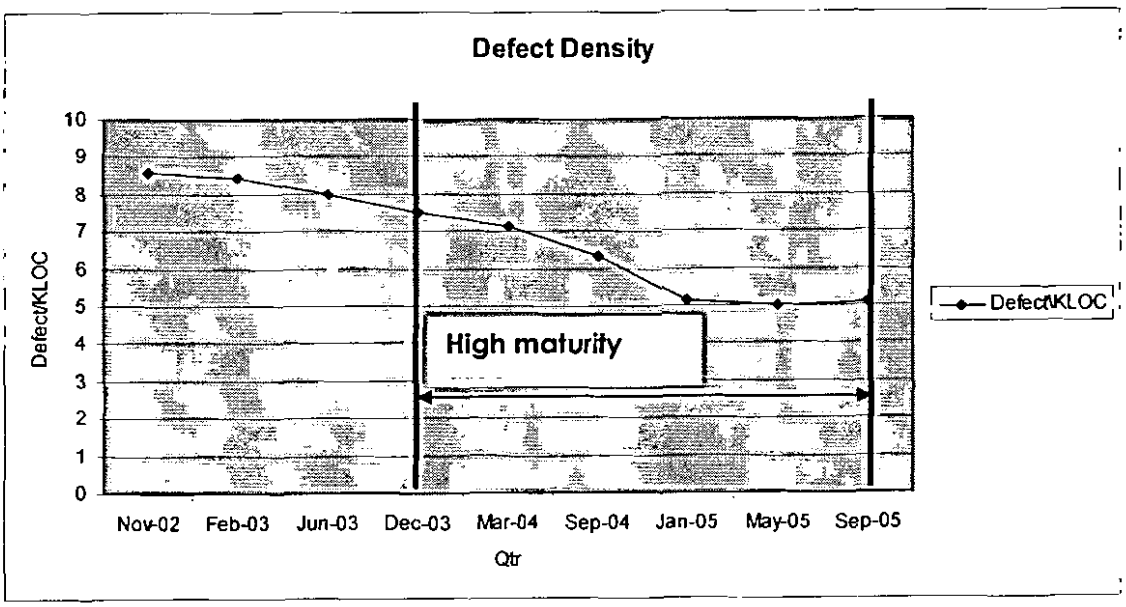


Figure 19: Company B Defect Density

4.3.2.3 Cost

The cost category covers instances where organizations report changes in the cost of final or intermediate work products, changes in the cost of the processes employed to produce the products, and general savings attributed to model based process improvement.

Although this area was difficult to analyze due to confidentiality of information. However metrics given in the summary table were studied to analyze the impact of CMMI based process improvement.

Summary of Impact on Cost

Company Name	Metric Name	UAL/LAL	Before High maturity level implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvemen
Cost						
Company A	Cost of Quality (COQ)	16% ≤ COQ ≤ 22%	23.19%	20.17%	26.18%	17.19%
	Cost of Poor Quality (COPQ)	2% ≤ COPQ ≤ 5%	8.16%	5.16%	8.19%	4.87%
Company B	COQ	<20%	24.98%	19.03%	25.17%	17.98%
	COPQ	<7%	8.89%	6.08%	9.19%	5.45%

Table 12: Summary of Cost

Detail Metric Analysis

Details of each metric associated with this Cost are described below in details.

4.3.2.3.1 Company A: Cost of Quality (COQ)

Major Category	Metric Name	Description	Formula
COST	Cost of Quality (COQ)		COP = (Review Effort+Rework Effort+Testing Effort+Training Effort)/Total Effort

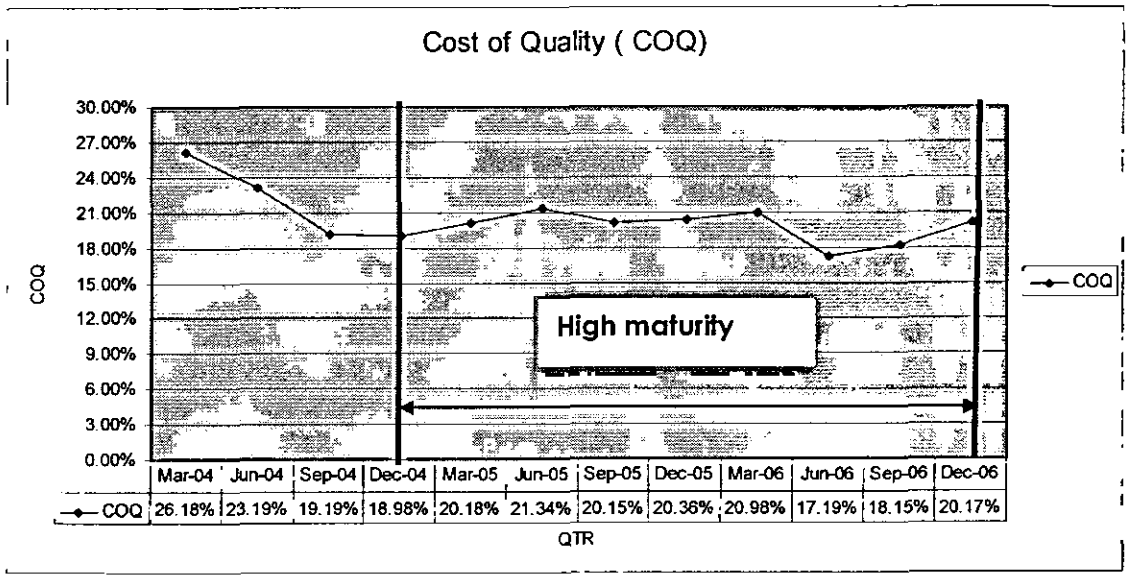


Figure 20: Company A: Cost of Quality

4.3.2.3.2 Company B: Cost of Quality (COQ)

Major Category	Metric Name	Description	Formula
COST	Cost of Quality (COQ)		COP = (Review Effort+Rework Effort+Testing Effort+Training Effort)/Total Effort

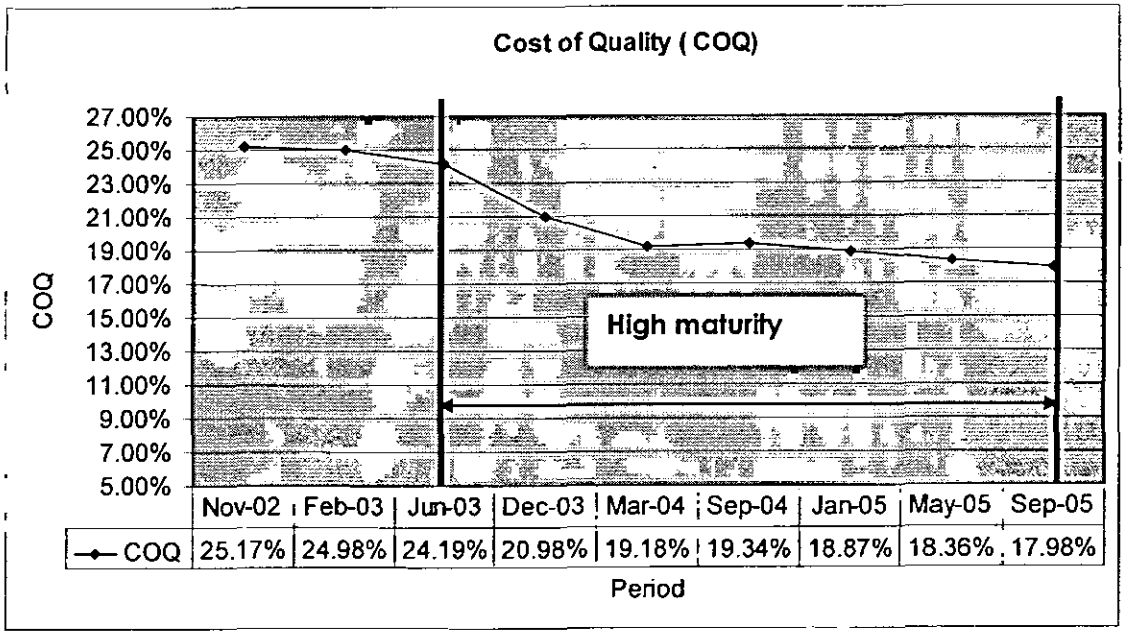


Figure 21: Company B: Cost OF Quality

4.3.2.3.3 Company A: Cost of poor Quality (COPQ)

Major Category	Metric Name	Description	Formula
COST	Cost of poor Quality (COPQ)	This metric describes that what is re-work effort percentage against all project activities	

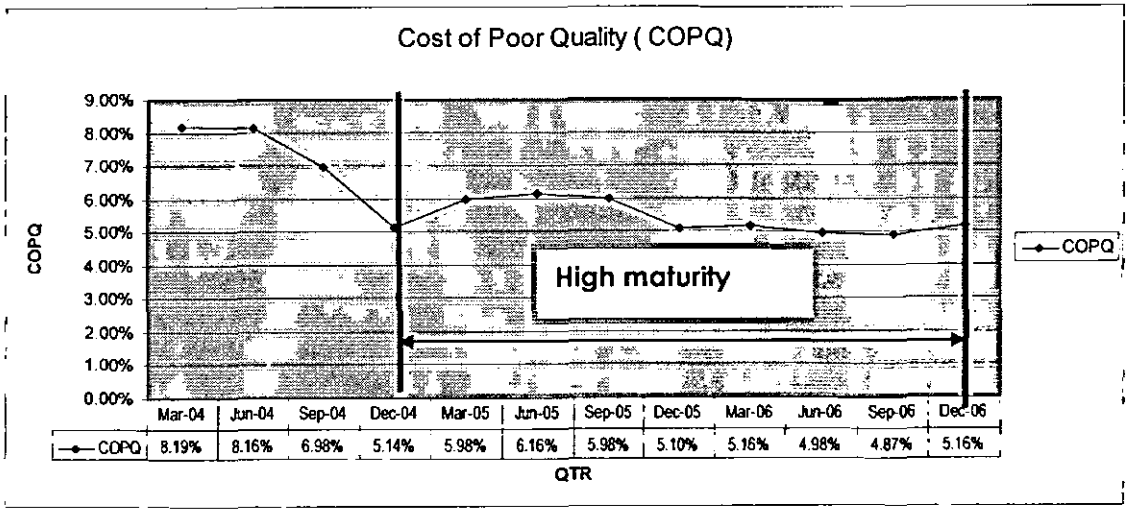


Figure 22: Company A: Cost of Poor quality

4.3.2.3.4 Company B: Cost of poor Quality (COPQ)

Major Category	Metric Name	Description	Formula
COST	Cost of poor Quality (COPQ)	This metric describes that what is re-work effort percentage against all project activities	

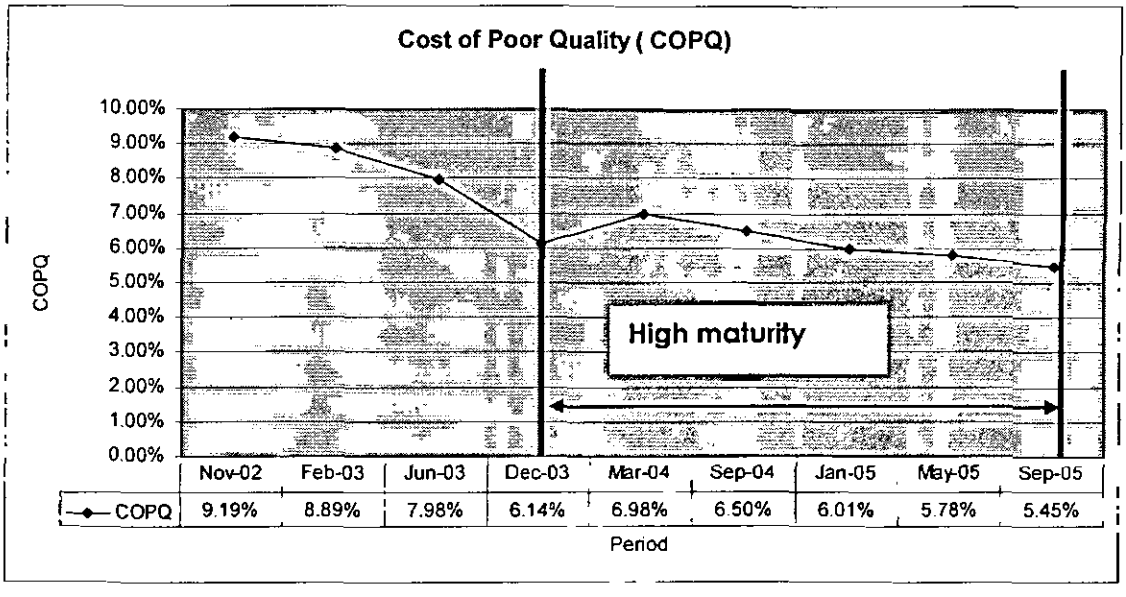


Figure 23: Company B: Cost of Poor Quality

4.3.2.4 Productivity

Company A measure productivity in terms of Productive hour percentage (PHP). This improved from 53.82% to 60.15 %.

Summary of Impact on Productivity:

Company Name	Metric Name	UAL/ LAL	Before High maturity level implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvement
Productivity						
Company A	Productive Hour Percentage (PHP)	100%	63.82%	75.98%	62.98%	81.15%
Company B	Productive Hour Percentage (PHP)	95%	77.97%	82.52%	75.15%	83.15%

Table 13: Summary of Productivity

Detailed Metric Analysis

Details of each metric associated with this productivity are described below in details.

4.3.2.4.1 Company A: Productive Hour Percentage (PHP)

Major Category	Metric Name	Description	Formula
Productivity	Productive Hour Percentage (PHP)	This metric describes that what is the productivity of projects members	Productive Hours Percentage (PHP) = ((No. of hours for productive activities / Total man hours) * 100)

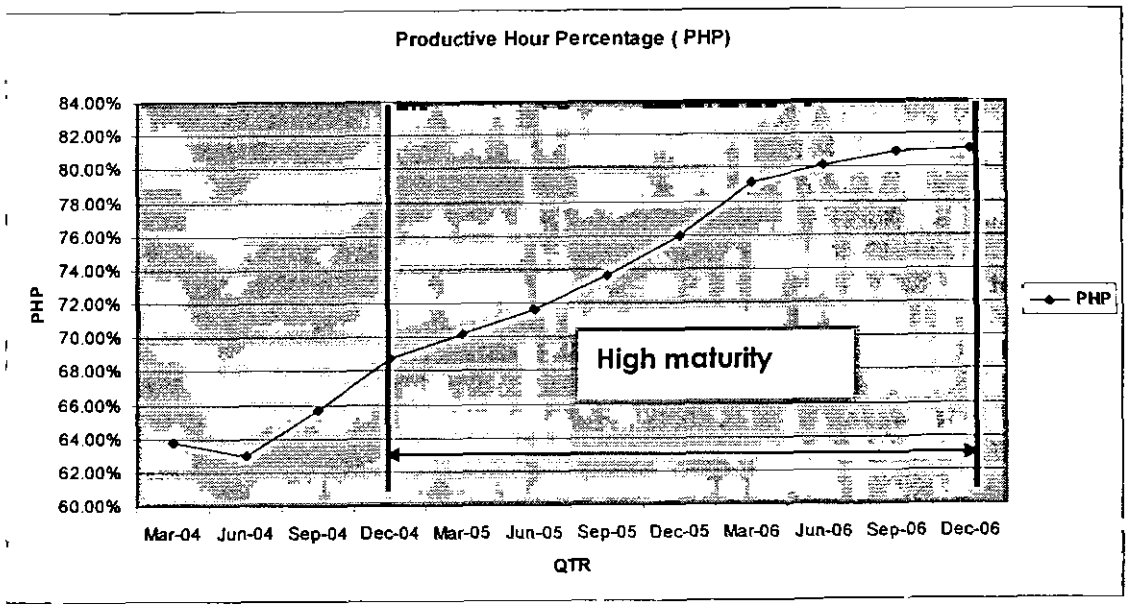


Figure 24: Company A: Productive Hour Percentage

4.3.2.4.2 Company B: Productive Hour Percentage (PHP)

Major Category	Metric Name	Description	Formula
Productivity	Productive Hour Percentage (PHP)	This metric describes that what is the productivity of projects members	Productive Hours Percentage (PHP) = ((No. of hours for productive activities / Total man hours) * 100)

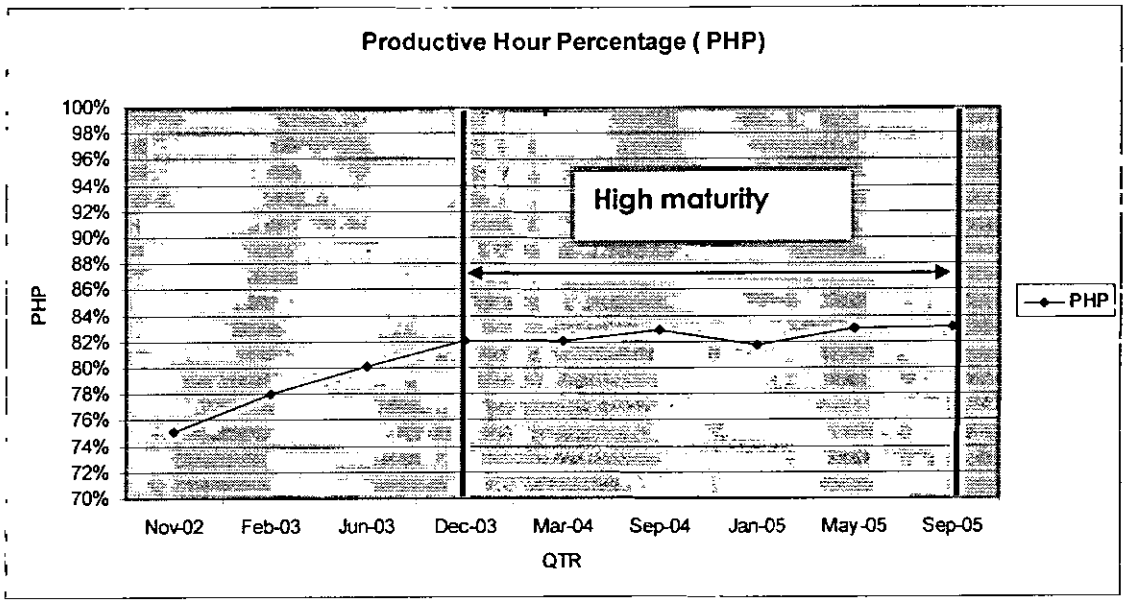


Figure 25: Company B: PHP

4.3.2.5 Return over Investment (ROI)

Return on investment (ROI) can be expressed in many ways [35]. Every action must help the organization to achieve its goal. In business, where the goal is profitability, virtually any strategic action is viewed according to its potential return on investment (ROI) computed in terms of cost of the effort relative to the expected benefit.

Company A measured ROI for process improvement project in terms of OSSP compliance, Employee Turnover and Implemented requirement percentage (IRP). Company A managed to raise OSSP compliance to 89.16%, Employee Turnover 11.18% and IRP to 99.15%.

Summary of Impact on ROI:

Company Name	Metric Name	UAL/LAL	Before High maturity implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvement
Company A	OSSP Compliance %age	>=95%	68.18%	89.16%	67.00%	98.18%
	Employee Turnover (ET)	ETO ≤ 8%	11.18%	11.18%	12.60%	5.08%
	IRP	IRP = 100%	93.73%	99.15%	91.95%	100%
Company B	OSSP Compliance %age	>90%	80.98%	90.31%	78.18%	95.75%
	IRP	100%	92.58%	98.16%	90.18%	99.58%

Table 14: Summary of ROI

Note: Data for employee Turnover rate was not available for Company B.

Detailed Metric Analysis

Details of each metric associated with this ROI are described below in details.

4.3.2.6 Company A: Organization set of Standard processes (OSSP) compliance

Major Category	Metric Name	Description	Formula
ROI	OSSP Compliance %age	This measure describes that what is average compliance of projects against Key practices of CMMI	Compliance Percentage = Weighted Key Practices Satisfied / Total Weighted Key Practices (as per OSSP Implementation Report)

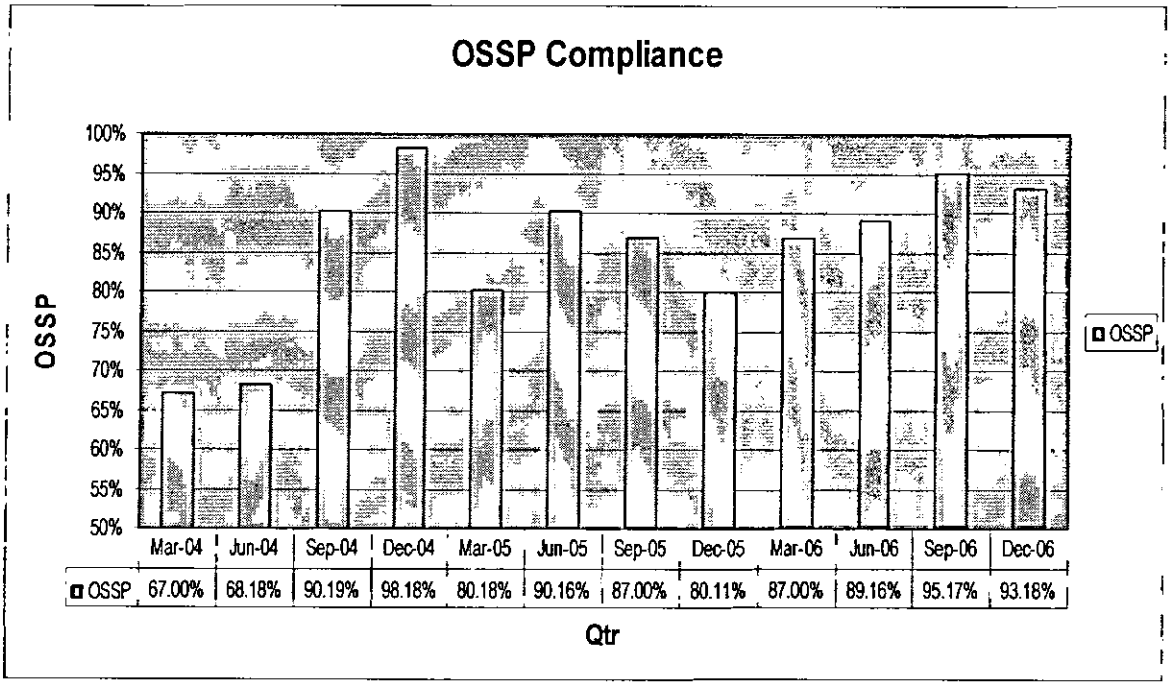


Figure 26: Company A: OSSP Compliance

4.3.2.7 Company B: Organization set of Standard processes (OSSP) compliance

Major Category	Metric Name	Description	Formula
ROI	OSSP Compliance %age	This measure describes that what is average compliance of projects against Key practices of CMMI	Compliance Percentage = Weighted Key Practices Satisfied / Total Weighted Key Practices (as per OSSP Implementation Report)

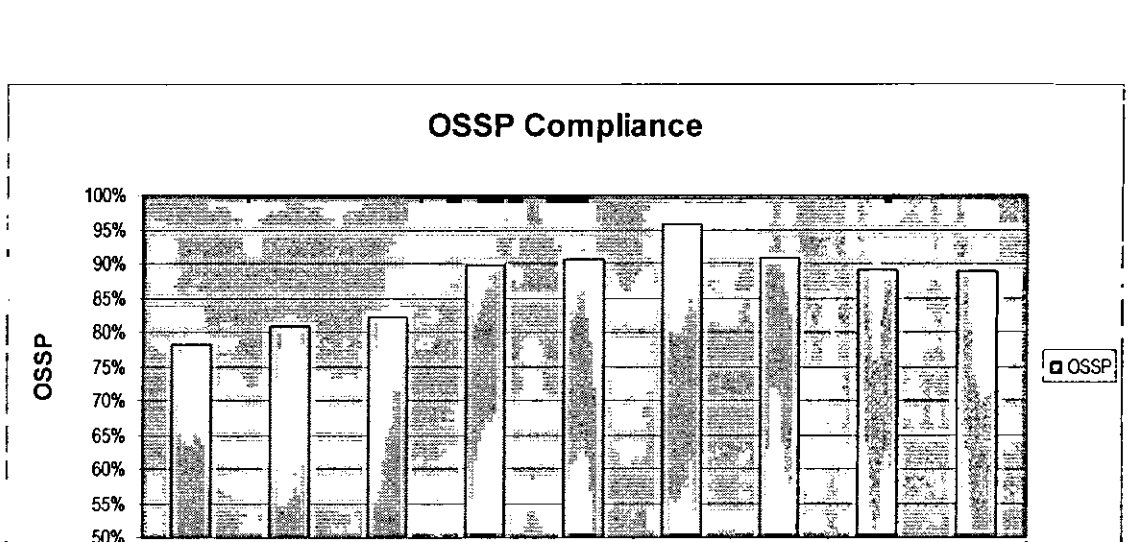


Figure 27: Company B: OSSP Compliance

4.3.2.8 Company A: Implemented Requirement Percentage

Major Category	Metric Name	Description	Formula
ROI	Implementation Requirement Percentage (IRP)	This metric describes that, how many requirements are implemented in project	Implemented Requirements Percentage (IRP) = ((No. of implemented requirements / Total No. of signed off requirements)*100)

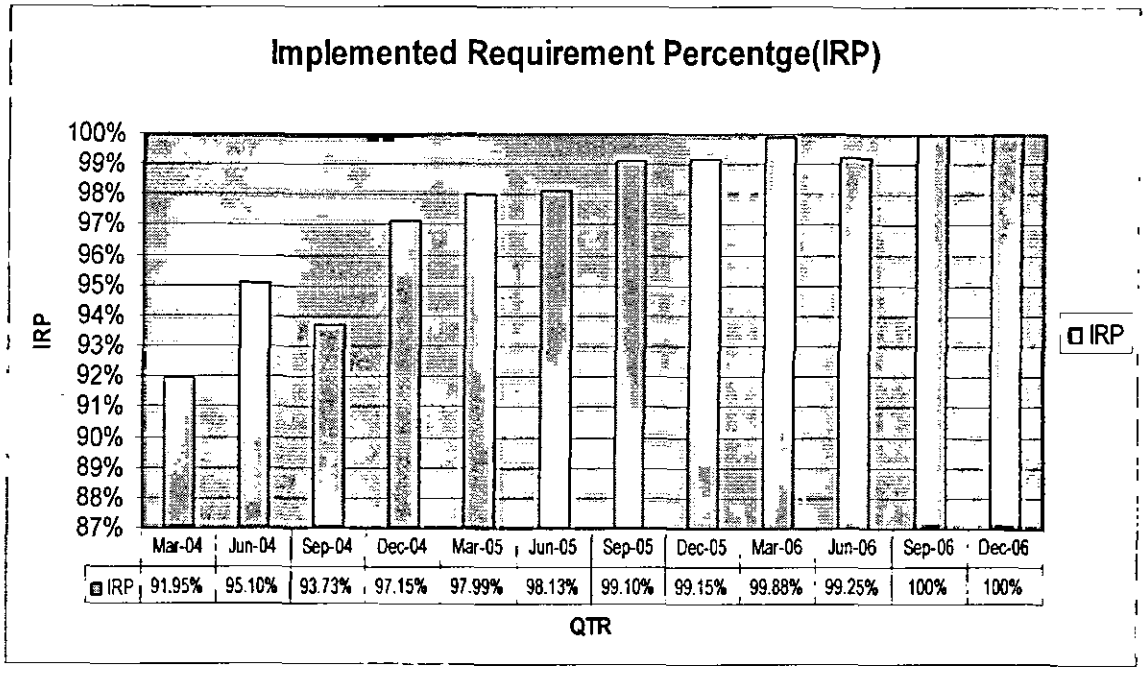


Figure 28: Company A: Implementation Requirement Percentage

4.3.2.9 Company B: Implemented Requirement Percentage

Major Category	Metric Name	Description	Formula
ROI	Implementation Requirement Percentage (IRP)	This metric describes that, how many requirements are implemented in project	Implemented Requirements Percentage (IRP) = ((No. of implemented requirements / Total No. of signed off requirements)*100)

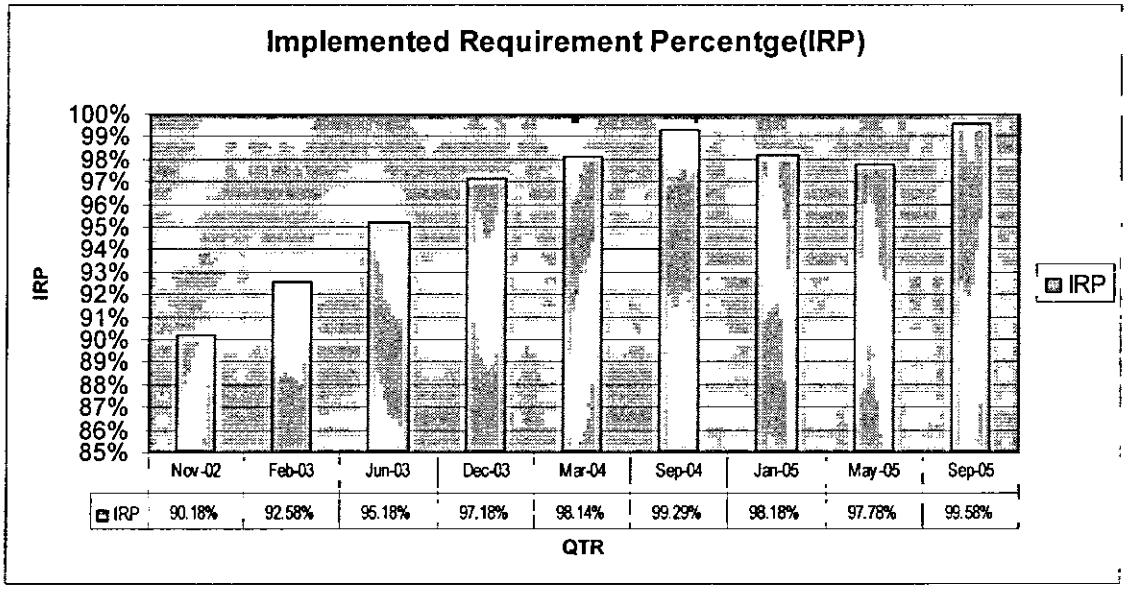


Figure 29: Company B: Implemented Requirement Percentage

4.3.2.10 Company A: Employee Turnover (ET) Percentage

Major Category	Metric Name	Description	Formula
ROI	Employee Turnover (ET)	This metric describes that, what is the employee turnover in Company A	Employee Turnover (ETO) = ((No. of resigned employee / (Total No. of employee – No. of new employee) * 100)

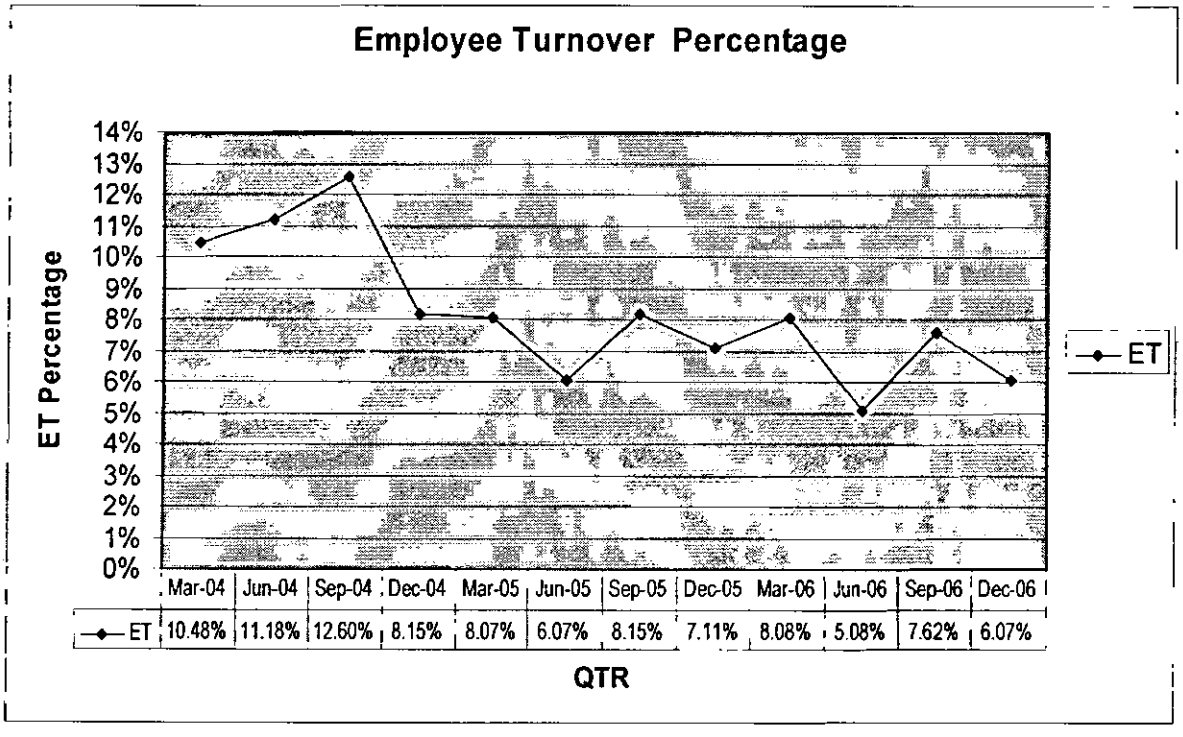


Figure 30: Company A: Employee Turnover

4.3.3 Customer Satisfaction

Although this subject was not part of the Process improvement project. However ultimate objective of the project was to provide better product quality with professional services.

Therefore, in this report Service Efficiency metric was included to analyze the impact of process improvement for this performance category. Process improvement project helped Company A to raise the Service Efficiency level to 89.19% and COMPANY B to 96.14%.

Summary of Impact on Customer Satisfaction:

Company Name	Metric Name	UAL/ LAL	Before High maturity implementation (Median Improvement)	After High maturity level implementation (Median Improvement)	Lowest Improvement	Highest Improvement
Company A	Service Efficiency	SE >= 90%	75.11%	89.19%	70.25%	94.15%
Company B	Service Efficiency	100%	96.98%	99.14%	96.15%	99.25%

Table 15: Summary of Customer Satisfaction

Detailed Metric Analysis

Details of each metric associated with this Customer Satisfaction are described below in details.

4.3.3.1 Company A: Service Efficiency

Major Category	Metric Name	Description	Formula
Customer Satisfaction	Service Efficiency	This metric describes that, what is the efficiency of services that company A is providing to customers	Service Efficiency (SE) = (No. of Critical/Major bug request serviced / No. of Critical/Major bug request received) * 100

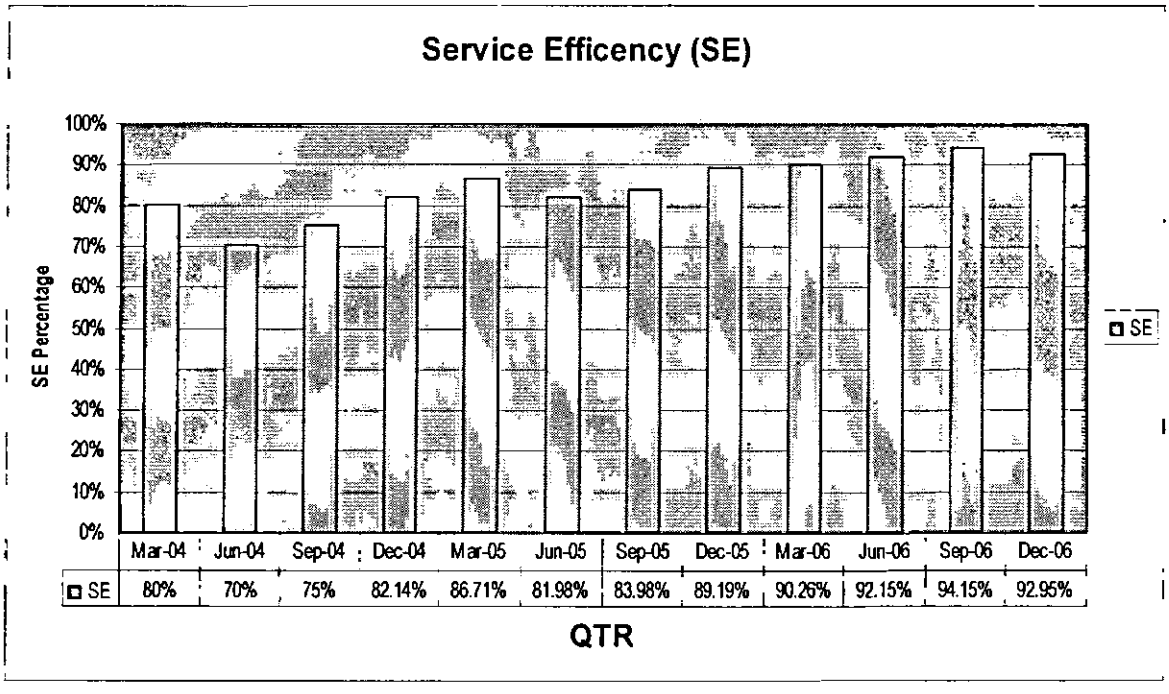


Figure 31: Company A: Service Efficiency

4.3.3.2 Company B: Service Efficiency

Major Category	Metric Name	Description	Formula
Customer Satisfaction	Service Efficiency	This metric describes that, what is the efficiency of services that Company B is providing to customers	Service Efficiency (SE) = (No. of Critical/Major bug request serviced / No. of Critical/Major bug request received) * 100

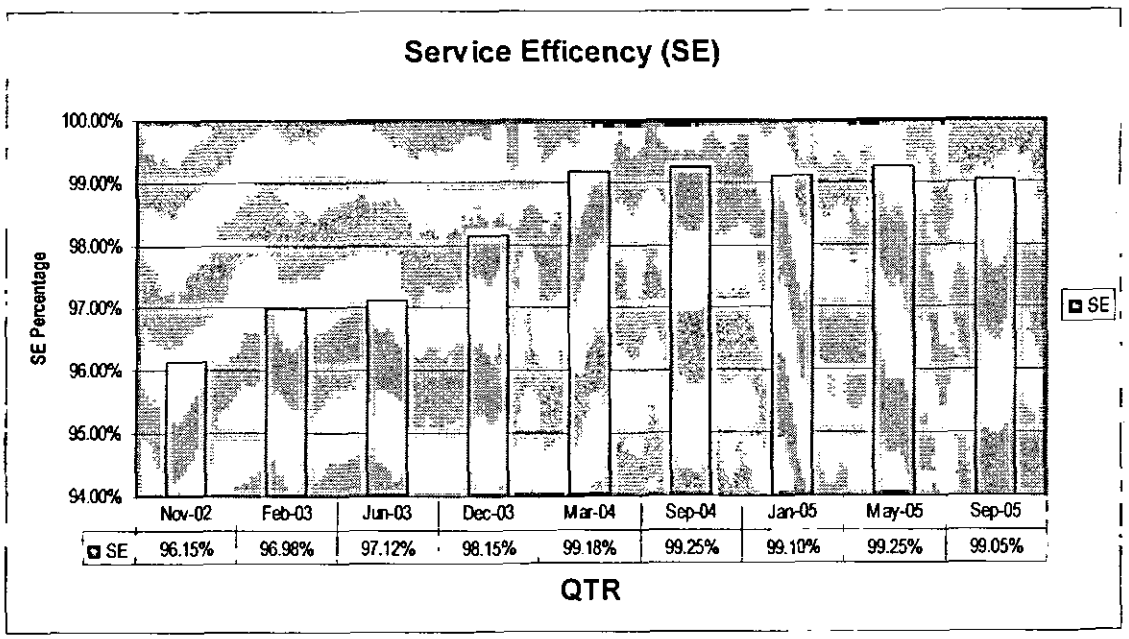


Figure 32: Company B: Service Efficiency (SE)

4.3.4 Comparative Analysis of results

While comparing and interpreting the results, following things are considered during this research:

- Every organization has different business objectives and driving process improvement and measurement programs according to it.
- Every organization has different targets for and thresholds for each metric.
- Every organization has different business model and limitations to implement the process improvement program.
- Organizations have different products and have to adapt different Software development life cycle for development.
- Organizations have International Presence and client base and therefore have corporate obligations

Above mentioned factors affect the performance of organization's to achieve desired results from the CMMI based process improvement program.

During performance results compilation and comparison, I have interpreted few measures, taken averages and medians to generate the comparable results.

In the first step results comparative analysis summary for both Company A and Company B is displayed. In the detailed results analyses section each category and involved metrics are analyzed in detail.

4.3.4.1 Results Comparative Analysis Summary

Following table shows the summary of CMMI based process improvement results. It shows that Company A has achieved higher performance results in all categories.

During Phase II interviews and overall comparison analysis it revealed that Company A implemented CMMI based process improvement program from scratch. When Company A started from very basic level and deployed dedicated Quality Engineering team which is not only improving internal processes of the company but also giving services to different companies in the Pakistan and world.

However on the other Side, when Company B started process improvement program. It was already a mature company with highly defined processes around the globe to deliver services to the customer. Products of Company B are mature have delivery time to market was very competitive. Although in comparison Company B has improved less than Company A but overall baseline values are higher than Company A.

Improvement Category	**Cost**	**Schedule**	**Quality**	**Productivity**	**Customer Satisfaction**	**ROI**
Company A	37%	52%	28%	16%	16%	15%
Company B	39%	46%	27%	10%	2%	8%

Table 16: Comparative analysis summary

Following graph shows the comparison of each category for Company A and Company B.

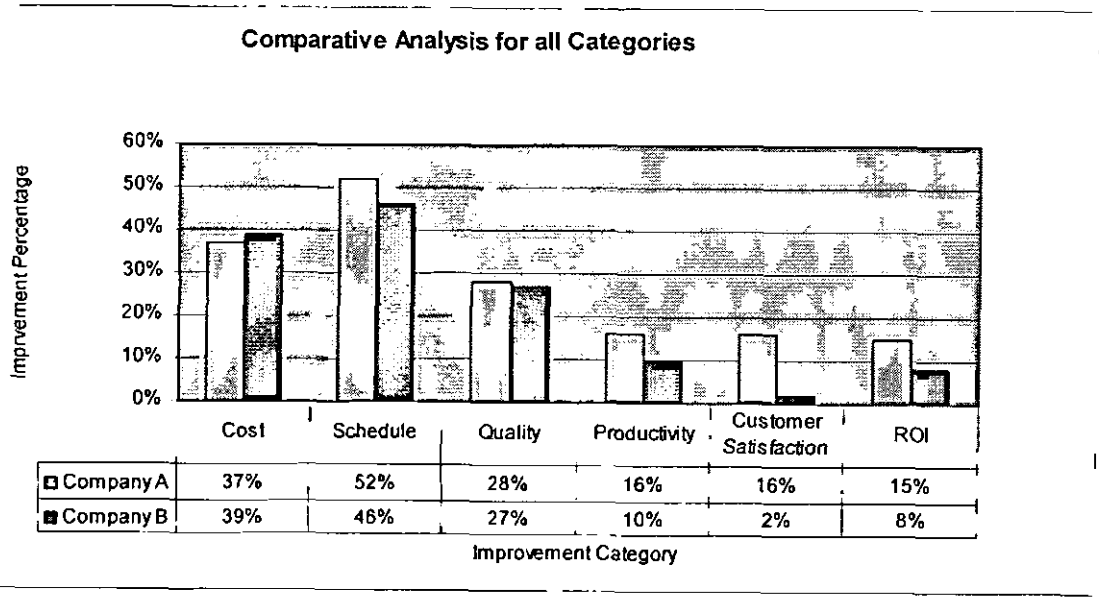


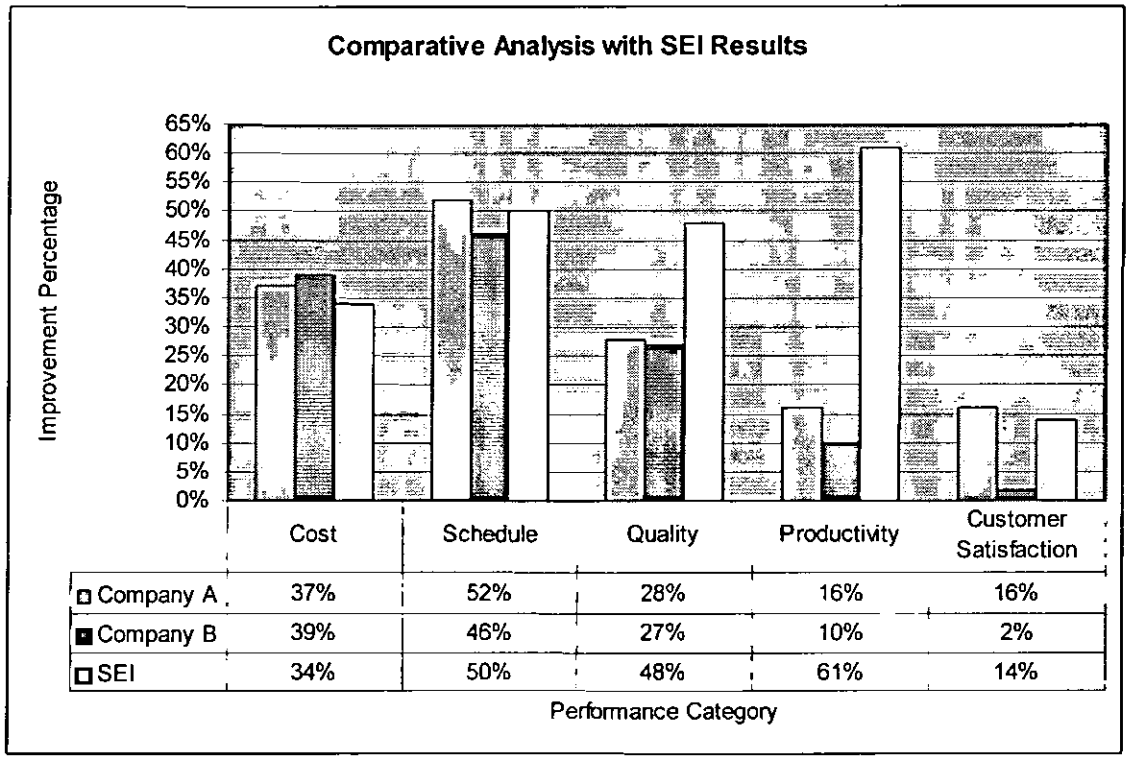
Figure 33: Comparative Analysis of All categories

Comparative Analysis with SEI

SEI compiled the results of 35 organizations from all over the world. These organizations were at different CMMI levels. However performance categories used during this analysis are same. Although Individual metrics associated with these performance categories are different at few places, especially in cost.

For comparison purpose and to get an idea how Pakistani high maturity software companies have performed against these international results.

Following graph and table shows the comparison details of each performance category.



	Cost	Schedule	Quality	Productivity	Customer Satisfaction
Company A	37%	52%	28%	16%	16%
Company B	39%	46%	27%	10%	2%
SEI	34%	50%	48%	61%	14%

Figure 34: Comparative Analysis with SEI performance Results

4.3.4.2 Detailed Comparative Analysis of all categories

Following section describes the details of each metric associated with major performance categories i.e. Cost, Schedule, Quality, Customer satisfaction and ROI.

4.3.4.2.1 Cost

In this performance category comparative analysis of two metrics are done Cost of Quality (COQ) and Cost of Poor Quality (COPQ). Getting data for Cost was very difficult task. However during research we tried to analyze available metrics which could help in analyzing, how CMMI based process improvement helped these companies in improving COST category.

Overall Company A improved 37% in this category in comparison to Company B which was 39 %. This improvement means that Company A and Company B reduced COQ and COPQ by this percentage.

Major reason for this more COST was that Company A started process improvement program from immature processes and have to invest a lot to improve its quality program. However on the other side Company B have to invest less to implement process improvement program in the company.

Cost of Quality (COQ) Comparison

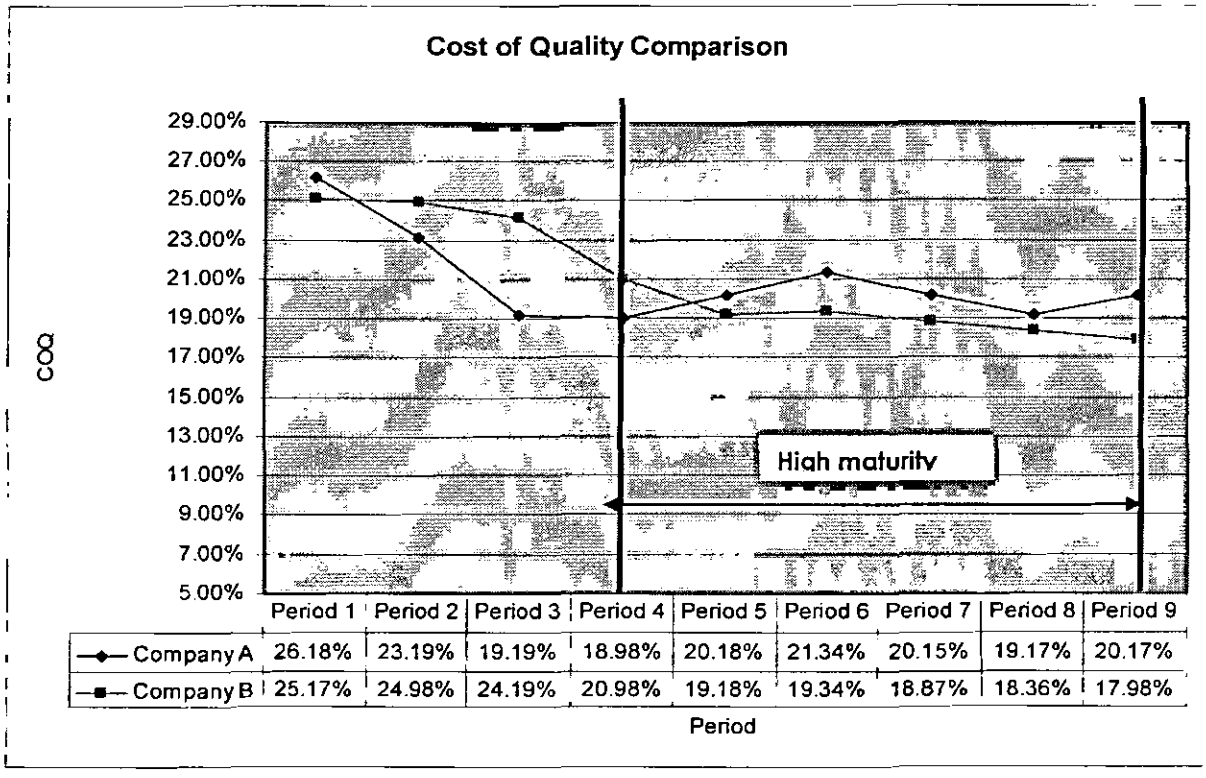


Figure 35: Cost of Quality Comparison

Cost of Poor Quality (COPQ) Comparison

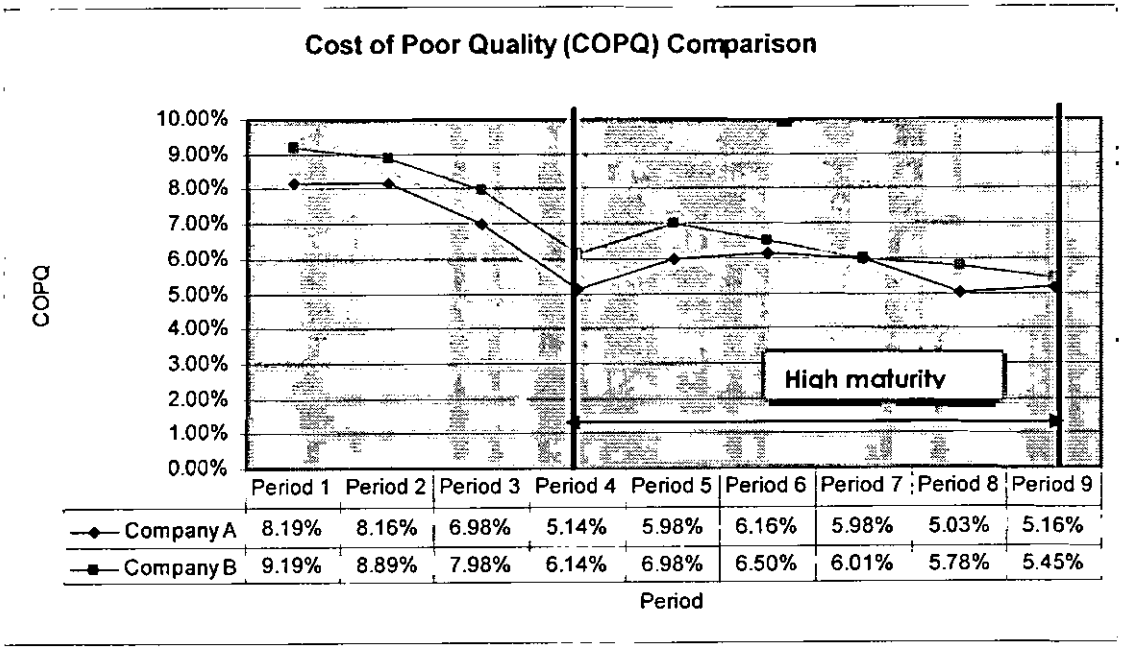


Figure 36: Cost of Poor Quality (COPQ) Comparison

4.3.4.2.2 Schedule

In this category comparative analysis of two metrics are done, SVP and EEA. These are two main metrics which helped the companies in building accurate estimates for Schedule effort and cost estimations.

Company A improvement ratio remained 52% in this category in comparison to Company B's 46 %.

SVP Comparison

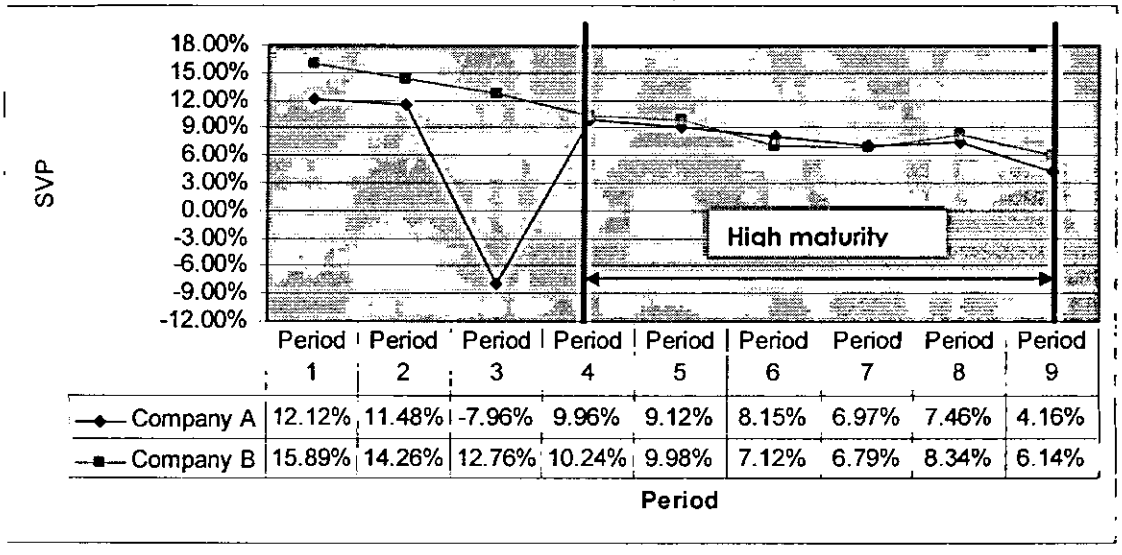
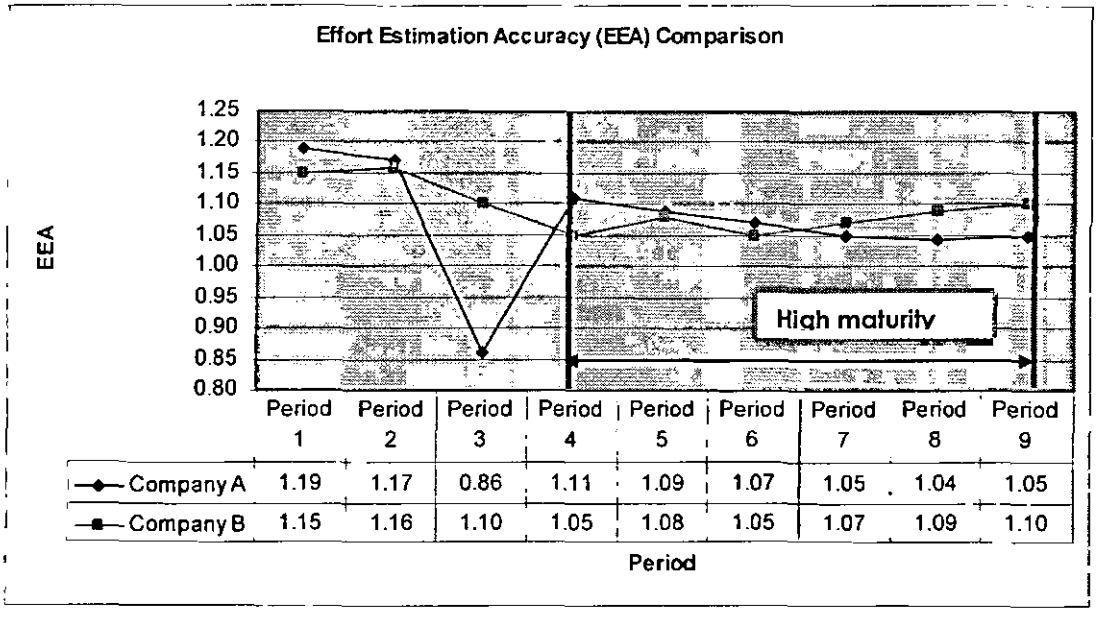


Figure 37: SVP Comparison

Effort Estimation Accuracy Comparison



	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8	Period 9
Company A	1.19	1.17	0.86	1.11	1.09	1.07	1.05	1.04	1.05
Company B	1.15	1.16	1.10	1.05	1.08	1.05	1.07	1.09	1.10

Figure 38: Effort Estimation Accuracy Comparison

4.3.4.2.3 Quality

Along with other categories, major performance category which every company wants to improve is Quality. In this category two metrics are analyzed in detail. Defect removal efficiency and Defect Density.

DRE performance in Company B remains consistent and higher. Major reason revealed during Phase II interviews was the mature products of the company. Although Company A performed very well for defect density and improved from 10.76 defects/KLOC to 7.5 defects/KLOC. However in comparison overall improvement was higher in Company B 47% as compare to Company A in which overall performance was 46%.

Major reason for higher values in Company B was the maturity of products. Company B is delivering mature products from many years. Over the years defects ratios has lowered in Company B products.

Defect Removal Efficiency (DRE) Comparison

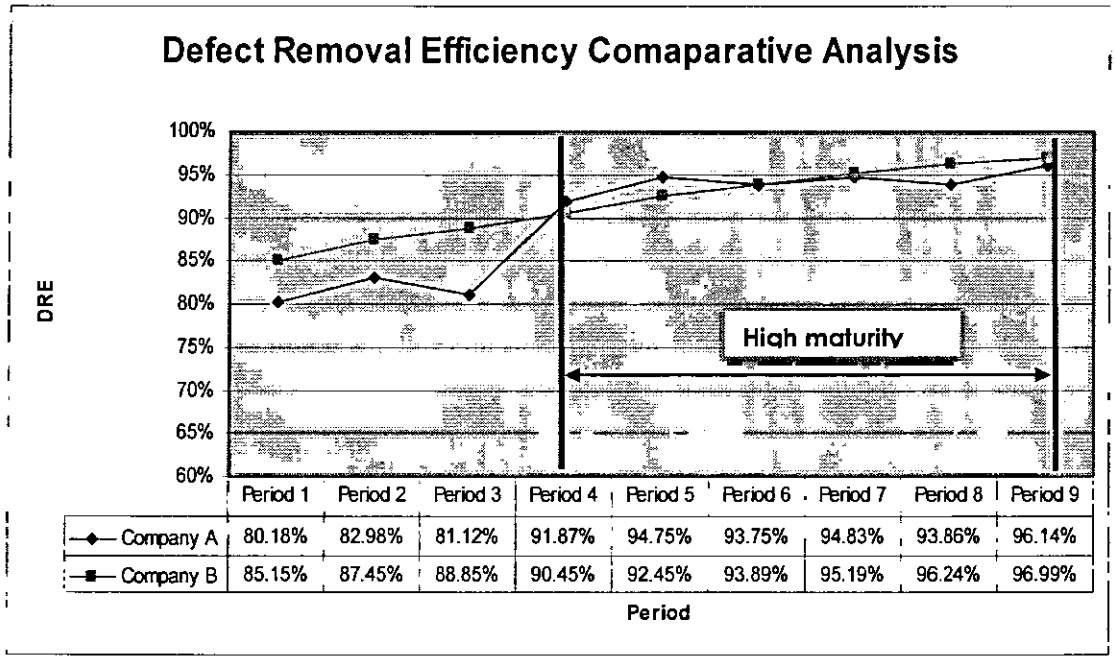


Figure 39: Defect Removal Efficiency Comparison

Defect Density (DD) Comparison

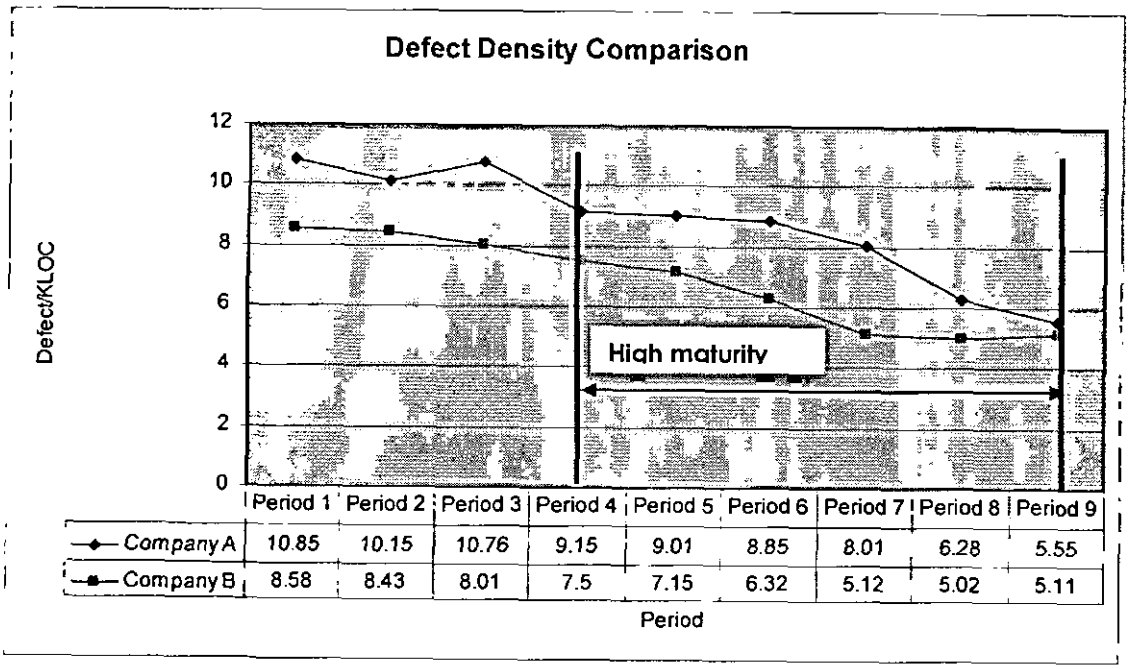


Figure 40: Defect Density Comparison

4.3.4.2.4 ROI

In this category following three metrics are compared for both companies. OSSP compliance, IRP and Employee turnover. However Employee turnover was not available for Company B. Therefore IRP and OSSP compliance are compared for both companies.

OSSP compliance was higher in Company A. Major reason for this higher ratio was due to the dedicated quality engineering department and frequent process compliance audits done in Company A.

Overall value of ROI was 15% for Company A as compare to Company B which was 8%.

OSSP Compliance Percentage comparison:

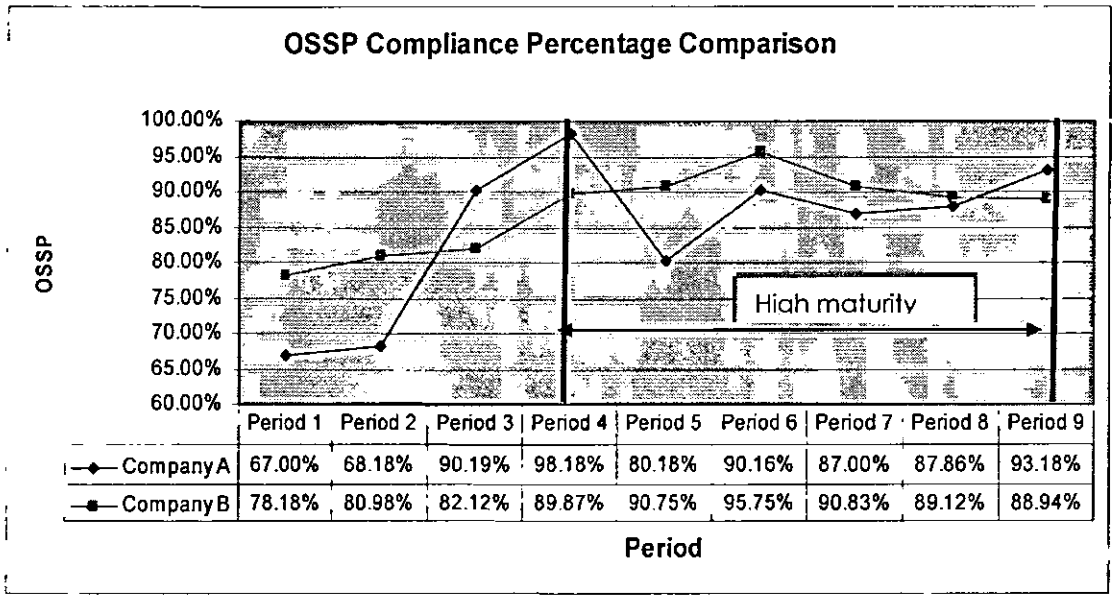


Figure 41: OSSP Compliance Percentage Comparison

Implemented Requirement Percentage (IRP) Comparison:

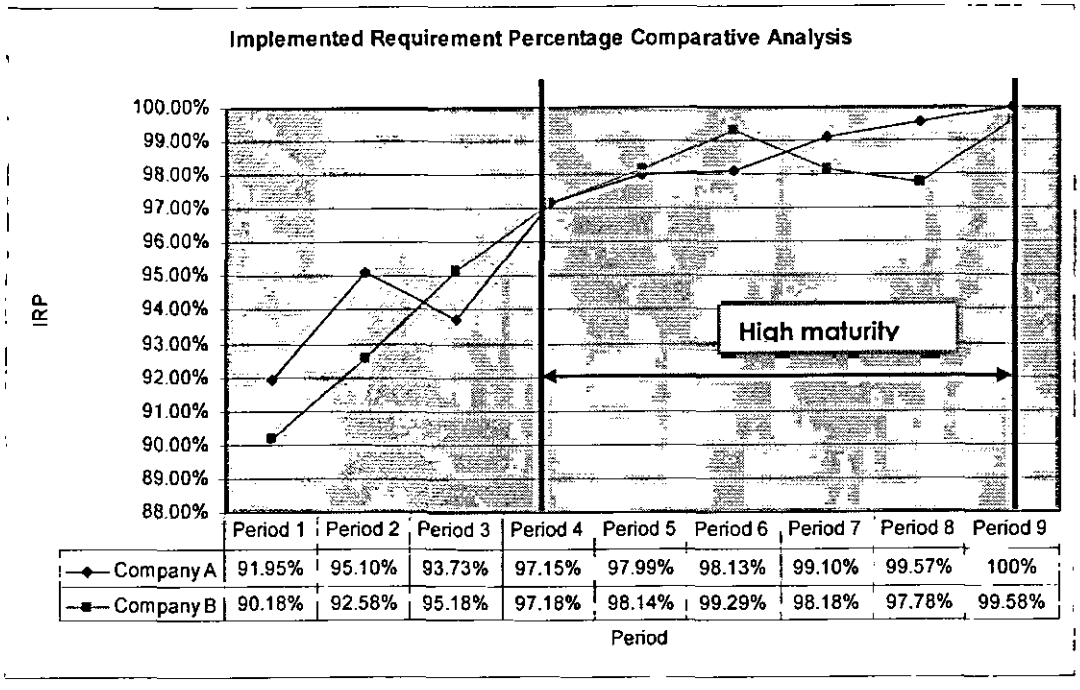


Figure 42: Implemented Requirement Percentage (IRP) Comparison

4.3.4.2.5 Productivity

In this category Productive hour percentage (PHP) metric is analyzed for both companies. PHP was higher in Company B. Major reason found during phase II interviews was company business model. As Company B was providing services to different clients and more projects are in support. Resources in Company B have to available to serve the customer all the time.

However overall improvement ratio for this performance category was 16% as compare to Company B's 10 %.

Productive hour percentage (PHP) Comparison:

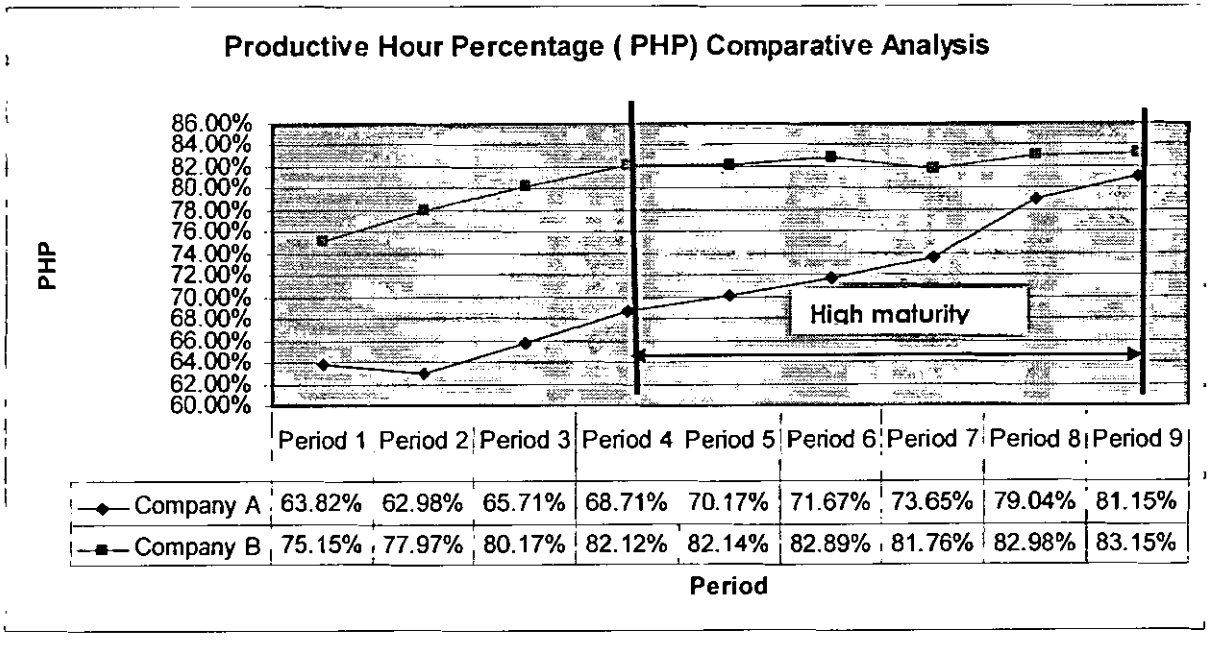


Figure 43: Productive hour percentage (PHP) Comparison

4.3.4.2.6 Customer Satisfaction

For Customer satisfaction category, Service Efficiency (SE) metric was analyzed. Although Company A improved 16% in this category in comparison with Company B's 2%.

However ending baseline values of Company B are much higher. Major reason for these variations is Company A improved its service efficiency from very low and corporate structure was very much mature in Company B due to their business model.

From graph we can see Company A did excellent work in the category.

Service Efficiency (SE) Comparison:

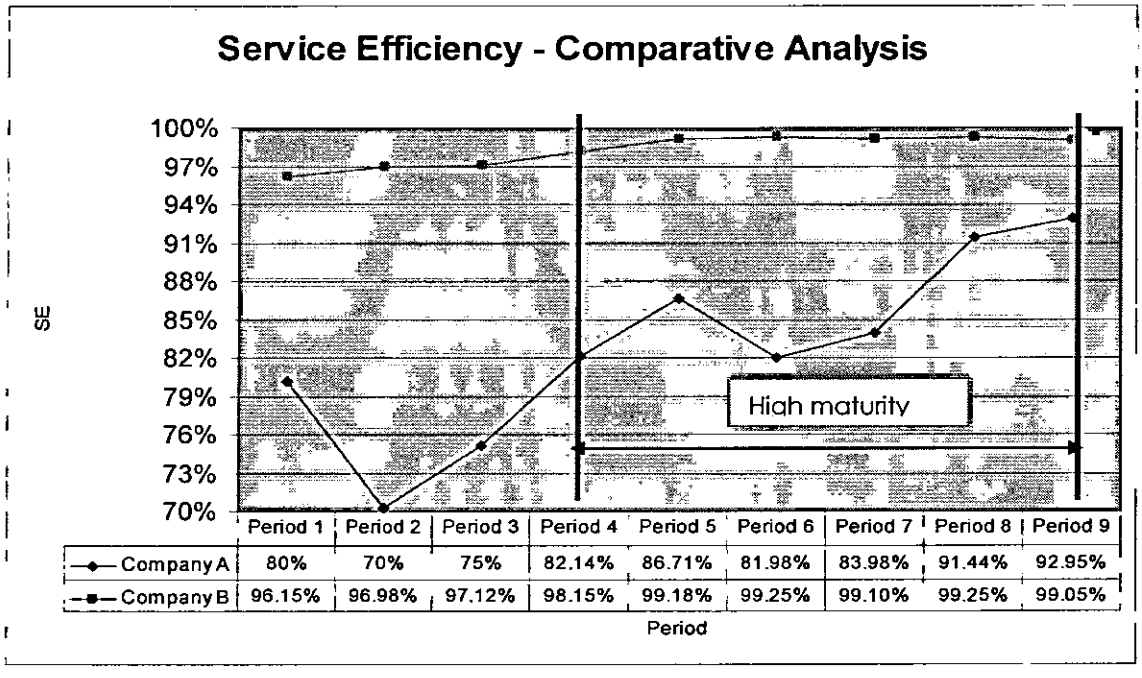


Figure 44: Service Efficiency Comparison

5 – Conclusion & Recommendations

Results of High maturity companies in Pakistan have shown tremendous improvement in all selected performance categories. These results were comparable to the results generated by SEI study. If implemented systematically companies can get enormous benefits. However to implement process improvement programs successfully companies need strong commitment from the top management, a dedicated team of process improvement professionals and quality culture in the company.

In Cost category the company B improved 39% as compared to Company A's 37%. In this category two metrics were analyzed, Cost of Quality (COQ) and Cost of Poor Quality (COPQ). For Cost of Quality (COQ) metric Company A improved from 23.19 % to 20.17 % while company B improved from 24.98 % to 19.03 %. The major reason for this difference was Company B started CMMI implementation with already mature processes and quality culture in place. They have to invest less in developing process improvement infrastructure in the company while company A started from scratch and have to invest more in the start. Other metric in Cost category was Cost of Poor Quality (COPQ), in this metric Company A improved from 8.16 % to 5.16 % and Company B improved from 8.89 % to 6.08 %. Company A improved more in this category due to efficient Process improvement infrastructure in place. Company A Used Control Charts to maintain the capability of the processes. Rigorous use of Controls charts helped the company A to operate in predictive mode.

In Schedule Category Company A improved 52 % as compared to Company A's 46 %. In this category two metrics were analyzed, SVP and Effort Estimation Accuracy (EEA). For SVP metric Company A improved from 11.48 % to 5.98 % and Company B improved from 14.26 % to 7.73 %. For Effort Estimation Accuracy (EEA), Company A improved from 1.17 to 1.15 and Company B improved from 1.15 to 1.08. In both categories Company A performed well. Major reason for this higher improvement was the nature of clients. Company A is working with more mature clients who have stable processes. This helped the company A to properly implement Requirement Development and management processes.

In Quality category Company A improved 28% as compared to Company B's 27%. For this category two metrics were studied, Defect Removal Efficiency (DRE) and Defect Density

(DD). Although overall the difference is marginal for this category for both companies. Major reason for this improvement was higher investment in COQ and more regular audits in Company A.

In Productivity category the company A improved 16 % as compared to Company B's 10 %. In this category, Productive Hour Percentage (PHP) metric was analyzed. For PHP Company A improved from 63.82 % to 75.98 % while Company B improved from 77.97 % 82.52 %. Although improvement ratio was higher for company A in this category, but ending baselines are greater for Company B.

In Customer Satisfaction category Company A improved 16% as compared to Company B's 2%. In this category Customer Satisfaction metric was analyzed. For Customer satisfaction Company A improved from 75.11 % to 89.19 %, while company B improved from 96.98 % to 99.14 %. In this category company A improved a lot, however ending values for Company B are way higher. The major reason for Company A higher improvement was they started from lower baselines while Company B started from Higher baselines. Secondly the business model of company B is service oriented therefore they have higher ending baselines in this category.

In Return over Investment (ROI) category company A improved 15% as compared to Company B's 8 %. In this category two metrics were studied, OSSP compliance and Implemented Requirement Percentage (IRP). For OSSP Company A improved from 68.18 % to 89.16 % while company B improved from 80.98 % to 90.31 %. Major reason for this difference was the Company A dedicated Quality Engineering team and audit frequency for the projects.

However, during Process improvement journey for High maturity levels, Company A improvement ratio was higher than Company B in Schedule, Quality, Productivity, Customer satisfaction and ROI performance categories. Company B improvement ratio was higher in Cost category. However from results comparison graphs it is evident that improvement variations in both companies for cost, schedule and quality are marginal.

It is a fact that overall improvement ratio for most of the performance categories of Company A remained higher due to dedicated Quality engineering team and frequent audits. However, one finding which is very important to mention here is that Company B started from higher baseline values for all performance categories while Company A started from lower baseline values. Although Company A improvement graph was higher but closing baselines are still higher for Company B in most of the individual metrics.

During study of Case studies of the companies in other part of the world and during my study of Pakistan High maturity companies in Pakistan, I have found that focus on following activities can help companies while attempting for High maturity levels:

1. High maturity Levels and especially CMMI L4 have lot of requirements for metrics and measurements. However it does not mean measuring more metrics and involving more people for reviews will return more value from L4 and will help more in Process improvement program. The key to achieving high maturity is measuring right metrics, using right techniques to analyze and generate the required results.
2. We should wait for the right data to start work on high maturity levels.
3. In CMMI L4 Control charts are used for checking the process stability, however this is not the end of world. The requirement is only to use thresholds based on specification limits is an acceptable alternate for the Quantitative project management implementation.
4. In industry there is understanding that HM levels can only be applied if the company has big projects. However in reality there are only few sub processes which required that must be statistically managed before the implementation of High maturity levels.
5. Organization should understand High maturity levels are difficult and complex in nature. These process areas training should not arranged a single presentation or overview presentation. Detailed learning is often required at all levels for effective implementation of CMMI high maturity levels.
6. From the current research it is evident that dedicated Process improvement group or quality engineering team could help more in achieving the Process improvement objectives for the company.
7. ROI for lower maturity levels are rapid and can be seen quickly. However calculating ROI can be very difficult. There while calculating ROI direct and indirect benefits should be taken care.

8. Most of the companies first run into trouble when attempting to implement Level 4 because they have not established baselines for performance. If you do not have current baselines, how can set estimates, improvement goals, Upper acceptable and lower acceptable limits for cost, schedule, quality and other performance categories.
9. Companies should understand the real aspects/attributes of process performance versus building control charts purporting to show stable processes is another misapplication of Level 4 methods. A control chart showing that you have a stable process is meaningless unless it contains a useful and valid relationship to the work being performed.

Data gathered during the research, I found that following strategies can optimize the Process improvement results.

1. Focus on improving new projects. It is extremely difficult to change projects, once they have started. By saying this I do not mean that Process improvement activities can not be applied on running projects, however it become difficult as some time company have different understanding with client on delivery timelines and other documentation requirements.
2. Adopt a top-down focus before immersing yourself in CMMI details; start by assessing the intent of each PA so that you can determine how it fits into your environment.
3. Emphasize productivity, quality, and cycle time. Avoid process for its own sake.
4. Management commitment is needed from all levels; commitment from upper management won't be enough unless individual project leaders and managers are also determined to succeed.
5. Practitioners and task leaders from inside the company, not outside process experts, should be used to define processes. This will help in building institutionalization.
6. Especially Managers should be convinced of process improvement's value; it's not free, but in the long run it more than pays for itself.
7. The customer must be kept informed about the process, especially when process changes occur.
8. Copying process documents or buying the box solutions from other organizations usually does not work well; the process must match your organization needs. Every

organization has different culture and has different business objectives. Your process documentation should target the business objectives of your company.

9. Handling resistance to change is probably the most difficult rung to climb on the SEI CMMI ladder. Process change takes time, talent, and a commitment that many organizations are uncomfortable with. Based on our experience, we believe the investment is worth it.

I have compared the results of SEI for CMMI based process improvement for High maturity software companies in Pakistan. Research can be further extended to all maturity levels or to only lower maturity levels to generate the wider sample for results. However researcher should keep in mind that data gathering can be difficult job while pursuing research in this area. I found it very difficult to find data for all performance categories and especially for Cost.

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7 – Glossary

SEI: Software Engineering Institute

CMMI: Capability Maturity Model Integration

DOD: Department of Defense

PSEB: Pakistan Software Export Board

CMMI: Capability Maturity Model Integration

DACS: Data & Analysis Center for Software

HM: High Maturity Levels

ROI: Return over Investment

High maturity Level: Companies appraised at CMMI L4 or CMMI L5 are called high maturity companies.

OSSP: Organization set of standard processes

ROI: Return over Investment

SPI: Software Process Improvement

DD: Defect Density

SVP: Schedule variance percentage

LAL/UAL: Lower acceptable limit/Upper acceptable limit

Appendix A

Questionnaire

Appendix A

Questionnaire

Interviewee Name: _____ Dated: _____

Designation: _____ Company:

_____

1. What is the EPG structure in your organization?
2. How many people are working in QE department?
3. What is Process definition, review and approval process?
4. What methods have you used to improve your software process?
5. How frequently internal audits are conducted for your organization?
6. What methods are you planning to use to improve your software process?
7. How will you introduce the selected software process improvement methods?
8. What problems are you anticipating in improving your process?
9. What are the benefits you have realized after achieving CMMI L5?
10. What are the major issues resolved with CMMI based process improvement?
11. What kinds of artifacts are generated in your company?