Software Process Improvement: A Systematic Review

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By

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1 - systems

2. systems analysis

Faculty of Basic & Applied Sciences

Department of Computer Science & Software Engineering

FINAL APPROVAL

It is certified that we have read the thesis, entitled "Software Process Improvement: A Systematic Review", submitted by Zil-e-Huma Reg. No. 290-FBAS/MSSE/F09. It is our judgment that this thesis is of sufficient standard to warrant its acceptance by the International Islamic University, Islamabad for MS degree in Software Engineering.

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Declaration

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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

PARENTS,

TEACHERS,

AND

MY HUSBAND

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

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Abstract

***CONTEXT**: Software Process Improvement (SPI) initiatives create new and improve existing processes to increase productivity, customer satisfaction, quality of product while reducing cost, and time to market thus maximizing Return on investments. During the last decade the software industry is paying a lot of attention towards software process improvement (SPI). As a result today there are a various models, frameworks, methodologies and initiatives for SPI e.g., the Quality Improvement Paradigm (QIP), the IDEAL model and SPICE, CMM, CMMI (Capability Maturity Model Integration), ISO and Bootstrap.*

Problem with SPI is not to develop the model but how to use these models. That is the reason there is not as much amount of work on real implementation of SPI. Literature has evidence about the successful SPI implementation but SPI is considered as problematic activity due to its reluctant nature. Software Process Improvement (SPI) of any kind requires a substantial contribution of effort, time, resources and money. Hence literature is also evident about the SPI implementation problems.

***OBJECTIVE**: The main focus of research is to know about the state of art in SPI and to find out the strength of evidence in empirical work reported within SPI literature. This research is aimed to systematically review the empirical studies of SPI (Case studies, Experiment, Survey, Experience report). The objective is to gather the empirical work from different SPI domains at a single place to know about the state-of-the art in empirical literature of SPI. Few numbers of SLRs have been conducted on SPI but those are domain specific and for limited time of starting ending date. They do not give an up to date picture of SPI from all SPI areas.*

***METHOD** – Methodology of systematic literature review (SLR) is used. A protocol has been developed and executed. Search strings developed and mentioned in the protocol were applied to the databases to extract relevant papers. A set of papers were identified after reading abstracts of papers extracted after application of search string. A quality criterion was applied on this set to finally select the studies for data extraction. For analyzing the data frequency count is used for quantitative data and technique of thematic analysis is used to analyze the qualitative data.*

***OUTCOME**: The outcome of this research gave current picture of SPI. Results showed that the people involved in carrying out the SPI activities are the most important part of SPI. People related motivators are the highest scored motivators for SPI. Staff and management are the key*

success factors of SPI. But surprisingly most of the SPI implementation problems also fall in the staff and management categories. Results also made it clear that after 2009 the industry is focused on SI implementation and CMMI is the most used reference model. There exist a number of tools, techniques, methods and models for successful implementation of SI but among all these models are highly used and most of the models are inspired by CMMI. That is the reason CMM and CMMI are the rich area of SPI with extensive work. Other areas with good amount of work are Requirement Engineering process improvement, Assessment and Personal software process. The areas that demand for more work are configuration and knowledge management, software development process improvement, measurement and architecture maturity. Strength of evidence is calculated by research methods, data collection methods and study settings. This SLR is very helpful for all the practitioners of SPI in software industry especially for the developers and managers. It has many opportunities for further research so it is also very useful for researchers of SPI.

Chapter 1: INTRODUCTION

1. INTRODUCTION

Software process improvement has become the key approach to improving software quality and reliability, bringing employee and customer satisfaction, and getting return on investment. During the last decade the software industry is paying a lot of attention towards software process improvement (SPI). As a result today there are a various models, frameworks, methodologies and initiatives for SPI e.g., the Quality Improvement Paradigm (QIP), the IDEAL model and SPICE, CMM, CMMI (Capability Maturity Model Integration), ISO and Bootstrap. These models provide set of guidelines and practices to carry out the development process. Software Process Improvement (SPI) of any kind requires a substantial contribution of effort, time and money from the organizations that try to follow it. Niazi [1] calculated results from literature to prove the impact of SPI on improving high quality product, customer satisfaction and reducing development cost and time; and these are the main reasons to go for SPI.

Enough amounts of empirical studies exist in literature but most of them are exploratory in nature. They focus on the identification of problems caused by SPI and solutions are provided on general level. And those solutions are fit in some specified context. There is no standard or recipe for the successful implementation of SPI. Most of the studies provide frameworks/models for SPI but their true implementation is not carried out in real context and if implemented; it is for some specific sub area of SPI. Although in some studies successful initiation of SPI has been discussed as well.

Our focus here is to systematically review the empirical studies on the SPI. This systematic review is not for any specific sub area of SPI. Rather it is on broader level and covers all empirical studies relevant to SPI from all sub areas of SPI. And this SLR is not for any defined interval of time. Date constraint is not put in search. This SLR will be very useful in knowing the sate of art in SPI. With the help of SLR we will come to know the actual practices being used for SPI, tools, models and techniques. Barriers in the initiation of SPI will also be clear. So it would be very easy for the other researchers and practitioners to know from this SLR that what SPI area requires more work and most of the empirical work belongs to which areas of SPI. This SLR will also be very helpful for future research of SPI.

1.1 Problem Discription

In the field of SPI few number of Systematic reviews have been conducted in the sub areas of CMM [2], SPI for small & medium companies [3] [6], evaluation framework for SPI [4], Evaluation and measurement strategies for SPI [5]. The problem with these SLRs is that these are not only for some specific sub area but also for some defined interval of publications based on starting and ending date.

Our work is different from others in terms of scope and objectives. This SLR is for all sub areas of SPI to collect empirical evidences. Results will be obtained without date restriction up to 2011. Unlike other SLR on the subject, we are not targeting specific sub area within the concept but we will cover all empirical studies relevant to SPI from all sub areas of SPI. Secondly search

is not restricted to any specific range of starting/ending date. Results will be obtained for entire range of publications up to 2011.

1.2 Objtctive Of the Study

The objective of this study is to systematically review the empirical literature on the Software Process Improvement (SPI). We are talking about the state of the art in SPI. Empirical studies (case study, experiment, and survey and experience report) relevant to any SPI area are our concern. The aim is to bring the empirical work at a single place from different sub areas of SPI. There is no restriction for starting or ending date on search process until restricted by any database. So the objective is to show the up to date work in empirical SPI. This SLR will be very useful in knowing the sate of art in SPI. With the help of SLR we will come to know the actual practices being used for SPI, tools, models and techniques. Barriers in the initiation of SPI will also be clear, so it would be very easy for the other researchers and practitioners to know from this SLR that which areas of SPI belongs to most of the empirical work and which area is under lack of consideration. This SLR will also be very helpful for future research of SPI.
Major inspiration of this SLR is from [40]. They conducted same SLR but for Global Software Development (GSD). We modified the all the procedure according to our area of study i.e. Software Process Improvement (SPI).

1.3 Methodology: Systematic Literature Review

Systematic reviews aim to provide the means for carrying out literature reviews that are thorough and unbiased, such that their results are of scientific value. Initially, Systematic Literature Review (SLR) was used to support evidence based medicines. Many steps were defined according to that view point. B. Kitchenham customized those steps and provided guidelines how to use SLR in Software Engineering [7]. Kitchenham defines SLR as:
"A systematic literature review (often referred to as a systematic review) is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest."
I decided to use this methodology because it has more efficient feature than the conventional review like these are more clear, unambiguous, unbiased and in a defined systematic way. Systematic reviews aim to provide a comprehensive summary of existing empirical literature about a defined question but in a systematic way.
Some of the features that differentiate a systematic review from a conventional expert literature review are:

- Systematic reviews start by defining a review protocol that specifies the research question being addressed and the methods that will be used to perform the review.
- Systematic reviews are based on a defined search strategy that aims to detect as much of the relevant literature as possible.
- Systematic reviews document their search strategy so that readers can assess their rigor and the completeness and repeatability of the process (bearing in mind that searches of digital libraries are almost impossible to replicate).
- Systematic reviews require explicit inclusion and exclusion criteria to assess each potential primary study.
- Systematic reviews specify the information to be obtained from each primary study including quality criteria by which to evaluate each primary study.

- A systematic review is a prerequisite for quantitative meta-analysis.

According to Barbara's guidelines three main phases are defined in SLR i.e. Planning, Execution and Reporting the review.
Protocol document is the outcome of first stage planning the review. Figure 1 shows the associative activities with each phase.

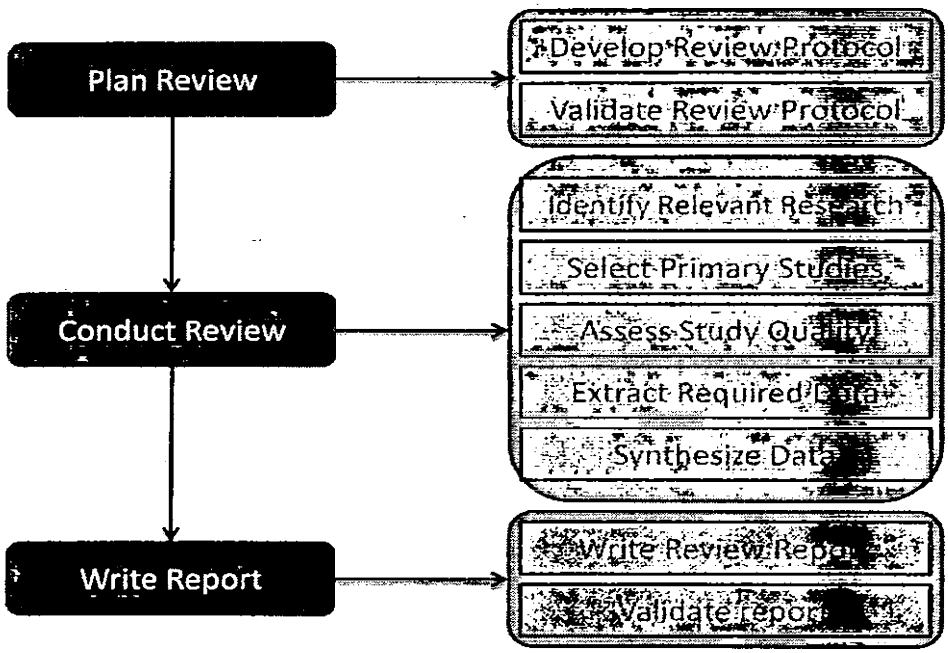

Figure1 SLR Steps

Following information must be contained inside the protocol and is part of systematic review planning.

1.3.1 Formulating the Research Questions (RQ)

Formulating the research question is the most important part of any systematic review. Research question drives the entire systematic review methodology in the following way:

- Search for those primary studies that address the research question
- In data extraction phase data items must answer the research question
- And in the analysis phase data must be synthesized in such a way that research question can be answered.

For clear understanding structured approach is used while constructing research question. Structured question has the following parts:

- Population
  - People, projects types, applications types affected by the intervention
- Intervention
  - Software method, tool, procedure
- Comparison
  - What is the method/tool/procedure being compared

- Any constraints on type of primary studies to be included for comparison
- Outcomes
  - Impact of technology in terms relevant to practitioners
    - Cost, quality, time to market
- Context
  - The context in which the experiment/research is being carried out e.g. academia or industry

1.3.2 Search Strategy

Search strategy defines the steps that will carry out the actual search process. It is necessary to follow the search strategy. Common way of search strategy for research question is to break it in some major parts, identify synonyms of each term and then construct sophisticated search string by using "AND" and "OR" operators.

1.3.3 Study Selection Criteria

Once the primary studies are obtained they are checked for their direct relevance to the research question. Only those primary studies are selected that provide direct evidence to the research question. Study selection is multistage process. Primary studies can be selected on the title and abstract basis. In the next step full copy can be obtained for further in depth inclusion/exclusion decision. Criteria is defined that n which basis the studies will be excluded or included e.g. on the basis of languages, settings, date of publication etc.

1.3.4 Study Quality Assessment

In addition to general inclusion/exclusion criteria it is considered critical to assess the quality of the study. For that purpose a quality instrument is developed that is composed of checklist of factors that need to be assesses in every study and relevant scores are assigned. But the problem is there is no agreed quality instrument. So it must be formulated according to type of research question with the help of many checklists provided in the literature. The assessment scores of the studies help in the analyses phase to judge how reliable the results are. These checklists are also helpful in reducing the biasness of researcher.

1.3.5 Data Extraction

The objective of this stage is to design data extraction forms to accurately record the information researchers obtain from the primary studies. To reduce the opportunity for bias, data extraction forms should be defined and piloted when the study protocol is defined. The data extraction forms must be designed to collect all the information needed to address the research questions. Data extraction forms have the data items for general study information like publication date, abstract, aim etc and specific data items to answer the research question. Data extraction forms must be piloted on some studies to check its completeness and accuracy but it is possible that data extraction forms evolve as the protocol is executed.

1.3.6 Synthesis

This is the phase where we decide how data will be analyzed after extraction. In systematic reviews the researcher gets qualitative and quantitative both types of data. The guidelines [38] suggest that when researchers have a systematic literature review that includes quantitative and qualitative studies, they should:

- Synthesize the quantitative and qualitative studies separately.
- Then attempt to integrate the qualitative and quantitative results by investigating whether the qualitative results can help explain the quantitative results. For example qualitative studies can suggest reasons why a treatment does or does not work in specific circumstances.

1.3.7 Reporting the review

After the synthesis the results should be summarized. The last stage is reporting the systematic review and this output is called technical report. It contains information about all the steps when you plan and execute the protocol. There is need to keep the detailed record of what happened in conducting review it is mentioned in the review report. It points out the deviations from protocol and the reasons to those deviations.

1.4 Thesis Organization

This first section was about introduction of the research and the methodology to carry out that research. Remaining sections are organized as: Chapter 2 is about defining the protocol it contains information how actual protocol was defined and what steps were defined to conduct SLR. Chapter 3 tells about executing the protocol. How each defined step was achieved and what are the deviations from protocol definition. Chapter4 describes the results that were achieved after executing the protocol and how these results were analyzed to draw conclusion. And finally chapter 5 concludes the results of last step and describes the principal findings that were obtained as a result of this SLR and the future implication of this effort.

Chapter 2: PROTOCOL DEFINITION

2. Protocol Definition

2.1 Background and Motivation

Any software process should be continuously improved to become a standard execution guide. When a software process is immature it means it is executed without set of guidelines and practices, and the outcome of a project depends largely in the way the practices are carried out. Process capability is an inherent ability of a process to produce desired/planned results. When a process is capable of doing this, it is called mature. The main objective of mature process is to produce the quality product that meets the customers' need. And to achieve this task the continuous improvement is required in overall process.

The history of process maturity and foundation of SPI starts from the establishment of Software Engineering Institute (SEI) at Carnegie Mellon University in 1984. SEI was established by US Department of Defense (DoD) for making standards of excellence for software engineering and to speed up the evolution of advance technology [8]. Watts Humphrey was founded the software process method and served as director of program from 1986 until the early 1990s [9]. SEI released the technical report of process maturity model in 1987 [8] and later on by Humphrey [10] [11]. In 1987 highly influential paper of Leon Osterweil, in which there was great emphasis on formal models, was published around the time Watts Humphrey developed the first CMM version [15].
Basic principles of that method were based on statistical process control and concepts of Deming, Juran, Crosby and others [16]. These early ideas became the foundation for Capability Maturity Model (CMM) released in 1991[41]. CMM characterized the levels of maturity based on key process areas that define practices/activities/improvements for each process area [42]. This structure of CMM provided basis for upcoming models CMMI, PSP, TSP and others.

There are various models to guide SPI initiatives— such as, CMM, CMMI (Capability Maturity Model Integration), ISO and Bootstrap. These models provide set of guidelines and practices to carry out the development process, but successful SPI requires efficient change management, it does not matter what the model is adopted [16].

Many models and techniques are suggested in literature that tells about the guidelines for SPI. But for their implementation very little amount of work exist in literature. Though, the concept of SPI was realized in 1980s but literature shows that most of the work was started after 1990s. Recently the trend is moving towards the implementation of these guidelines (models). Among all other models comparatively more empirical work exist in literature on the implementation of CMMI on different levels and perspectives: such as CMMI Level3 implementation for specific practice-requirement change management [17], high perceived value practices for CMMI Level2 [18], comparison of CMMI and SPICE [19] and integrating CMMI with Six Sigma [20].

Some empirical work has been done on successful initiation of SPI programs in small and medium organizations (SMEs) [21] [22] [23] [24]. However, the research efforts to date are limited, inconclusive and without sufficient theoretical rationalization [25].
As we discussed above that SPI methods are characterized by process areas. So each empirical study belongs to some process area(s) of SPI. Some explore Organizational area of SPI [25] and [27] while other focus project management [26]. Similarly other areas as process management, project management, support, supply also have work done as well. So this SLR will help out to find which area is under more consideration and which is being ignored and why is it being ignored (challenges).

History of SEI shows that quality was the main reason to initiate software process improvement (SPI). Because Humphrey's personal role at that time was to improve quality and productivity in software development and to simplify the software crisis. However, literature tells about many other reasons\causes\factors to initiate SPI. For example to reduce software development cost, to reduce time-to-market, to improve management visibility in software development, to increase productivity, to improve the quality of the software developed, to meet customer requirements, to automate the production of relevant development documentation [27], to improve cost and schedule predictability (business reasons), improve quality and due to customer support [29]. While some SPI motivators are related to developers, project managers and senior managers [28].

Software Process Improvement (SPI) of any kind requires a substantial contribution of effort, time and money from the organizations that try to follow it. Despite of enough empirical work on SPI literature shows that SPI is a problematic activity [30]. Change management theory suggests four related organizational elements must change to have lasting effects: process, structure, people, and management [31]. So to implement SPI means to get ready for change at large scale. It requires commitment, resources, and skills at all organizational levels, and the most important thing is it carries a large risk of failure. So many organizations are reluctant to adopt the change. Even they hesitate to absorb the minor change either in process or in infrastructure. And those who try to adopt that change do not fully succeed. Many companies give up SPI effort and one possible reason is that their goal is just to achieve a particular certification level rather than letting the process of reaching the goal be their reward.

The reluctant nature of SPI put barriers in the initiation and therefore little amount of work exists in literature about actual initiation of SPI. Although literature has enough models and techniques about SPI but the most challenging issue that the SPI field is facing today is how successfully to implement the SPI? It is not the problem with SPI to develop models and standards but the main problem is how to successfully implement those models [28]. Regardless of so many techniques, tools and models why SPI is not successfully implemented; it was imperative to identify the obstructions. Literature has empirical evidences for these challenges such as: the resistance factors implementing SPI [32] [34], cultural differences affecting the initiation of SPI [33], organizational readiness to implement SPI [26] and other demotivators of SPI are discussed in [35][36].

In the field of SPI few number of Systematic reviews have been conducted in the sub areas of CMM [2] [39], SPI for small & medium companies [3] [6], evaluation framework for SPI [4],

Evaluation and measurement strategies for SPI [5]. These SLRs are limited not only sub area specific but also for some defined interval of publications.
Our work is different from others in terms of scope and objectives. We are conducting SLR for all areas of SPI; any empirical evidence related to SPI is our concerned. Secondly we are not limiting our search to any specific starting and ending date. Results will be obtained without date restriction up to 2011.
From this SLR we will come to know about the state of art in SPI at broader level. This SLR would be very helpful not only in summarizing the empirical data but will also be helpful in finding the following patterns and many other.

- What type of tools, techniques and models etc are being used in the world to implement SPI?
- Which of the areas of SPI are under more consideration and where more work is required?
- Where is the gap in literature concerning SPI?
- Problems in implementing SPI

2.2 SLR Protocol

Protocol defines the number of steps that were decided to carry out Systematic review and the strategy to perform those steps as well. These are the set of guidelines to perform SLR. All types of constraints are mentioned inside the protocol before actually conducting the SLR. Thus defining the protocol limits the biasness of researcher in deviating from standard steps. Following are the sections that were defined in the protocol in planning phase.

2.3 Research Questions

One of the rationales for this SLR was to summarize the existing evidence concerning SPI. So evidence based investigation was mainly focused. To understand state-of-the-art in Software Process Improvement, in terms of gaps and commonalities in existing empirical results, the following two research questions were formulated The research questions were formulated to form a baseline for state-of-the-art and hence the objective was that the systematic review should form a stepping-stone for both future research and for practical use by practitioners. Thus, the research questions were as follows:

RQ.1: What is the state-of-the-art in SPI?
RQ.2: What is the strength of the evidence reflected in the empirical literature on SPI?
The aim was to understand the existing research directions within software process improvement and in particular empirical research on the topic. The latter is particularly important since it provides information about what we actually know in terms of having evidence. Empirical findings may vary due to the strength of the studies, taking aspects such as sources of evidence and research approaches into account. Some researchers explore the impact of SPI by conducting experiments either on large or small companies (SMEs). While others present survey that more exploratory in nature (empirical based). Case studies exist in literature to check the impact of SPI initiation.

- ***RQ.1: What is the state-of-the-art in SPI?***

This question was decided to answer in the form of where, what, how and why. Following sub questions were derived from RQ1 to answer it.

1.1 What are the geographical locations of the companies involved in SPI? *(Geographical location of organizations)*

1.2 What are the challenges/issue/problems of SPI?

1.3 What research topics in SPI have been addressed so far?

1.4 What are the tools and models used for SPI?

1.5 What are the future directions for SPI i.e. what type of more work can be done in SPI?

1.6 What people and institutions are most active in this area and who is leading the research?

1.7 Categorization of the empirical observations in terms of success and failure, i.e. how successful are the cases reported (how);

1.8 How many SLRs have been published in the area of SPI?

1.9 Reasons for going to engage in process improvement i.e. Motivators of SPI (why).

1.10 Improvements reported in empirical literature of SPI in terms of success or failure?

The strength of the empirical evidence in the field provides important information when making decision both about future research and how to practice distributed development globally. Thus, we derived second research question from the results of first research question

- ***RQ.2: What is the strength of the evidence reflected in the empirical literature on SPI?***

Following data will be extracted to answer RQ2:

- Sources of evidence (methodological)
- Research approach (academic, industrial etc)

It was decided that the strength of evidence will be determined by counting the studies frequencies for each SPI area.

From those frequencies it was decided to find out which area is under more consideration and which area is under lack of attention. (Gap in literature)

The major question was RQ1 and the RQ2 was derived from RQ1, so it will be answered by the results of RQ1. No separate search string and inclusion/exclusion criteria were defined for RQ2. It can be understood as the RQ2 is sub part of RQ1.

Structured Questions:

RQ.1: What is the state-of-the-art in SPI?

- **Population:** software projects
- **Outcome:** SPI challenges/problems, geographical areas where SPI is more in practice, tools, techniques and models for SPI, SPI success factors, reasons to initiate SPI initiatives
- **No Intervention, No Comparison**

RQ.2: What is the strength of the evidence reflected in the empirical literature on SPI?

- **Population:** software projects
- **Outcome:** frequency of studies in different areas of SPI, **SPI** areas with extensive work, SPI areas that require more work
- **No Intervention, No Comparison**

2.4 Search Strategy

For this search strategy inspirations were from the guidelines of Barbara Kitchenham [34] and used them according to requirements of these research questions. Following steps were performed to conduct search strategy

1. Major/key search terms were derived from research questions;
2. Alternative spellings and synonyms were identified for major terms; also alternative terms used in literature were considered (e.g. Software Process Enhancement, Software Maturity Attitude)
3. Then the Boolean AND was used to connect **two** key terms in the search strings and Boolean OR to allow synonyms and **alternatives**.
4. According to the use of each database, the search string was broken down and unique ID was assigned to each segmented string for every database. Those unique strings were customized to be applied on **the** available resources.
5. Used endnote reference manager for managing citations.

2.4.1 Major/Key Search Terms for RQ1 and RQ2:

As it has been mentioned above that the major question is RQ1. So the key terms and search string was made for RQ1 only. RQ2 was derived from RQ1 and answered by analyzing the results from RQ1. So there was no need to construct separate search string for RQ2. Following were key terms for RQ1:

- SPI
- Empirical

- **Alternative spellings and synonyms for major terms and use of Boolean "AND" and "OR":**

SPI: (SPI OR Software Process Improvement **OR** Software Maturity Attitude Software Process Enhancement OR **Soft**ware Process Enrichment OR Software Process Assessment OR Soft**ware** Process Evaluation OR Software Process Appraisal OR Software **Process** Review OR Process improvement OR CMM OR CMMI OR **Capab**ility Maturity Model OR SPICE)

Empirical: (Empirical OR Industrial OR Exp**eri**ment OR Case Study OR Survey OR Experience report)

➢ **Integrating Boolean <OR> and <AND>**

((SPI OR Software Process Improvement **OR** Software Maturity Attitude Software Process Enhancement OR Software Process Enrichment OR Software Process Assessment OR Software Process Evaluation OR Software Process Appraisal OR Software Process Review OR Process improvement OR CMM OR CMMI OR Capability Maturity Model OR SPICE) **AND** (Empirical OR Industrial OR Experiment OR Case Study OR Survey OR Experience report))

➢ **Use of tools for automating the search process**

To speed up the process of documenting following tool was used that helped in automating the process.

- End notes [for documenting bibliography from searches]; search results were retrieved in End notes and later on the basis of titles and abstracts were included or excluded. It helped in documenting the searching results.

2.4.2 Resources to be searched

A range of data bases was selected for rigorous search and to reduce the bias. Following data bases were decided to search for the retrieval of primary studies:

1. Springer link
2. IEEE Explore
3. ACM Digital library
4. Science Direct
5. EI Compendex

Other sources to be searched

- Various databases have been selected to reduce the bias of study including published Technical Reports, Journal Papers and Conference Proceedings.
- Then it was planned to go for secondary studies mentioned in references of the primary studies by applying same procedures as applied for primary studies.

2.5 Study Selection Criteria

- The initial selection was based on the TITLE and ABSTRACT of the paper.
- All obtained data from the search process was archived in data base according to the database from which it was retrieved.
- From data base the duplicates were removed after initial scan of results.
- Inclusion and exclusion criteria were applied on the results to sort out the accepted papers.
- Full papers of all studies that were not clearly disqualified were then obtained. Disagreements in the studies were resolved by discussion with supervisors.
- On accepted papers detail inclusion criteria which is a Quality Instrument for studies, was applied to assess their quality.

- .The excluded papers and reasons for exclusion were recorded in a file, and the included papers and study type were recorded in another file.

2.5.1 Study Inclusion and Exclusion Criteria

The criteria were intended to identify those studies that provide direct evidence for the research questions. Following are the inclusion and exclusion criteria for our research questions:

➢ Inclusion Criteria:

The goal of the selection process was to identify the articles relevant for the objectives of the systematic review. Only those studies were included that were empirical based i.e. experiment, case study, survey or industrial experience report and where the main focus was Software Process Improvement or SPI. Following checklist was applied to all the studies for their inclusion or exclusion decision.

Each question was answered in terms of Yes/ No/Unclear

- ✓ Is the study relevant to SPI?
- ✓ Is the study empirical based i.e. Experiment, survey, case study, experience report.

Only those studies were included that were marked as "Yes". The studies marked as "Unclear" were discussed with supervisors to decide for their inclusion or exclusion.

➢ Exclusion Criteria

- Those studies were excluded that were based on personal expert opinion.
- Literature surveys and books were excluded.
- One study can be reported in multiple papers so on the basis of validity score so included the highest ranked paper and excluded others.
- Multiple studies can be reported in one paper; if any of them did not stand to our inclusion criteria then only that study were excluded.

2.6 Search Process Documentation

➢ Primary search Documentation

The customized search strings were applied to the data bases according to decided strategy. As the process went on, the results were saved by the following decided strategy.

i. Folders by the name of specified data base were created.
ii. Within each database folder, further sub folders were created with the name of unique IDs for each segmented search string.
iii. All records for one unique search string were stored in the one library of reference manager (endnotes).
iv. Results of that unique search string were kept in that folder created by the name of unique ID of that search string.
v. Same process was performed on all data bases.
vi. Records were scanned to remove duplicates

vii. Inclusion/exclusion criteria were applied on each folder by the name of specified database. Two separate folders were decided to create for included and excluded papers.
viii. Data base was updated for included and excluded papers.
ix. Reasons for exclusion were recorded in a file.
x. All included papers were moved to one folder.
xi. Conflicts for papers where inclusion or exclusion was ambiguous were consulted with the supervisors

➢ **Secondary Search Documentation**

From accepted primary studies, secondary searches were made and same procedure was followed as for the documentation of primary searches.

2.7 Quality Instrument for Assessing Validity

After initial selection of studies, a more detail criteria was required to judge the quality of study to see whether it is worth considering as evidence to answer our research question or not.
Quality Instrument was designed for assigning numerical values for factors in the checklist to be evaluated for each study. My main focus was on the **study design.**
The research questions and inclusion / exclusion criteria suggested that evidences were expected to be in the form of empirical studies like case studies, industrial experience reports etc.
So firstly a check list was created or assessing the quality of study and assigning numerical values to the questions so that that studies can be ranked.
It was planned that if any paper is considered to be very poor in quality it will be excluded at this stage and will be recorded in the file of excluded papers with reasons.
One paper can report multiple studies, in that case those studies were evaluated individually for their criteria to be included or excluded.

➢ **Applying Quality Instruments Checklist**

My quality checklist was composed of two parts; first part contained generic quality criteria that were applied on all empirical studies. This part contained 7 quality questions but weight age was decided to assign out of 5.
Second part contained quality questions specific to that study type e.g. experiment; survey etc. Scores for this part were also calculated out of 5. So each study obtained scores out of 10 (5 scores from generic part + 5 scores from relevant part of study type). For reviewing the case study the checklist of Martin and Runeson [27] was followed. Quality assessment checklists for other empirical data e.g. survey, experiment and experience report etc were used from guidelines of Kitchenham [7][37]. ***Each question was marked as "yes=1", "partly=0.5" and "no=0".*** Following is the quality checklist:

Generic Quality Checklist
Are the aims clearly stated? YES/NO
Are the study participants or observational units adequately described? (YES if all are

defined, PARTIAL if anyone is missing, NO if all are missing) • Domain of study • Types of participants • Team experience
Are the data collection methods adequately described? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • All measured clearly defined (units, scales, counting rules) • Data collection method described • Form of data collection described e.g. tapes, videos, recording, notes etc
Are the statistical methods justified by the author? (YES/NO)
Is the study design appropriate with respect to research aim? (YES if both are defined, PARTIAL if anyone is missing, NO if both are missing) • Study design described • Study design justified
Is the statistical methods used to analyze the data properly described and referenced? (YES/NO)
Are negative findings presented? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • Limitations expressed explicitly • External threats to validity with respect to subjects/material/task
Is all the study questions answered? (YES/NO)
Do the researchers explain future implications? (yes if any of the following is true) • Consider other ways in which research can be used • Findings transferred to other populations • Identify new areas of research
Quality Checklist for Survey
Was the survey design appropriate with respect to research aim? (YES if both are defined, PARTIAL if anyone is missing, NO if both are missing) • Survey design described • Survey design justified
Was the denominator (i.e. the population size) reported? (YES/NO)
Did the author justified sample size? (YES/NO)
Is the sample representative of the population to which the results will generalize? (YES if it is randomized otherwise NO)
Have "drop outs" introduced biasness on result limitation? (YES/NO/Not Applicable when there are no drop outs. In that case scores will be calculated out of 4 and then accordingly out of 5)
Quality Checklist for Experiment
Were treatments randomly allocated? (YES/NO)
If there is a control group, are participants similar to the treatment group participants in terms of variables that may affect study outcomes? No if: • Some treatment groups were given less training than others.

• Training was of better quality for some treatment groups than others (e.g. experimenters were experts in one method but not another). • Experimenters gave more attention to some groups than others. • Some treatment groups were recognized as more important or prestigious than others. • Some treatment groups expected expertise not available to the subjects.
Could lack of blinding introduce bias? Yes if either of the following is true: • Experimenters knew which subject was in which experimental group during the experiment. • Outcome assessment (i.e. any marking/evaluation of experimental outcomes) made it clear which group a subject was assigned to.
Are the variables used in the study adequately measured (i.e. are the variables likely to be valid and reliable)? These are indicators of valid measures: • The measures are plausible measures of the construct they are meant to represent. • The measures are direct measures of defined concepts. • The measurement scales are respected (e.g. categorical measures are not treated as ordinal or interval)? • The data collection process is defined and appropriate
Quality Checklist for Case Study
Is case study context defined? (YES/NO)
Are sufficient raw data presented to provide understanding of the case? (YES if following is true) • Are the data collection procedures presented, with relevant motivation?
Is the case study based on theory and linked to existing literature? (YES if following is true) • Is the theoretical basis - relation to existing literature and other cases - defined?
Are ethical issues addressed properly (personal intentions, integrity issues, consent, review board approval)? (YES if any of the above is present)
Is a clear Chain of evidence established from observations to conclusions? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • Is the observed phenomenon correctly implemented (e.g. to what extent is a design method under study actually used)? • Are the data collection procedures well traceable? • Is a chain of evidence shown with traceable inferences from data to research questions and existing theory?
Quality Checklist for Industrial Experience Report
Has the assessment of Software Technology been properly described? (YES/NO)
Did the author discuss the limitations of the results and conclusions? (YES if both are defined, PARTIAL if anyone is missing, NO if both are missing)

Interpret the results, explain their consequences, and draw conclusions. (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing)

2.8 Data Extraction

- Data-Extraction form was decided to apply to all the accepted papers and differences between results was resolved by returning to the relevant literature, discussion, and when necessary consultation with supervisors.
- The data-extraction forms were entered into the Data base for results.
- Duplicate publications were identified by cross-checking the study population and location for all studies reporting same results.
- When duplicates were identified, the paper that reported the most recent results of the study was decided.
- Data extraction was performed only for that decided paper.
- For each paper an ID was given to the study.
- For one paper having multiple studies I gave separate Study ID to each study.
- The form was first obtained general information about the paper and then data extraction procedure was applied related to the research questions.
- As RQ2 was decided to answer from the data extracted for RQ1, so the field "study of focus area" was used to extract data for RQ1 and RQ2 as well.
-

2.8.1 Pilot Results

The protocol was piloted for evaluation purpose and to check the validity of search strings and data forms. Following are the results of protocol pilot testing:
These strings were applied on title, abstract and key words as supported by the databases.

Search String for IEEE on 15 April 2011

SS ID	IEEE	
	Query on Abstract	Results Found
IEEE1.1	(("Abstract":"Software Process Improvement" OR "Abstract":"Software Process Enhancement" OR "Abstract":"Software Process Enrichment" OR "Abstract":"Software Process Assessment" OR "Abstract":"Software Process Evaluation" OR "Abstract":"Software Process Appraisal" OR "Abstract":"Software Process Review" OR "Abstract":"Process Improvement" OR "Abstract":"Software Maturity Attitude" OR "Abstract":"SPI" OR "Abstract":"Capability Maturity Model" OR "Abstract":CMM OR "Abstract":CMMI OR "Abstract":SPICE) AND ("Abstract":Empirical OR	840

	"Abstract":Industrial OR "Abstract":Experiment OR "Abstract":Case Study OR "Abstract":Survey OR "Abstract":Experience report))	
Results= 840 emoving duplicates=		

Search String Results for ACM on April 2011

SS-ID	ACM PORTAL	
	Query on Abstract	Results Found
ACM1.1	((Abstract:"Software Process Improvement" OR "Software Process Enhancement" OR "Software Process Enrichment" OR "Software Process Assessment" OR 'Software Process Evaluation" OR "Software Process Appraisal" OR "Software Process Review" OR "Process Improvement" OR "Software Maturity Attitude" OR "SPI") and (Abstract:Empirical OR Industrial OR Experiment OR "Case Study" OR Survey) and (PublishedAs:journal OR PublishedAs:proceeding) and (FtFlag:yes) and (AbstractFlag:yes) and (ReviewFlag:yes)) and (FtFlag:yes) and (AbstractFlag:yes) and (ReviewFlag:yes)	47
ACM1.2	((Abstract:"capability maturity model" OR "CMMI" OR "SPICE" OR "CMM") and (Abstract:Empirical OR Industrial OR Experiment OR "Case Study" OR Survey OR experience report) and (PublishedAs:journal OR PublishedAs:proceeding) and (FtFlag:yes) and (AbstractFlag:yes) and (ReviewFlag:yes)) and (FtFlag:yes) and (AbstractFlag:yes) and (ReviewFlag:yes)	57
Results=104 emoving duplicates=		

Search String Results for Springer Link on April 2011

SS-ID	SPRINGER LINK	
	Query on Title-Abstract	Results Found
SPR1.1	("Software Process Improvement")AND(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	92

SPR1.2	("Software Process Enhancement")AND(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	25
SPR1.3	("Software Process Enrichment")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	7
SPR1.4	("Software Process Assessment")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	
SPR1.5	("Software Process Evaluation")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	
SPR1.6	("Software Process Appraisal")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	5
SPR1.7	("Software Process Review")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	
SPR1.8	("Process Improvement")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	
SPR1.9	("Software Maturity Attitude")**AND**(Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	0
SPR1.10	SPI **AND** (Empirical OR Industrial OR Experiment **OR** Case Study OR Survey)	
SPR1.11	Software Process Improvement AND experience report	
SPR1.12	(Software Process Enhancement or Software Process Enrichment)and (experience report)	3
SPR1.13	(Software Process Assessment or Software Process Evaluation) and (experience report)	13
SPR1.14	(Software Process Appraisal or Software Process Review) and (experience report)	7
SPR1.15	(Process Improvement or Software Maturity Attitude) and (experience report)	
SPR1.16	(CMMI OR SPICE)AND (Empirical OR Industrial **OR** Experiment OR Case Study OR Survey)	39
SPR1.17	(CMMI OR SPICE) AND (Experience report)	3
SPR1.18	(Capability Maturity Model) AND (Empirical **OR** Industrial OR Experiment OR Case Study OR Survey)	30
SPR1.19	(Capability Maturity Model) AND (Experience report)	1
Results= emoving duplicates=		

Search String Results for Science Direct on April 2011

SCIENCE-DIRECT		
SS-ID	Query on Title-Abstract	Results Found
SD1.1	(tak("Software Process Improvement" OR "Software Process Enhancement" OR "Software Process Enrichment" OR "Software Process Assessment" OR "Software Process Evaluation" OR "Software Process Appraisal" OR "Software Process Review" OR "Process Improvement" OR "Software Maturity Attitude" OR SPI) AND tak(empirical OR Survey OR Experiment OR Industrial OR case study))	63
SD1.2	(tak("Software Process Improvement" OR "Software Process Enhancement" OR "Software Process Enrichment" OR "Software Process Assessment" OR "Software Process Evaluation" OR "Software Process Appraisal" OR "Software Process Review" OR "Process Improvement" OR "Software Maturity Attitude" OR SPI) AND tak(experience report))	7
SD1.3	((tak("capability maturity model" OR SPICE OR CMMI OR CMM) AND tak(empirical OR Survey OR Experiment OR Industrial OR case study OR experience report))	2
Results= 72 emoving duplicates=		

***SAMPLE DATA EXTRACTION FOR "An Empirical Investigation of the Key Factors for Success in Software Process Improvement",* Tore Dyba°, May 2005**

Name of Reviewer:	Zil-e-Huma
Date of Review	13th May 2011
Study Type:	Survey
Number of studies in paper:	1
Quality Assessment Ranking:	
Decision Status:	included
Title	An Empirical Investigation of the Key Factors for Success in Software Process Improvement
Author(s)	Tore Dyba
Journal / Conference	
Year of publication	MAY 2005

Publisher	IEEE Computer Society
Volume	31
Issue	Critical success factor, organizational issues
URL	
Key words	Empirical software engineering, software process improvement, critical success factors, organizational issues, survey research.
Abstract / Summary	Understanding how to implement software process improvement (SPI) successfully is arguably the most challenging issue facing the SPI field today. The SPI literature contains many case studies of successful companies and descriptions of their SPI programs. However, the research efforts to date are limited and inconclusive and without adequate theoretical and psychometric justification. This paper extends and integrates models from prior research by performing an empirical investigation of the key factors for success in SPI. A quantitative survey of 120 software organizations was designed to test the conceptual model and hypotheses of the study. The results indicate that success depends critically on six organizational factors, which explained more than 50 percent of the variance in the outcome variable. The main contribution of the paper is to increase the understanding of the influence of organizational issues by empirically showing that they are at least as important as technology for succeeding with SPI and, thus, to provide researchers and practitioners with important new insights regarding the critical factors of success in SPI.
Geographical Area	SINTEF ICT, NO-7465 Trondheim, Norway
Date (of conference)	26 May, 2005

11e2 c)

DATA EXTRACTION FORM

Does this paper repeat already reviewed paper(s)?	Yes	**2** No		
Empirical Background				
Research Method	3 Survey	Case Study	Interviews	
	Controlled Experiments	Observational Study	Other	
Sub Method	Survey	Case Study	Interviews	
	Controlled	Observational	Other	Archive

	Experiments	Study		analysis
Background	Laboratory		4 Industry/Real world	
Subject of Investigation	Students		5 Industry/Real world	
Empirical focus	6 Empirically based		Empirically Evaluated	
SPI Background				
What SPI model/technique is used by the organization?				
What SPI activities are considered successful to the organization being studied?	• Business Orientation • Involved Leadership • Employee participation • Concern for measurement • Exploitation of existing knowledge • Exploration of new knowledge			
How does the organization measure success and what are its indicators and how success is measured?				
Setting of study	7 Industry	products and processes used	in-house/supplier	
	Unclear	Irrelevant		
Study				
Focus of Study on SPI area	Project Management		Process Management	
	Support		8 Organizational	
	Engineering		Customer-supplier	
	Other			
Success or Failure	Clear success story		Success of practices described	
	Clear failure story		Failure of practices described	
	9 Evidence of the SPI related Issues		Unclear	Other
Organization(s) size	Large		Small	
	Medium		10 Mixed	Unclear
Location of organization (s) where study was conducted	Norway			
Number of Organizations involved in study	55			

Issues discussed in study (challenges)	• Critical success factors • Organizational issues associated with success of SPI
Reasons to initiate SPI initiatives	• To reduce software development cost • To reduce time-to-market • To improve management visibility in software development • To increase productivity • To improve the quality of the software developed • To meet customer requirements • To automate the production of relevant development documentation

Applying Quality checklist

Generic Quality Checklist	Marks
Are the aims clearly stated? YES/NO YES	1
Are the study participants or observational units adequately described? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • Domain of study(Yes) • Types of participants (yes) • Team experience (yes)	1
Are the data collection methods adequately described? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • All measured clearly defined (units, scales, counting rules) (yes) • Data collection method described (yes) • Form of data collection described e.g. tapes, videos, recording, notes etc (yes)	1
Are the statistical methods justified by the author? (YES/NO) Yes	1
Is the statistical methods used to analyze the data properly described and referenced? (YES/NO) Yes-	1
Is the study design appropriate with respect to research aim? (YES if both are defined, PARTIAL if anyone is missing, NO if both are missing) • Study design described (YES) • Study design justified (YES)	1
Are negative findings presented? (YES if all are defined, PARTIAL if anyone is missing, NO if all are missing) • Limitations expressed explicitly (yes) • External threats to validity with respect to subjects/material/task (yes)	1
Is all the study questions answered? (YES/NO)	1

Yes	
Do the researchers explain future implications? (yes if any of the following is true) • Consider other ways in which research can be used (yes) • Findings transferred to other populations • Identify new areas of research	1
Quality Checklist for Survey	
Was the survey design appropriate with respect to research aim? (YES if both are defined, PARTIAL if anyone is missing, NO if both are missing) • Survey design described (yes) • Survey design justified (yes)	1
Was the denominator (i.e. the population size) reported? (YES/NO) Yes	1
Did the author justified sample size? (YES/NO) Yes	1
Is the sample representative of the population to which the results will generalize? (YES if it is randomized otherwise NO) Yes	1
Have "drop outs" introduced biasness on result limitation? (YES/NO/Not Applicable when there are no drop outs. In that case scores will be calculated out of 4 and then accordingly out of 5)	
Total Score	

SAMPLE DATA EXTRACTION FOR " Organizational readiness for software process improvement", Mahmood Niazi, David Wilson, and Didar Zowghi, 2007

Name of Reviewer:	Zil-e-Huma
Date of Review	17th May 2011
Study Type:	Case study
Number of studies in paper:	3
Quality Assessment Ranking:	
Decision Status:	included
Title	Organizational readiness for software process improvement
Author(s)	Mahmood Niazi, David Wilson, and Didar Zowghi
Journal / Conference	
Year of publication	2007
Publisher	Springer-Verlag Berlin Heidelberg
Volume	
Issue	Are organizations in higher CMM (I) levels more ready for SPI implementation than organizations in lower CMM(I) levels?
URL	

Key words	Software Process Improvement, Case Study, Organizational Readiness.
Abstract / Summary	The Capability Maturity Model Integration (CMMI) is a structured representation of software development processes that can support an organisation's software process improvement (SPI) strategies. However, CMMI and SPI initiatives generally exhibit low levels of adoption and limited success. One of the major reasons for these shortcomings is that many organisations undertake SPI initiatives without knowing whether or not they are ready to undertake them. Our previous research has enabled us to develop a software process improvement readiness model/framework to address this problem. This paper reports on the implementation of the SPI readiness model in three large-scale case studies. We have found that organisations with higher CMMI levels are more ready for SPI initiatives than organisations with low CMMI levels. We suggest that organisations at higher CMMI levels have developed capabilities that enable them to further leverage SPI than organisations at lower CMMI levels.
Geographical Area	Australia
Date (of conference)	2007

DATA EXTRACTION FORM

Does this paper repeat already reviewed paper(s)?	Yes		11 No	
Empirical Background				
Research Method	Survey	12 Case Study	Interviews	
	Controlled Experiments	Observational Study	Other	
Sub Method	13 Survey	Case Study	14 Interviews	
	Controlled Experiments	Observational Study	Other	Archive analysis
Background	Laboratory		15 Industry/Real world	
Subject of Investigation	Students		16 Industry/Real world	
Empirical focus	17 Empirically based		18 Empirically Evaluated	
SPI Background				

What SPI model/technique is used by the organization?	SPI Readiness Model		
What SPI activities are considered successful to the organization being studied?	Organizations at higher level of CMMI are more ready for SPI initiatives		
How does the organization measure success and what are its indicators and how success is measured?			
Setting of study	Industry	✓ products and processes used	in-house/supplier
	Unclear	Irrelevant	
Study			
Focus of Study on SPI area	Project Management	Process Management	
	Support	✓ Organizational	
	Engineering	Customer-supplier	
	Other		
Success or Failure	✓ Clear success story	Success of practices described	
	Clear failure story	Failure of practices described	
	Evidence of the SPI related Issues	Unclear	Other
Organization(s) size	Large	Small	
	Medium	19 Mixed	Unclear
Location of organization (s) where study was conducted	Asia , Canada, Europe and United Sates, Australia		
Number of Organizations involved in study	3		
Issues discussed in study (challenges)	• At what level of CMMI organization is more ready to implement SPI initiatives • Lack of 'awareness of SPI', 'experienced staff', ' support', 'training and mentoring' and 'reviews are barriers to SPI implementation		
Reasons to initiate SPI initiatives			

2.9 Data Analysis and Synthesis

We decided to analyze data after applying the data forms on all the studies that would pass inclusion/exclusion criteria. General extraction form was created to extract general information about the study such as author, publication year, title etc. Data extraction form was created to extract all the data to answer RQ1 and RQ2. And it has been discussed earlier in the Research Question section that RQ1 had many other sub questions to be answered. Data extraction form contained all the required fields for these sub questions. RQ2 was decided to answer by analyzing the data field ***"focus on SPI area"***. To answer RQ2 strength of SPI areas was decided to calculate. SPI area will be stronger as more studies belong to that SPI area.

2.10 Validation of Review Process

The final version of the protocol was updated after performing two steps; Pilot testing and External review. As a result of pilot testing a set of empirical studies were gathered that were based on SPI and were sure to pass the inclusion criteria. So in the end of inclusion/exclusion process, these studies were included. We got all studies in the list and it gave confidence that we conducted the protocol in the right way. Again and again application of search strings made the strings more refined and accurate when we started getting repetition in our results we understood it was the saturation and strings are able to replicate.

Chapter 3: PROTOCOL EXECUTION

3. PROTOCOL EXECUTION

3.1 Search String Application

Search strings were customized according to syntax of each database. Results were stored in the same way as defined in the protocol. One deviation here is that instead of using EI Compendex database; CiteSeerX was actually used. The reason was that EI Compendex was not accessible at the time in any case. Queries were applied on abstract. All categories of publication and entire range of publication were included in results. Search strings results are as follows:

3.1.1 IEEE Search Query Results

SS-ID	IEEE		
	Query on Abstract	Results Found	Date
IEEE1.1	(("Abstract":"Software Process Improvement" OR "Abstract":"Process Improvement" OR "Abstract":"Software Process Enhancement" OR "Abstract":"Software Process Enrichment" OR "Abstract":"Software Process Assessment") AND ("Abstract":Empirical OR "Abstract":Industrial OR "Abstract":Experiment OR "Abstract":Case Study OR "Abstract":Survey OR "Abstract":Experience report))	293	April-2011
IEEE1.2	**(("Abstract":"Software Process Appraisal" OR "Abstract":"Software Process Review" OR Abstract":"Software Maturity Attitude" OR "Abstract":"Software Process Evaluation" OR "Abstract":"SPI") AND ("Abstract":Empirical OR "Abstract":Industrial OR "Abstract":Experiment OR "Abstract":Case Study OR "Abstract":Survey OR "Abstract":Experience report))**	73	
IEEE1.3	**(("Abstract":"Capability Maturity Model" OR "Abstract":CMM OR "Abstract":CMMI OR "Abstract":SPICE) AND ("Abstract":Empirical OR "Abstract":Industrial OR "Abstract":Experiment OR "Abstract":Case Study OR "Abstract":Survey OR "Abstract":Experience report))**	584	
Results= 950 emoving duplicates= 859			

3.1.2 ACM Search Query Results

SS-ID	ACM PORTAL Query on Abstract	Results Found	Date
ACM1.1	((Abstract:"Software Process Evaluation" OR Abstract:"Software Process Appraisal" OR Abstract:"Software Process Review" OR Abstract:"Software Maturity Attitude") AND (Abstract:Empirical OR Abstract:Industrial OR Abstract:Experiment OR Abstract:"Case Study" OR Abstract:Survey OR Abstract: experience report))	1	April 2011
ACM1.2	((Abstract:"capability maturity model" OR Abstract:CMMI OR Abstract:SPICE OR Abstract:CMM) AND (Abstract:Empirical OR Abstract:Industrial OR Abstract:Experiment OR Abstract:"Case Study" OR Abstract:Survey OR Abstract:experience report))	254	
ACM1.3	((Abstract:"Software Process Improvement" OR Abstract:"Software Process Enhancement" OR Abstract:"Software Process Enrichment" OR Abstract:"Software Process Assessment")AND (Abstract:Empirical OR Abstract:"Case Study" OR Abstract:Industrial OR Abstract:Experiment OR Abstract:Survey OR Abstract:experience report))	128	
ACM1.4	((Abstract:"Process Improvement" OR Abstract:SPI)AND (Abstract:Empirical OR Abstract:"Case Study" OR Abstract:Industrial OR Abstract:Experiment OR Abstract:Survey OR Abstract:experience report))	323	
Results= 706 emoving duplicates=526			

3.1.3 Springer Link Search Query Results

SS-ID	SPRINGER LINK Query on Title-Abstract	Results Found	Date
SPR1.1	(Software Process Improvement OR Process Improvement)AND(Empirical)	102	
SPR1.2	("Software Process Enhancement")AND(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	26	

SPR1.3	("Software Process Enrichment")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	7	
SPR1.4	("Software Process Assessment")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	99	
SPR1.5	("Software Process Evaluation")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	163	4th may-2011
SPR1.6	("Software Process Appraisal")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	5	To
SPR1.7	("Software Process Review")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	67	11.may-2011
SPR1.8	(Software Process Improvement OR Process Improvement)**AND**(Case Study)	194	
SPR1.9	("Software Maturity Attitude")**AND**(Empirical OR Industrial OR Experiment OR Case Study OR Survey)	0	
SPR1.10	SPI **AND** (Empirical OR Industrial OR Experiment OR Case Study OR Survey OR Experience report)	52	
SPR1.11	(Software Process Improvement OR Process Improvement)**AND**(Experience report)	29	
SPR1.12	(Software Process Enhancement or Software Process Enrichment)and (experience report)	3	
SPR1.13	(Software Process Assessment or Software Process Evaluation) and (experience report)	13	
SPR1.14	(Software Process Appraisal or Software Process Review) and (experience report)	7	
SPR1.15	(Software Maturity Attitude) and (experience report)	0	
SPR1.16	(CMMI OR SPICE)AND (Empirical OR Industrial OR Experiment OR Case Study OR Survey)	43	
SPR1.17	(CMMI OR SPICE) AND (Experience report)	3	
SPR1.18	(Capability Maturity Model) AND (Empirical OR Industrial OR Experiment OR Case Study OR Survey)	32	
SPR1.19	(Capability Maturity Model) AND (Experience report)	1	
SPR1.20	(Software Process Improvement OR Process Improvement)**AND**(Industrial)	103	
SPR1.21	(Software Process Improvement OR Process Improvement)**AND**(survey)	36	
SPR1.22	(Software Process Improvement OR Process Improvement)**AND**(Experiment)	180	

Results= 1165 emoving duplicates= 887			

3.1.4 Science Direct Search Query Results

SS-ID	SCIENCE-DIRECT Query on Title-Abstract	Results Found	Date
SD1.1	(tak("Software Process Improvement" OR "Software Process Enhancement" OR "Software Process Enrichment" OR "Software Process Assessment" OR "Software Process Evaluation" OR "Software Process Appraisal" OR "Software Process Review" OR "Process Improvement" OR "Software Maturity Attitude" OR SPI) AND tak(empirical OR Survey OR Experiment OR Industrial OR case study))	**68**	April-2011
SD1.2	(tak("Software Process Improvement" OR "Software Process Enhancement" OR "Software Process Enrichment" OR "Software Process Assessment" OR "Software Process Evaluation" OR "Software Process Appraisal" OR "Software Process Review" OR "Process Improvement" OR "Software Maturity Attitude" OR SPI) AND tak(experience report))	**7**	
SD1.3	(tak("capability maturity model" OR SPICE OR CMMI OR CMM) AND tak(empirical OR Survey OR Experiment OR Industrial OR case study OR experience report))	**2**	
Results= 77 emoving duplicates= 71			

3.1.5 CiteSeerX Search Query Results

SS_ID	CITESEERX		
	Query on Title-Abstract	Results Found	Date
SD1.1	abstract:((("Software process improvement" OR "Software process enhancement" OR "Software process enrichment" OR "Software process assessment" OR "Software process evaluation" OR "Software process appraisal" OR "Software process review" OR "Software maturity attitude" OR "process improvement" OR SPI OR CMM OR CMMI OR SPICE OR "capability maturity model") AND (empirical OR industrial OR experiment OR "case study" OR "experience report" OR survey)))	500	Dec-2011
Results=500 emoving duplicates=500			

3.1.6 Summary of Identified Studies

DATABASE	DATE OF SEARCH	TOTAL NUMBER OF RETRIEVED PAPERS	NUMBER OF PAPERS AFTER REMOVING DUPLICATES
IEEE	Apr-2011	950	**859**
ACM	April-2011	706	**526**
SCIENCE DIRECT	April-2011	77	**71**
SPRINGER LINK	May-2011	1165	**887**
CiteSeerX	Dec-2011	500	**500**
Total number of papers from all databases			**2843**
Total number of papers from all databases after removing duplicates			2545

One important point to discuss here is that after selecting CiteSeerX it was known that it does not provide facility to export reference in endnote. So they were copied and stored on WORD file. It was difficult to manually remove duplicate from these 500 studies and after combining the all databases results. Therefore I merged the above 2843 papers from all databases and using endnote duplicates were removed remaining 2545 studies in the end. But 2545 studies were not including the CiteSeerX results because it was time taking to manually enter 500 references in the end note. So the duplicates regarding CiteSeerX were moved side by side as reading full text studies.

3.2 Studies Inclusion/Exclusion Process

3.2.1 Title and Abstract Screening

Studies inclusion/exclusion was performed in two stages. First inclusion was based on reading the abstract. And the studies that did not qualify the inclusion criteria defined in the protocol; were excluded. It means those studies were excluded that were either not SPI based or not empirical (experiment, case study, survey, experience report). After this step 404 studies were selected.

3.2.2 Full Text Screening

The studies that were not clear after reading the abstract were further studied for full text reading. Confusion or ambiguity at any stage was discussed with the supervisors. After full text reading the final primary studies were selected and their number was 182 including 4 secondary studies that were obtained by reading the references of primary studies. I mention here again that during these steps duplicates were also removed as described above. Following Figure shows step by step inclusion process

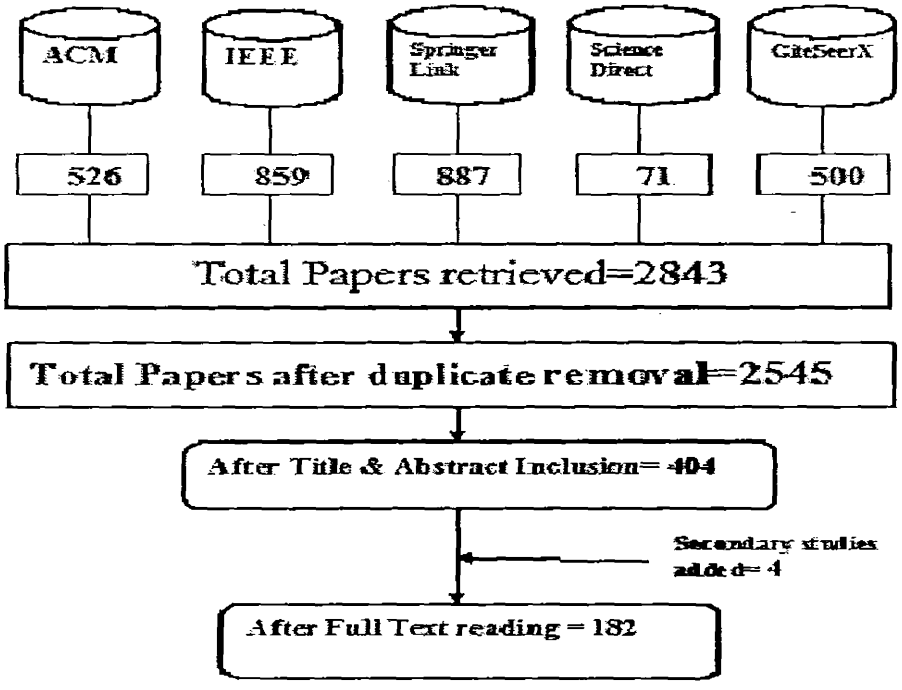

Figure2 Study screening steps

3.3 Study Quality Assessment

The quality instrument that was developed during the protocol definition was applied than to these final selected studies. Here it was decided not to exclude any study on the basis of quality score but studies assessment was necessary for the reliability of results. Quality scores were calculated in the same way as described in the protocol. 5 scores are for general study information and 5 for specific study type. Total study scores were calculated out of 10. The quality assessment forms were stored in separate folder with the name of each study ID.

%age Score	Survey	Case study	Experiment	Experience report	Total number of studies
10%---20%	-	-	-	1	1
21%---30%	4	14	-	-	18
31%---40%	14	16	-	11	40
41%---50%	12	18	1	9	40
51%---60%	11	24	1	-	36
61%---70%	5	12	1	10	28
71%---80%	5	6	-	-	11
81%---90%	3	2	1	-	6
91%---100%	2	-	-	-	2
Total	56	91	4	31	Total=182

Table 1 Summary of quality scores

As shown by the table 1 most of the study quality scores are in between 21% to 60% and most of them are case studies. About 50.5% studies scored below 50% (1%—50%). Among those 53.2% were case studies and 32.6% were surveys. From the total surveys 35% scored below 50 and 65% were above 50 score. While from the total case studies 52% were below 50. This shows that case studies mostly scored less in quality assessment. The main reason that caused the reduction in the score was lack of contextual information including data collection method. Study design was also many times not clearly described. And in many studies there was not clearly established link of traceability from results to research question. One other important lack was that many case studies did not validate the results by using some statistical method properly used and referenced. All such missing information reduced the overall scores of study. Surveys were better than case studies in some points. Detail of all studies quality scores is given in appendix

- **Highest scored study:**
  Following study scored highest mark of 97% and it is a survey.
  Tore, D. (2005). "An Empirical Investigation of the Key Factors for Success in Software Process Improvement." IEEE Trans. Softw. Eng. 31(5): 410-424.

- **Lowest scored study**
  Following study scored the lowest mark of 16% and it is an experience report
  Monvorath, P. and B. Barry (2005). Improving quality through software process improvement in Thailand: initial analysis. Proceedings of the third workshop on Software quality. St. Louis, Missouri, ACM.

3.4 Data Extraction

Data extraction form evaluated as the more studies were extracted. There was need to improve the data form. One more thing was to store data in Excel sheet rather than in word file for easy data manipulation and analysis. So it was created in excel 2007. More fields were added to the data extraction form for qualitative data.

Chapter 4: RESULTS AND ANALYSIS

4. Results and Analysis

4.1 RQ1. What is the state of art in empirical studies of Software Process Improvement?

To answer this questions many sub questions need to be answered. One by one analysis will be done on each question to know about the state of the art in empirical studies of SPI. Following sub questions will combine show the current picture of SPI

4.1.1 Yearly Distribution of Studies

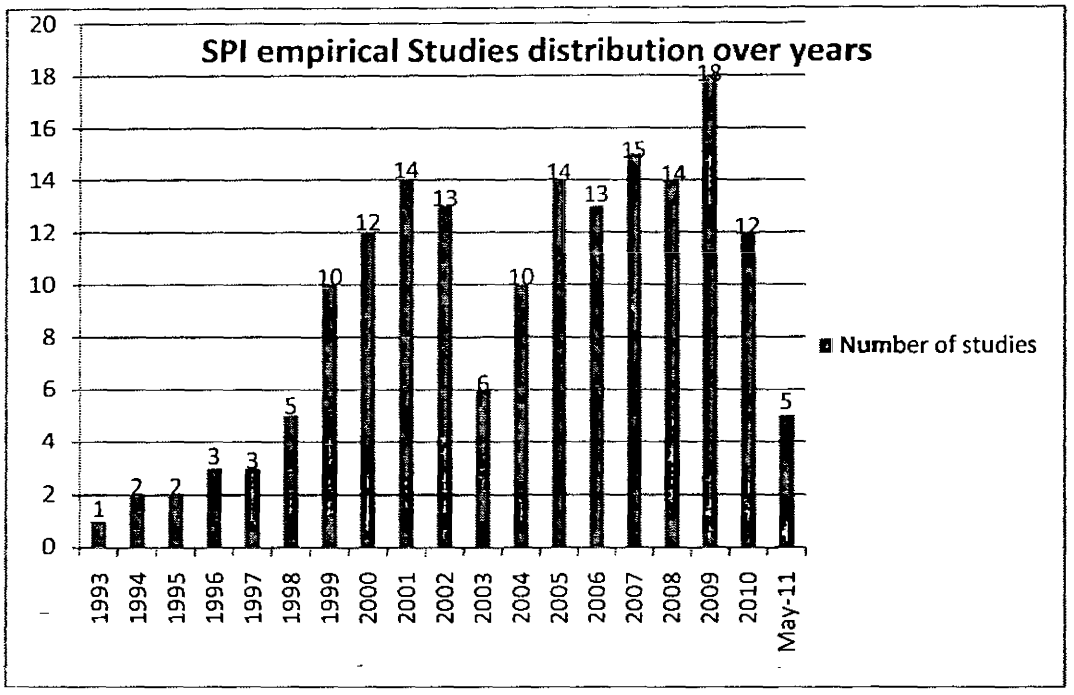

Figure 3 SPI empirical studies distribution over years

Discussion: As it can be seen from the figure 3 that most of the empirical work on SPI is done in 2009 that is 9.8% of the total work up to 2011. These results also confirm the previous SLR findings that most empirical work was done after 1998 [5]. It was 2.7 % in 1998 and in 2008 it became 7.6%. But that SLR included studies up to 2008. The more clearly and up to date picture shows that in 2009 most of the empirical work has been done on SPI. The positive trend that appeared in this era was that industry was turning towards the initiation efforts in SPI. These studies emphasized on the use of CMMI as in 2009 and 2010 33.3% in each year and 66.6% collectively. Here trend of using CMM has been decreased. Now it seems that CMMI is more in practice. In this time SPI was also spread to many other sub areas as well like RE, assessment, software development etc. The use of agility with or without CMMI has been supported in this period. Although the figure 3 shows that 2009 is saturated area of work but the search process

had been stopped at May 2011 so it is expected that after 2010 more work would have been done on SPI. But the trend would be same because up to May 2011 I found 5 studies and two were based o CMMI. It confirms the previous year trends.

4.1.2 Major Publication Channels

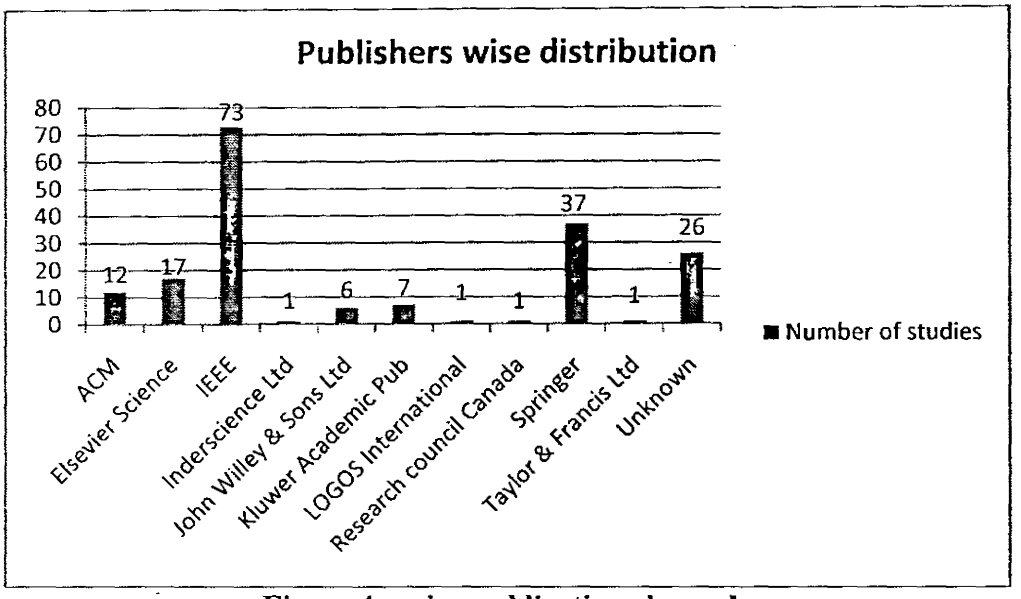

Figure 4 major publication channels

Discussion: Among the finally included studies the most were published by IEEE i.e. 40.1% as depicted in figure 4. Although the results obtained from 1993 onward but the more frequent results retrieved were after 1998 and 1994 in IEEE. The highest studies obtained from IEEE were 10.9% in 2001. ACM started giving results from 2000 onward. Before 2000 no study was retrieved from ACM that passed our inclusion criteria. Total 6.5% studies were retrieved form ACM among those highest were obtained in 2000 i.e. 25%. Springer gave results from 2001 onward but frequent results were retrieved from 2006. Total 20.3% studies were published by Springer and highest retrieval was 13.5% in 2007. These also support the previous finding that most of the empirical work on SPI was started after 1998 and it can be derived that rapid growth of the work had been started after 2000 onward.

4.1.3 Organization Sizes wise distribution of studies

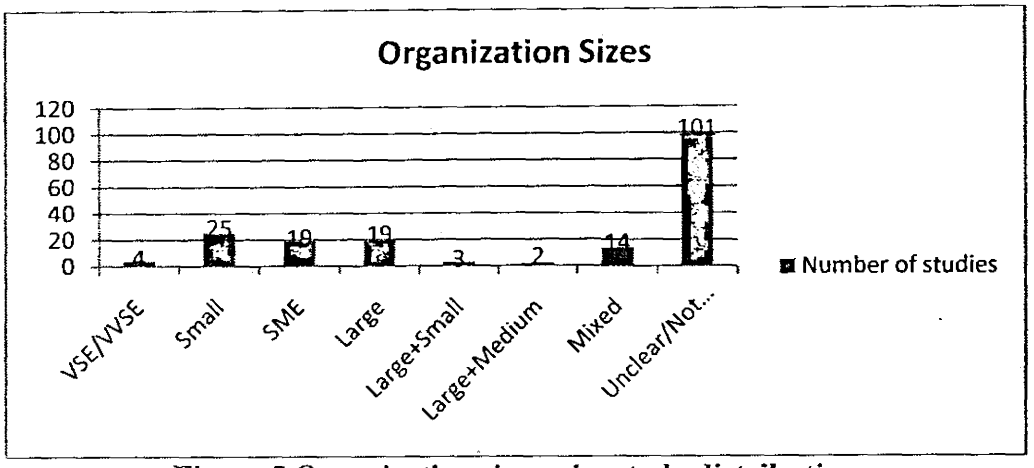

Figure 5 Organization sizes wise study distribution

Discussion: It is clear from figure 5 that SMEs specially the Small companies are more involved in SPI than the large companies. Total 23.7% work is done in SMEs including small and small/medium, among those 13.3% reported specifically small companies. SPI literature is also evident for this. But the surprising point is that more than half of the total studies 55.4% did not mentioned the organization size. This is the lack of contextual information that downs the scores of the studies.

Most of the studies that did not gave this information were case studies i.e. 43.5% and survey was 31.6%. It shows that case study and survey methods mostly lack the contextual information that downs the study quality ranking.

4.1.4 Country wise distribution of studies

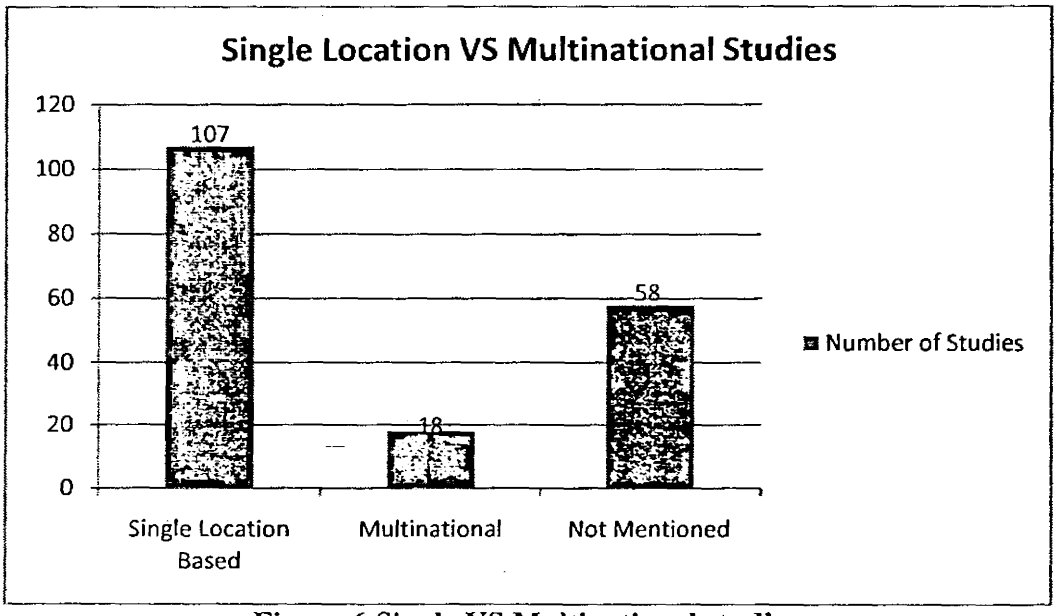

Figure 6 Single VS Multinational studies

Details of Single location based and multinational countries

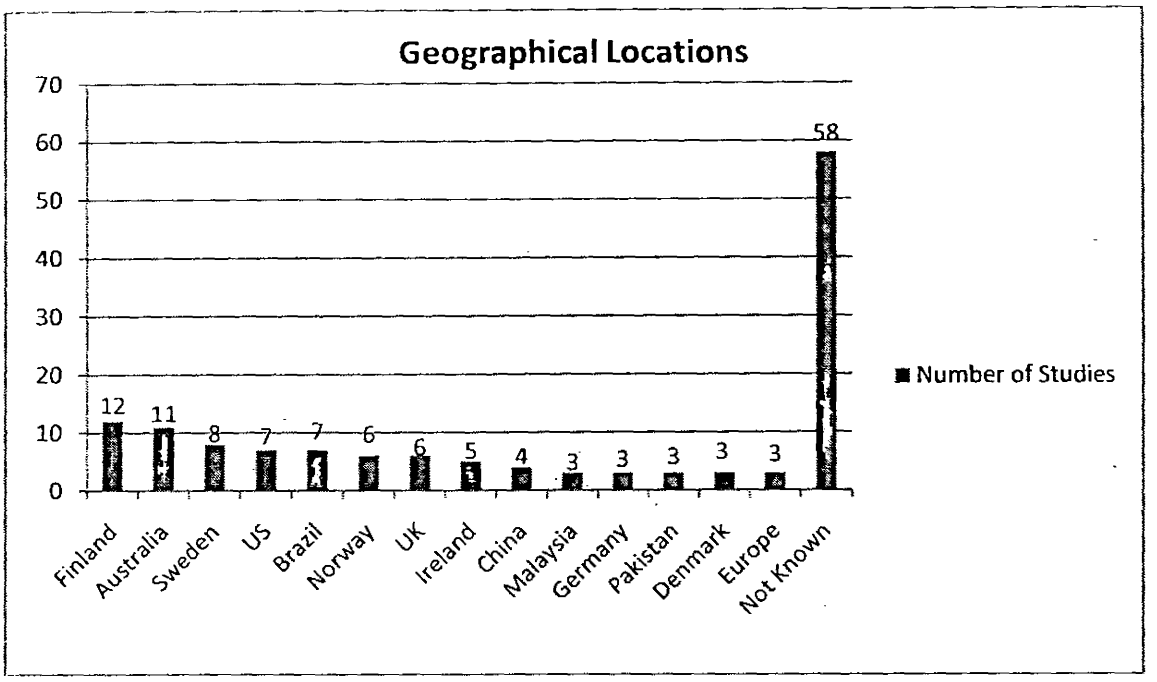

Figure7 Countries wise study distribution

Discussion: As it is understandable from figure 7 that in Finland and Australia most of the empirical work is done in SPI. Most of the work in Finland was done in 2004 and 2009 i.e. 25% each. One study from 2011 was also retrieved. But in Australia the work is scattered in many years. In this region work had been started from 1997 but not every year onward. There were gaps of many years for the next study in Australia. But interestingly in many of these missing periods some multinational studies were being conducted on SPI and Australia was part of them. This point gives power to the Australian region because 10.2% 0f studies are single location based in Australia and 22.2% actively involved in multinational as well. So it can be said that more or less this region is consistently full of activity in SPI work. The large amount of studies i.e. 31.8% did not mentioned the locations of the organizations where empirical work was done. This is again another way to the lack of contextual information and will reduce the study quality. Most empirical work is done in single location based geographical areas. But the most of the studies that took part in multinational studies did not performed well in chart ranking of single location based studies. As in figure 7(a) UK and Europe shows the low ranking but Europe is most actively involved in multinational empirical studies on SPI. Same is the case with UK. Malaysia and Germany are also involved in multinational studies. Details of multinational countries can be seen in Table. For rest of the geographical areas like Pakistan and Malaysia it can be understood that these are developing countries. The concept of SPI had been introduced very late in these areas and due to many constraints these started work very slowly not only in the sub area of SPI but overall the IT industry was brought into apply very late. But this is flourishing now. And need of SPI has been understood in these areas as well.

Details of Multinational Countries	
Countries Involved	Frequency
Argentina, Spain	1
Neither land, Finland	1
Europe, North Asia, South Asia, USA	1
Australia, Brazil, France, Germany, Italy, Switzerland, UK	1
UK based and multinational	1
Wallonia (Belgium), Quebec (Canada), France	1
Germany, US	1
Canada & US	1
Multinational	1
Europe, north asia, south asia, usa, Canada	1
Malaysia & veitname	1
Australia and Veitname	1
Veitnam and UK	1
Australia, Europe ,US ,Canada	1
Australian & multinational	1
Europe, India and USA	1
europe, asia, America	1
Wallonia (Belgium). Qubec (canada)	1

Table2 Details of multinational countries

4.1.5 Tools, Techniques, Models, Approaches, Framework Used

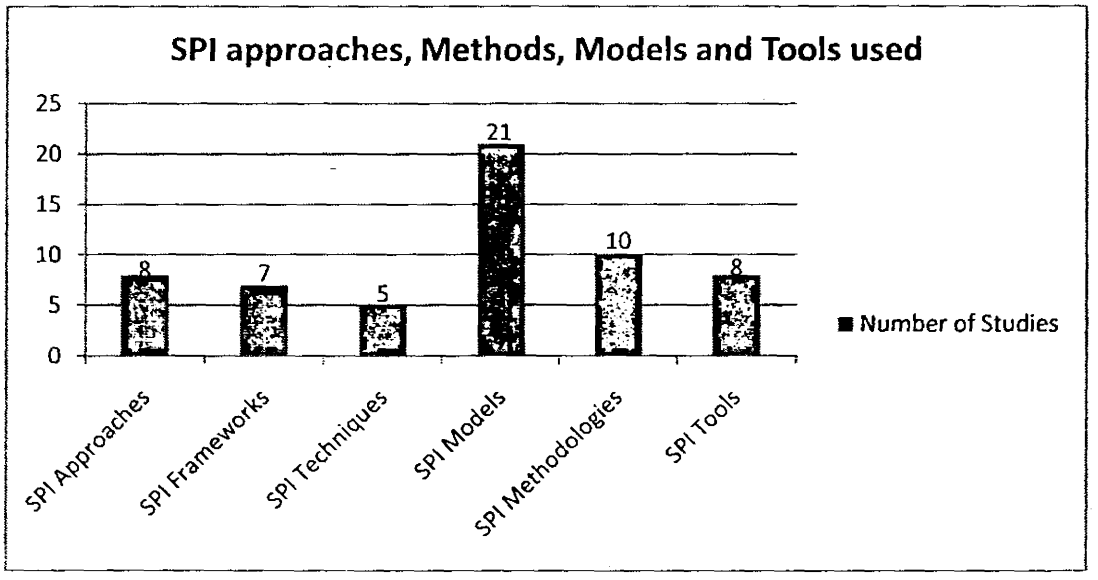

Figure 8 SPI models, techniques and methods used in empirical studies

Discussion: There are several models, tools, techniques, methodologies and frameworks used in the studies. Each of these is categorized in the following way according to their usage possibilities:

- Developed, used and proposed
- Developed by others, used and proposed
- Only proposed in the form of study outcome

On clear evidence obvious from figure8 is that there are many tools, models, techniques and methods that can be used for successful initiation of SPI. Models are most widely used for SPI initiation interestingly most of these are based on CMMI. It is evidence that CMMI is most in use now a day. On the second number is CMM. Practitioners of SPI can benefit from these existing ways and can see how these were used by the earlier practitioners for the specific purpose in SPI. It can be seen that majority of the methods, models, tools and approaches are developed by the practitioners rather than using the already developed one (see appendix). Or many of the existing ways were modified to some new way of implementation. Practitioners customized those methods, models, tools and approaches and developed for their own needs and context; as these are inspired from some reference model like CMM, CMMI or IDEAL or they used some interesting combinations of existing techniques. Details of these methods are given in appendix

4.1.6 Motivators of SPI

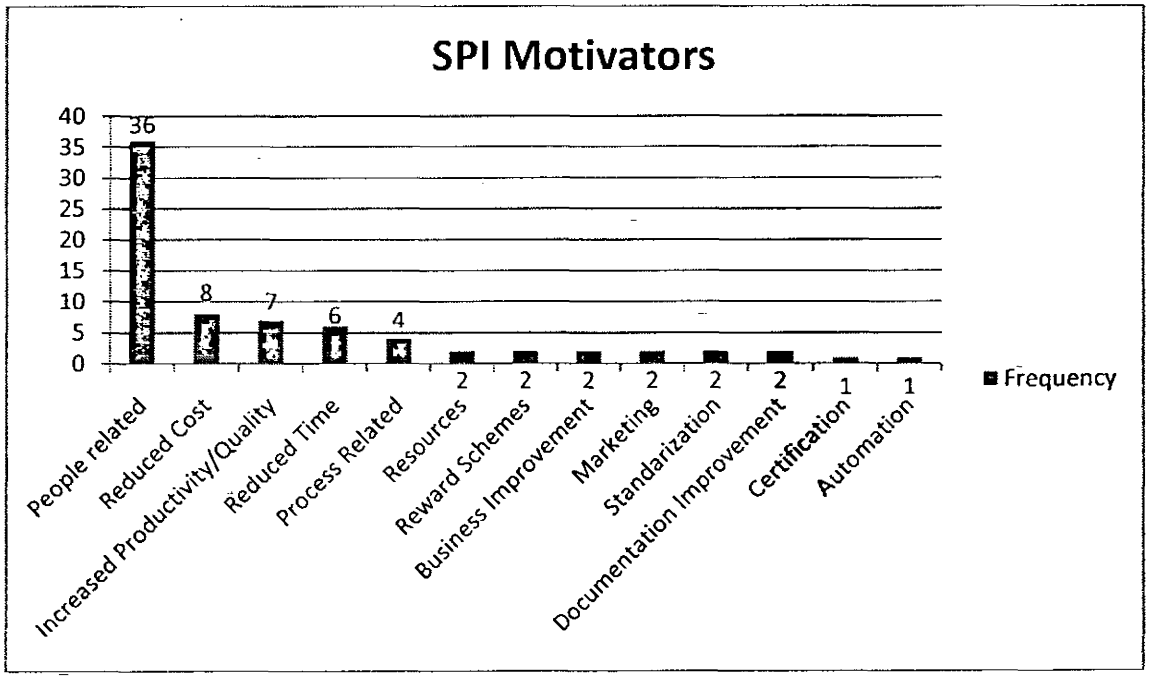

Figure9 SPI Motivators

Discussion: From the figure 9 it can be observed that people related factors are the most motivating factors for SPI. These factors are further categorized in Developers, managers, customers and common motivators based on the study findings. It is evident that motivators

common to developers and managers are highly reported with the greatest frequency. Total 6.5 % of the studies reported the motivators of SPI; among those 33.3% reported People related motivators as the most motivating factors. It can be verified from the results in section 4.1.8 that most SPI motivators are common to as SPI success factors. Hence, the importance of people related factors (i.e. developers/staff and management) is sure to SPI Success. But interestingly these two are highly problematic factors as well (See Section 4.1.6). One possible reason to this can be that people always resist change and purpose of SPI cannot be achieved without having change. To see the impact of these motivators on organization sizes we analyzed the results that showed 33.3% studies mentioned SMEs, 33.3 % mixed, 16.6% large and 25% were unclear. As the mixed and SMEs are equally reported so it cannot be said that these identified motivators are for some specific organization size. Rather these are common to all. Less number of large organization's studies here does not mean that these are not motivated but overall large organizations are less involved in SPI as compare to SME as confirmed in section 4.1.3 before. The geographical regions that were frequently involved in these studies were Australia, Europe and UK. Other regions like Finland, Germany, New England and Japan were also concerned but with less frequency. From this one more inclination is that these motivators not geographical region dependent as well.

4.1.6 SPI Initiation Problem

SPI Initiation Problems		
Total Studies that reported SPI problems= 12%		
SPI Problems		% Frequency out of total problems
Staff Problems		
Inexperienced Staff	47.05%	77.2%
Lack of Staff Participation	23.5%	
Staff turnover	11.6%	
Inertia- laziness	11.6%	
Lack of employee motivation	5.8%	
Management Problems		
Lack of management knowledge and skills	47.05%	77.2%
Lack of Management Support and Commitment	35.2%	
lack of project management	17.6%	

<table>
<tr><td>Organization Specific Problems
<table>
<tr><td>Organizational Politics</td><td>36.3%</td></tr>
<tr><td>Lack of Commitment on all organizational levels</td><td>27.2%</td></tr>
<tr><td>Getting started</td><td>9%</td></tr>
<tr><td>lack of commitment in all levels of the organizations</td><td>27.2%</td></tr>
<tr><td>Organizational changes</td><td>9%</td></tr>
<tr><td>best practices not shared with in organization</td><td>18.1%</td></tr>
</table></td><td>50%</td></tr>
<tr><td>Lack of Resources</td><td>40.9%</td></tr>
<tr><td>Time Management</td><td>27.2%</td></tr>
</table>

Table 3a

Discussion: As evident form table 3a staff and management related problems are at the top in implementing SPI. This is evidence that people involved in SPI (staff and management) are critical to its accomplishment. But the role and responsibility over the management is more than the staff. Management is the decision maker. It is also responsibility of management to keep its employee motivated to actively involved in SPI. One major problem with the management is that it does not have up to date knowledge of SPI even most reported that management is unaware of software engineering concepts. In this condition management cannot have know how about latest tools and techniques of SPI. Management need to enhance its vision about SPI and must keep itself up to date in this area. Only in this way it will be able to satisfy and help out the staff as well. It is management responsibility to give SPI knowledge to the staff. If the staff problems become higher; on the other hand it is lack of management ability. Hence management problem is more important than the staff and must be set on as soon as possible for the success of SPI. Most of the above studies reporting problems were conducted with the aim to identify the resistance factors/barriers in implementing SPI.

Total 23% studies that reported problems were using some reference model; among those only 9% were based on CMM/CMMI. Remaining studies were not using any defined reference model. From these results it is clear that most of the problems occur in the absence of some valid reference model. And it gives strength to the findings that use of some valid reference model is helpful in successful initiation of SPI. No pattern exists in these studies between the problems identified and organizations geographical locations. So it is clear that these problems can be generalized to any location that is implementing SPI.

Only the most powerful relation was seen between the organization size and the reported problems as depicted by following table 3b.

SPI Problems	Large	SME	Mixed	Medium/Large
Staff Problem	2	4	3	-
Management Problem	1	6	1	1
Organization Specific	1	2	3	-
Lack of Resources	1	4	2	-
Time Management	1	1	1	-
Total frequency	6	17	10	1

Table 3b Association between SPI Problems and organization size

Small/medium (SMEs) organizations are more likely to face problems in implementing SPI as compare to large one. As among the above studies 42.8% are SMEs especially small one. Only 9% were independent large size organizations. It gives clear evidence that large organizations are likely to have less initiation problems than the small organizations. The foremost promising explanation can be that the large organizations follow some SPI methodology more frequently than the small one. There can be many reasons to this like large organizations are more concerned to their business impact, quality and early to market to win the competition of products etc. Other major reason is they have less constraints like budget, resources etc as compared to small organizations. So large organizations have better potential to absorb the SPI change but surprisingly the results confirmed earlier that small organizations are more actively involved in SPI work (See Section 4.1.3).

While analyzing whether these problems are geographical area dependent or not I found that: 28.8% studies were conducted in Australia (5 single location based and 1 multinational), 9% in Vietnam, 9% in Brazil and 9% in Malaysia. Many other countries were also involved. This leads toward two possibilities. One is that Australian practitioners are more likely to face SPI initiation problems. In the other way around the more positive impact is that the work in the field of SPI initiation is more frequent in Australia than the other countries. This also confirmed in section 4.1.4 before. The findings also expose that most of the primary researchers of SPI belong to this geographical area as well. These problems are scattered over different geographical regions. No pattern has been found among those regions so it can be said that these problems are not dependent on the geographical region but on the size of the organizations.

4.1.7 Strength of SPI Areas

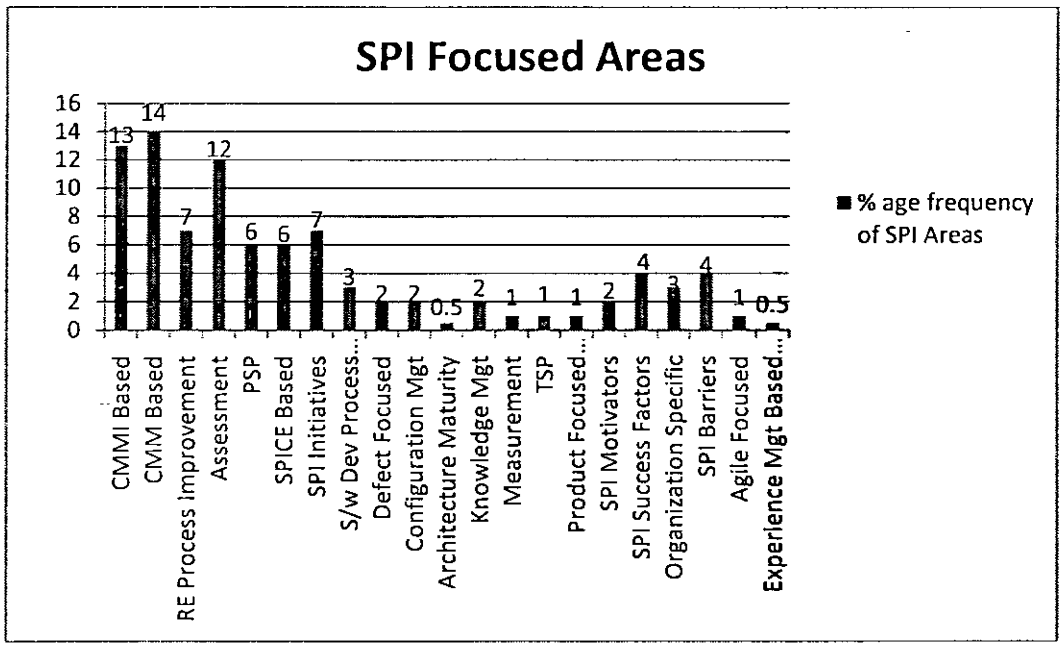

Figure 10a SPI Focused areas

Discussion: The categorization and frequency count in the SPI area is little bit trickier and requires thoughtfulness to understand. The reason is that one study can belong to more than one area. So once it is count for some specific area it does not mean it will not included in the frequency of second area to which it belongs. For this reason it might be carefully observed that which study can belong to more than one area because each study is written once in the relevant area to which it suits best. For example a single study can belong to Assessment and CMM or SPICE or IDEAL at the same time. Total strength of area is calculated after counting all the studies belonging to that area from other categories as well. In this perspective the figure 10a shows the CMM based studies ranked high on the graph. This confirms the previous study findings [5]. But that SLR was up to 2008. If have a look at the growing trend of usage between CMM and CMMI; finding make it clear that CMMI is more rapidly being adopted as there is very little difference in the strength of CMM and CMMI (only 1%). Though CMM has been established since 1988 and CMMI came in 2002 but CMMI gained huge progress in the 9 years and became second most used model for SPI. As this SLR reports for the studies up to May 2011 so now it is certain that the trend would have been changed. CMMI would have gained much strength than CMM. Following figure 10b shows the usage of some well-known reference models in the empirical literature of SPI that once again confirms the high tradition of CMMI.

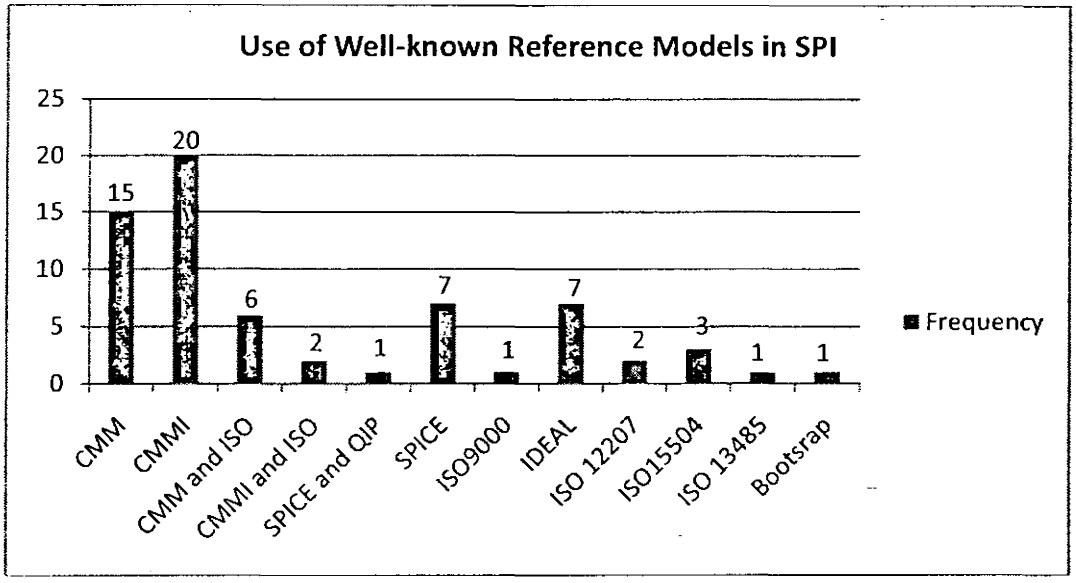

Figure 10b Use of well known reference models

CMM is mostly used as guidance reference model or some times for assessment. But most of the studies used CMM as their reference model and derived their own specific to their context and need by customizing the CMM areas and practices. Same is the case with CMMI. There were some old believes about CMMI like it is not suitable for small companies as it is made for large one. Similarly it was assumed that CMMI has no space for the companies that want to use agile approach. But these myths are resolved now. 20.8% of studies were SMEs that used CMMI and success was reported. It is confirmed that CMMI is not only beneficial for large companies but for small as well. 25% of the studies supported that CMMI and agile together are very attractive for SPI and convenient to use by adding some practices with agile method.

SPI areas that require extensive empirical work include: Architecture maturity, Measurement, Team Software Process (TSP), Configuration Management and Knowledge management. These are the areas where the frequency count is very poor that depicts the low strength of these areas. About TSP it can be considered that it is relatively late coming field as compare to other areas. As it first technical report on TSP was published in 2000. But other areas are not new. It is surprising that these areas are under lack of consideration in SPI empirical work. This is the gap in empirical work of SPI. One new area came into sight with the name of Experience management that is based on implementing SPI on the basis of previous experiences of SPI. This demands for more work as well.

4.1.8 Success Factors in SPI

<table>
<tr><th colspan="2">SPI Success Factors</th></tr>
<tr><td colspan="2">Total studies that reported SPI Success Factors= 12.6%</td></tr>
<tr><td>Critical Success Factors</td><td>Frequency</td></tr>
<tr><td>Staff Related
<table><tr><td>Staff Involvement</td><td>50%</td></tr><tr><td>Experienced Staff</td><td>31.2%</td></tr><tr><td>Other</td><td>50%</td></tr></table></td><td>91.3%</td></tr>
<tr><td>Management Related
<table><tr><td>Management Commitment</td><td>43.7%</td></tr><tr><td>Management Involvement</td><td>31.2%</td></tr><tr><td>Management Support</td><td>25%</td></tr><tr><td>Other</td><td>18.7%</td></tr></table></td><td>82.6%</td></tr>
<tr><td>SPI Awareness and Implementation Methodologies</td><td>30.4%</td></tr>
<tr><td>Organization Specific factors</td><td>30.4%</td></tr>
<tr><td>Resources</td><td>26%</td></tr>
<tr><td>Knowledge Management</td><td>21.7%</td></tr>
<tr><td>Business Related Factors</td><td>21.7%</td></tr>
<tr><td>Training</td><td>17.3</td></tr>
</table>

Table 4a SPI Success factors

Discussion: The findings of SPI success factors from table 4a once again realize the role and significance of people in the success of SPI. These results are in relation with the previous section that emphasized on the people factors as SPI motivators. But astonishingly the highest reported SPI problems are also the people related i.e. staff and management. This becomes an interesting situation. But it shows the way towards the actuality that people involved in SPI are the key to its success. More emphasis is on the experience of staff and commitment/support from the management. Without support from higher management the staff alone cannot achieve the goal of SPI and with lack of experienced staff and their all out effort and involvement, management cannot accomplish the SPI goals. The responsibility on management is little more

than the staff because management is the authority. It shows the path to the success. Thus its role is more important in SPI success. The effect of identified success factors is not geological. Because the studies that described this factor belong to diverse areas that include Norway, Japan, Thailand, Sweden, Canada, Germany, New York, Neither land and China. 13% were from Australia and 17% were multinational having Australia and Europe frequently involved. This shows that all regions realize the effect of staff and management on SPI success. For details of these success factors see appendix.

Association of success factors with organization size				
Success Factors	Mixed	SME	Small & Large	Large
Management Factor	3	5	1	0
Staff Factor	5	4	1	0
SPI Awareness	2	0	0	0
Organization Specific	2	0	0	1
Resources	3	2	0	1
Knowledge Mgt	1	0	0	1
Business Factor	3	0	1	1
Training	1	1	0	1
Total frequency	20	12	3	4

Table 4b Association of success factors with organization size

Discussion: Table4b portrays the effect of Organization size on SPI success factors. High frequency of mixed size shows that these factors can be generalized to all organization sizes. Due to the large difference between SMEs and large organizations it can also be said that SMEs are more affected by these success factors as compare to large organizations.

4.1.9 Future Work highlighted in the empirical studies

Future implications in SPI empirical studies	
Total studies that reported future work = 51.3%	
SPI Area demanding future work	% Frequency
Knowledge Management	**8.7%**
Product Focused Improvement	3.5%
Measurement	**10.5%**
Software Development Process Improvement	**10.5%**
Risk Management	1.7%
RE Process Improvement	**10.5%**
Impact on Cost	**7%**
Impact of SPI factors	7%
Organization Maturity	3.5%
Fault Driven Process Improvement	1.7%
People Impact	**5.2%**
Configuration Management	3.5%
Assessment	7%

CMMI Based	5.2%
PSP	1.7%
Other	8.7%

Table 5

Discussion: The results in table 5 are the future opportunities of SPI described by the empirical studies. It is obvious that the highest percentages are of those areas that are proved to be under lack of consideration in the empirical findings in section 4.1.7 before. It means SPI literature also confirms these results that the areas Knowledge management, Software Development Process Improvement, RE process improvement and ROI require more work SPI empirical work. The other areas that are hungry for more work but future work opportunities are mentioned in less ratio are configuration management, fault driven, organization maturity, measurement and risk management. The understanding that develops to this relationship is that these areas had already very less amount of work so relevant studies were in fewer amounts. Therefore future work is obtained from less number of studies.

4.1.10 Improvement mentioned in terms of success or failure

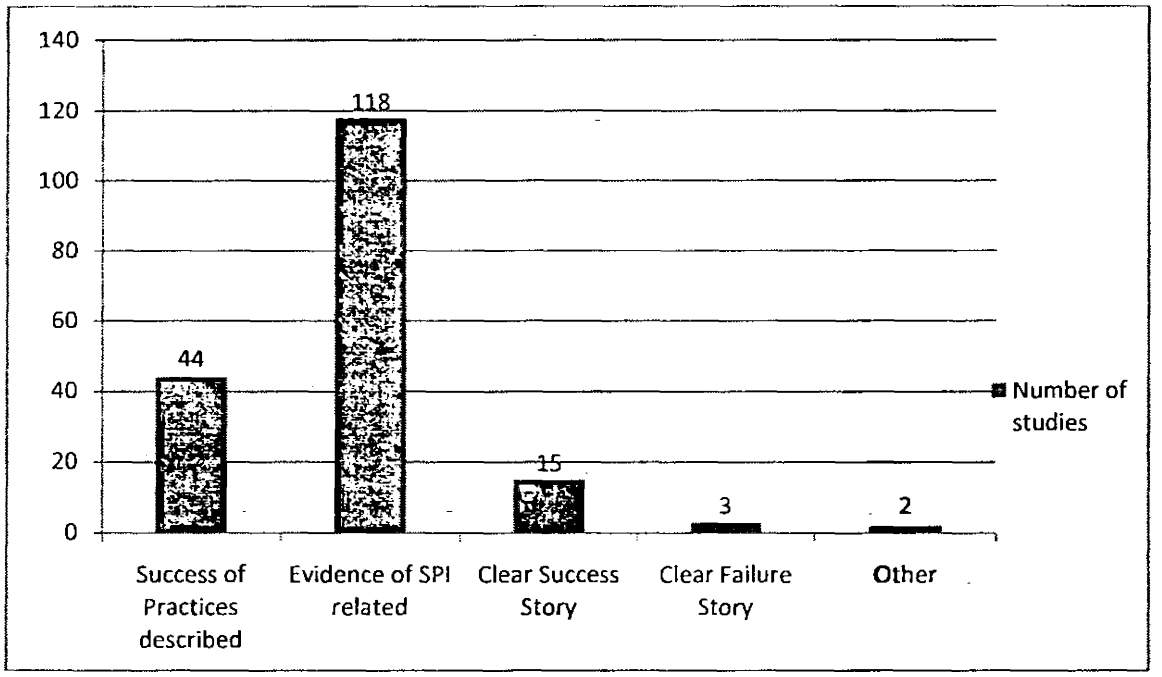

Figure 11 Studies in terms of success/failure

As it is clear from the above figure that only three studies reported about the failure of SPI but majority of the studies are talking about the success or improvement as a result of SPI. Highest ratio is for the evidence of SPI related issues. These evidences are not about the failure but they are collected in during the SPI activities that can be useful for the success of SPI. So the trend is very positive in terms of success reported in the empirical literature of SPI.

4.2 RQ2. What is the strength of empirical evidence reflected in empirical literature of SPI?

4.2.1 Study Settings

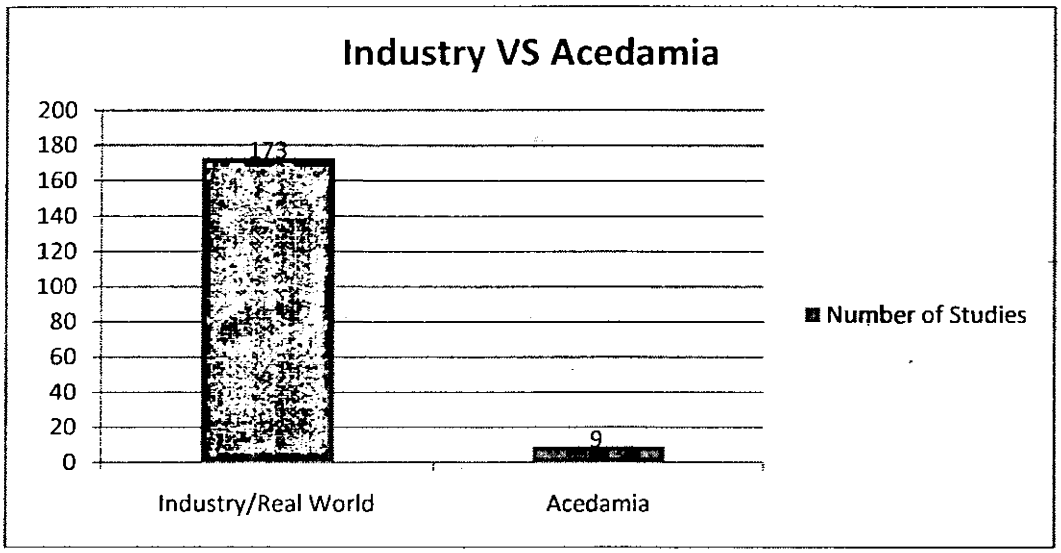

Figure 11 Industrial VS academia context of studies

Discussion: It is a good sign as shown by figure11 that more than 95% of SPI empirical work is done in the industrial context. It will increase the generalize ability of the findings of this SLR over the IT industry. As the implications of this SLR are mostly for the SPI practitioners in real world rather than the academic context. Among these industrial studies 50.5% used case study methods and 31 % used survey. 77% of the work in academic context was done in the area of PSP. This shows that there is more need of PSP work in industry. 33.3% used case study in academic context, same was the experience report ratio, 22.2% used experiment and 11.1% was survey.

4.2.2 Research Methods Used

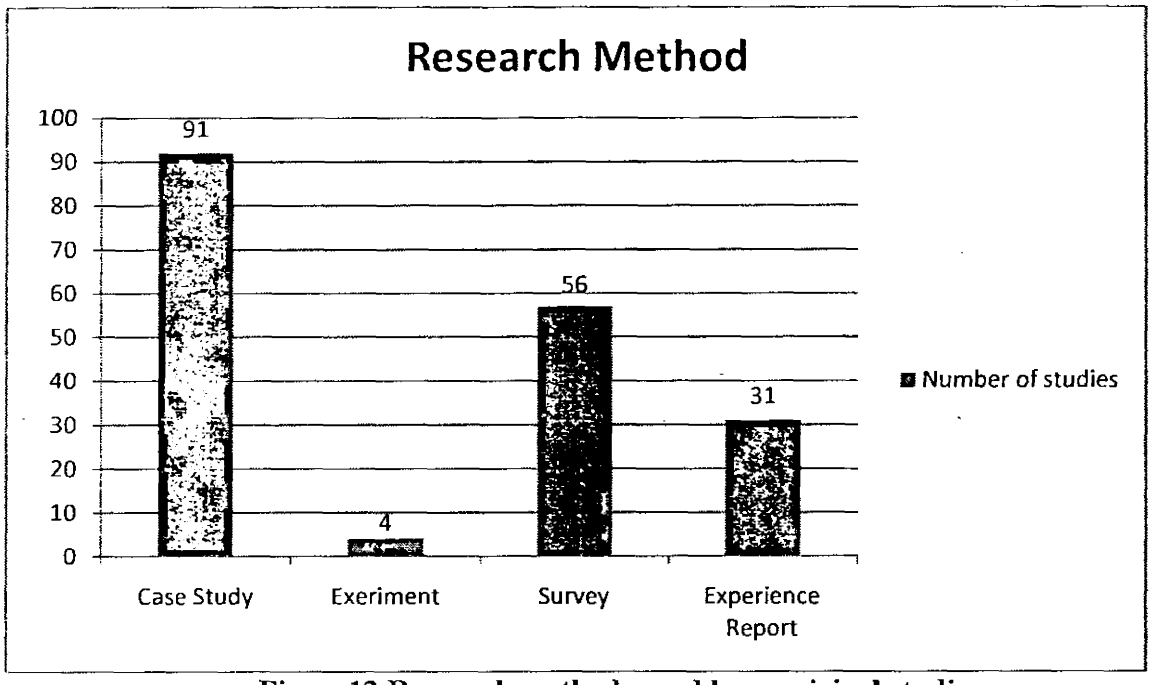

Figure12 Research methods used by empirical studies

Discussion: The suitability and use of case study research method is evident from figure11. Most of these case studies were used in industrial context only 3.2% were in academic. This shows that case study is more convenient in industry. Similarly most of the surveys were in industrial context only one survey was in academic. 66.6% of the experiments were in academic context. It is clear that experiment is difficult to conduct in the industry due to the lack of control over variables. One more reason is that failure chances are greater in experiment than the case study and industry is not willing to face the failure.

4.2.3 Data Collection Method Used

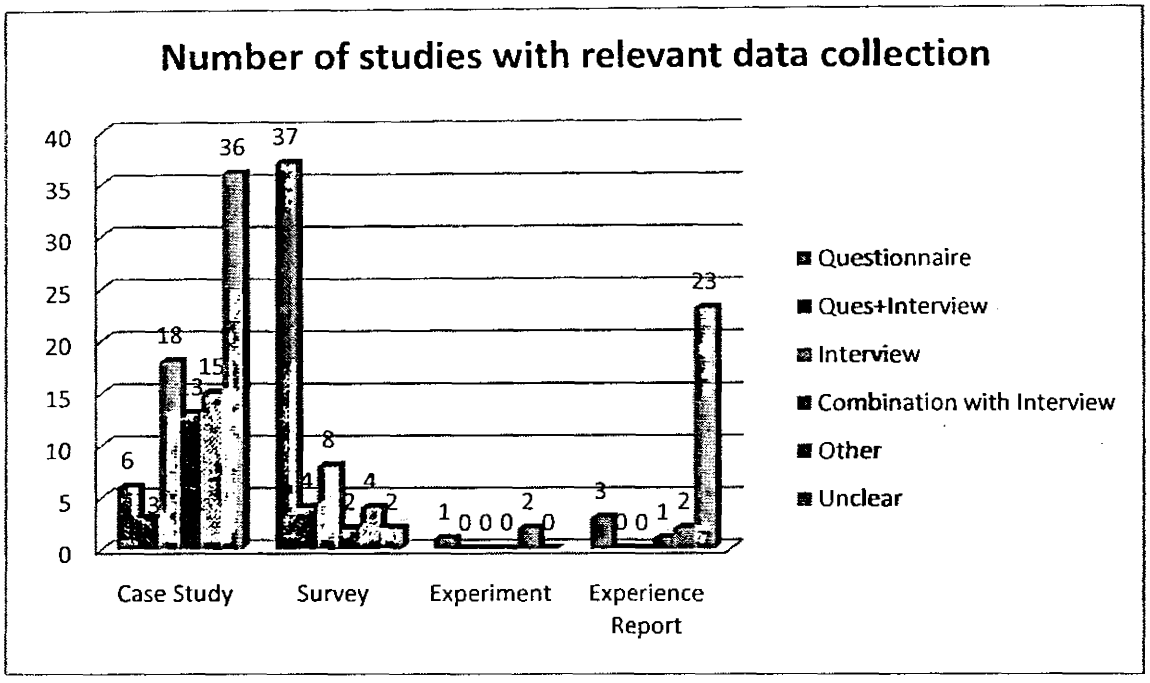

Figure 13 Data collection methods in combination with research methods

Discussion: Different data collection types were used with various combinations. But most widely used data collection types were questionnaire and interview. As it is clear from figure13 that interview was most widely used method with the case studies as compare to surveys. In contrast, questionnaire was most widely used with surveys rather than case studies. This shows the appropriateness of data collection method with the particular research method. Unexpectedly there is an extensive range of studies that did not mention any data collection method. That is clear from the figure above that case studies mostly did not report the data collection method i.e. 39.1%. And 3.5% were among those where data collection was unclear. Data collection is associated with the source of evidence and lack of this information decreases the quality of the studies. The case studies that lacks this information also not have described other contextual information that is required for quality assessment of the study e.g. organization size, location, organization context etc. An interesting finding that can be seen from the figure13 is that most of the studies preferred interviews with the combinations of other methods. Studies that mentioned these combinations most of the time also mentioned their sequence of use. Except these other data collection methods artifacts were widely used either single way or in combination. Assessment results, workshops, tools and observations were also used but in less numbers. Details of data collection methods and their combination with research method is given in appendix.

Chapter 5: CONCLUSIONS

5. CONCLUSION

5.1 Principal Findings

a) SPI Work Progression

- ✓ Most f the empirical work on SPI started after 1998 and the greatest amount of work was done in 2009.
- ✓ Rapid growth in SPI work started from 2000 and onward.
- ✓ In 2009 and onward the trend has been changed from CMM to CMMI and it is most widely in use now.

b) Association of organization sizes with SPI

- ✓ SMEs are more actively involved in SPI than the larger organizations.

c) SPI in geographical regions

- ✓ Single location based SPI work is higher than the multinational. Finland and Australia are the regions where most of the empirical work on SPI has been done. Primary researchers of SPI belong to this area as well.
- ✓ In Finland, maximum empirical work on SPI was done in 2004 and 2009
- ✓ Australia is more or less consistently involved in SPI from 1997 onward.

d) Supportive methods and tools for SPI initiation

- ✓ A number of models, methods, tools, techniques, frameworks and approaches exist in empirical literature of SPI to support its initiation.
- ✓ Models are frequent in use as compared to any other method. Most of these are based on CMMI and some on CMM.
- ✓ Most of the models are newly developed by taking inspiration from CMMI/CMM but times these are modified by customizing the KPAs and practices of reference models.
- ✓ Using the interesting combinations of existing methods, models and techniques are also often in practice

e) SPI Motivator

- ✓ People involved in the SPI are the most motivating factor than the cost, quality and resources.
- ✓ These SPI motivators are not associated with geographical regions or organization sizes.

f) SPI Problems

- ✓ Staff and management related problems are the most critical to SPI but role and responsibility of management is higher than the staff so it makes the management more significant.
- ✓ Maximum management problems are lack of support and commitment and management does not have up to date SPI knowledge.
- ✓ The organizations that do not follow any valid reference model are more likely to face SPI problems.
- ✓ The identified SPI problems are not associated with geographical regions. Rather these are associated with organization size.

- ✓ SMEs are more likely to have problems in SPI than the large organizations

g) **Strength of SPI areas**

- ✓ Maximum work in SPI is based on CMMI s it is the richest area of SPI. Other SPI areas with extensive work are assessment, SPI initiatives, Requirement Engineering Process Improvement, SPICE and People Software Processes (PSP).
- ✓ There is gap in empirical literature of SPI for the following areas than are under lack of consideration
  - Knowledge Management
  - Measurement
  - Architecture Maturity
  - Team Software Processes
  - Configuration Management
  - Product Focused Process Improvement
- ✓ One new area of SPI came in sight with the name of Experience Management based SPI
- ✓ Old believes about CMMI are contradicted now. CMMI is not only beneficial for large organizations but SMEs can also get a lot from this.
- ✓ CMMI can be used successfully in combination with agile approach by adding some practices.

h) **SPI Success Factors**

- ✓ Experienced staff and management's support/commitment is the key to SPI success. Other critical success factors are SPI awareness and implementation methodology, Organization specific factors, Resources, Knowledge management, Business related factors and Training.
- ✓ Effect of the identified success factors is not geological
- ✓ Studies with mixed organization sizes are highest rated so it can be concluded that these success factors can be generalized to all organization sizes. But there is significant difference between SMEs and large organizations ratings so SMEs can be more affected by these success factors than the large companies.

i) **Strength of evidence in SPI**

- ✓ 95% empirical work in SPI is done in the context of Industry/Real world. Only 5% is done in the context of academia.
- ✓ Most of the academic based SPI work is done in the area of PSP. Hence there is need for more PSP work in industrial context to generalize its results.
- ✓ Around 50.5% studies used case study research method in SPI and 31% used Survey. This finding supports the suitability and convenience of case study in the area of SPI in industrial environment.
- ✓ Interview was most extensively used data collection method with the case studies. And questionnaire was commonly used with the surveys.
- ✓ Case studies are frequent in lacking contextual information and with low quality scores.

5.2 Implications

This research is beneficial for all the SPI practitioners but especially for the SPI managers and staff. These findings have great potential for the SPI managers. They can take guidance in the implementation of SPI strategy, decision making and especially managers can more deeply understand the staff related problems, their impact on success of SPI and what motivates them t carry out successful SPI effort. They can also find out the existing models, methods and techniques and modify them according to their need. For developers this SLR is also beneficial in understanding their role in the success of SPI. They can more accurately judge themselves by the assessment results. Developers individually can professionally grow themselves a lot in the guidance of PSP practices. They can learn from the practices that other developers used to get success in SPI. For researcher this SLR has opened the new ways of thoughts. Many of the future areas are discovered that are mentioned in empirical studies adding. And from the results of this SLR more areas other than those mentioned in the empirical findings are also exposed. Many opportunities have been identified to replicate the existing work in some other areas or the new way of carry out the existing task. Hence this SLR is valuable for all type of SPI practitioners.

5.3 Future Directions

One major future direction is to work for the low strength areas of SPI i.e. Architecture maturity assessment, Measurement, TSP, Configuration management, Knowledge management and new area of SPI evolved as Experience management that require more work. Further studies can be conducted to confirm the different findings of this SLR. One more area of research can be to expand the SPI work in different geographical regions and studies can be replicated in different regions to verify the existing finding in literature. Further the SPI demands for tool support for its successful initiation, this area of work is also demanding work. In short there are number of ways that can help out for future work.

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APPENDICES

APPENDIX A: Quality Assessment Scores				
Study ID	Study Type	General QA score out of 5	Specific study type score out of 5	Total score
4	Experience report			6.66
5	Experience report			6.66
6	Case study	5	4	9
7	Experience report			3.33
9	Case study	3.05	2	5.05
11	Case study	2.5	2	4.5
18	Case study	2.2	1	3.2
22	Case study	3.05	2.5	5.55
24	Case study	2.4	4	6.4
25	Case study	3.03	3	6.03
30	Case study	2.2	3	5.2
31	Case study	3.05	4	7.05
32	Survey	3.6	0.5	4.1
33	Case study	1.6	2.5	4.1
34	Case study	2.7	3	5.7
35	Survey	3.6	1.6	5.2
40	Experience report			3.3
41	Survey	3.05	5	8.05
42	Case study	1.9	3	4.9
43	Case study	2.5	2	4.5
44	experiment	3.6	5	8.6
45	Survey	4.1	2.5	6.6
47	Experience report			3.3

48	Survey	3.33	3.75	7.08
52	Experience report			3.3
53	Survey	2.2	0	2.2
54	Survey	2.5	0	2.5
56	Experience report			5
57	Case study	3.8	4	7.8
59	Case study	1.3	2	3.3
60	Case study	1.3	1	2.3
61	Case study	1.9	3	4.9
62	Case study	3.05	3	6.05
63	Case study	3.3	4	7.3
64	Experience report			6.6
66	Case study	2.7	3	5.7
67	Case study	2.2	1.5	3.7
68	Experience report			5
70	Survey	2.5	1.6	4.1
71	Survey	4.4	5	9.4
72	Experience report			1.6
73	Survey	3.8	4	7.8
78	Case study	1.9	1	2.9
79	Survey	2.2	1.25	3.45
83	Survey	2.5	1.6	4.1
87	Experience report			5
88	Experience report			5
90	Case study	2.5	2.5	5
96	Survey	3.05	3.3	6.35

98	Experience report			6.6
104	Survey	1.3	1.6	2.9
106	Experience report			3.3
107	Case study	2.7	2	4.7
108	Case study	1.1	2	3.1
109	Case study	1.6	1	2.6
110	Case study	4.7	4	8.7
116	Case study	2.5	2	4.5
120	Case study	3.8	2.5	6.3
122	Case study	1.6	2.5	4.1
123	Case study	3.05	2.5	5.55
130	Survey	3.3	5	8.3
133	Experience report			6.6
134	Case study	1.9	2.5	4.4
135	Case study	2.5	3.5	6
138	Experience report			5
143	Case study	3.05	2.5	5.55
144	Case study	1.38	1.5	2.88
146	Case study	3.8	2	5.8
147	Survey	2.7	1.6	4.3
149	Case study	1.6	1.5	3.1
150	Case study	2.7	1.5	4.2
151	Experience report			6.6
154	Case study	1.9	3	4.9
155	Case study	3.3	3	6.3
156	Case study	2.5	2.5	5
158	Survey	2.7	3.3	6
160	Survey	4.4	1.6	6
161	Case study	1.6	3.5	5.1

164	Case study	3.3	3	6.3
165	Survey	2.2	1.6	3.8
172	Survey	1.9	3.5	5.4
174	Case study	1.3	0.5	1.8
176	Case study	3.05	2.5	5.55
180	experiment	3.8	2.5	6.3
183	Case study	3.05	4	7.05
185	Survey	3.8	3.3	7.1
186	Survey	3.3	3.3	6.6
187	Survey	2.7	3.3	6
188	Experience report			6.6
191	Case study	2.7	3.5	6.2
192	Case study	2.7	3.5	6.2
195	Survey	2.2	1.6	3.8
196	Case study	2.2	2	4.2
198	Experience report			6.6
201	Case study	3.05	2.5	5.55
203	Case study	1.9	1	2.9
204	Case study	2.5	3.5	6
205	Survey	3.3	1.6	4.9
206	Survey	3.8	1.6	5.4
207	Survey	3.8	0	3.8
208	Survey	1.6	0	1.6
210	Survey	4.1	3.3	7.4
212	Survey	2.2	1.6	3.8
215	Case study	2.5	5	7.5
217	Survey	1.9	1.6	3.5
218	Experience report			6.6
220	Case study	2.7	3.5	6.2
221	Survey	2.5	3.3	5.8

223	Survey	3.05	1.6	4.65
225	Case study	1.3	1	2.3
231	Case study	3.8	4	7.8
232	Case study	2.7	1	3.7
238	Survey	2.5	2.5	5
242	Survey	1.6	1.6	3.2
244	Case study	1.1	1	2.1
245	Survey	1.6	1.6	3.2
246	Case study	1.6	1.5	3.1
249	Experience report			5
251	Case study	3.8	3	6.8
252	Case study	2.2	1.5	3.7
253	Case study	2.7	2.5	5.2
255	Case study	2.7	3	5.7
257	Survey	2.2	1.6	3.8
260				
262	Experience report			3.3
263	Case study	2.2	2	4.2
264	Experience report			3.3
266	Case study	1.9	1	2.9
267	Case study	1.3	1	2.3
268	Survey	2.7	3.3	6
272	Case study	1.6	1.5	3.1
276	Case study	1.6	2	3.6
279	Case study	4.4	2.5	6.9
281	Survey	3.3	5	8.3
282	Survey	4.7	5	9.7
289	Case study	2.7	3	5.7
290	Case study	1.9	3.5	5.4
292	Experience report			5

293	Survey	3.3	1.6	4.9
295-1	Case study	1.3	1.3	2.6
298	Experience report			5
302	Survey	1.9	1.6	3.5
309	Experience report			3.3
317	Case study	2.2	1	3.2
321	Case study	1.9	1	2.9
322	Experience report			5
324	Case study	2.2	3.5	5.7
329-1	Survey	1.6	1.6	3.2
332	Survey	1.9	1.6	3.5
334	Case study	1.6	1.5	3.1
335	Case study	1.3	1	2.3
338	Case study	1.6	2	3.6
342	Case study	2.5	3	5.5
344	Survey	3.3	3.3	6.6
346	Survey	2.5	1.6	4.1
348	Survey	2.2	3.7	5.9
350	Survey	2.5	1.6	4.1
352	Experience report			3.3
359	Experience report			3.3
360	experiment	2.7	2.5	5.2
364	Survey	4.4	2.5	6.9
365	Case study	2.2	3.5	5.7
368	Case study	0.8	2	2.8
376	experiment	2.7	1.6	4.3
379	Case study	1.9	1	2.9
381	Survey	2.7	1.6	4.3
382	Survey	3.8	3.3	7.1

384	Case study	2.7	3.5	6.2
386	Case study	2.2	1	3.2
387	Case study	1.3	2	3.3
389	Case study	1.9	0.5	2.4
393	Case study	4.1	1.5	5.6
394	Experience report			3.3
398	Case study	2.5	2	4.5
399	Survey	1.6	1.6	3.2
402	Survey	2.2	1.6	3.8
408	Survey	3.05	1.6	4.65
409	Case study	2.5	2.5	5
410	Survey	2.2	3.3	5.5
234	Case study	2.7	1.5	4.2
407	Experience report			6.6
406	Case study	2.2	1.5	3.7
411	Case study	2.2	1	3.2

APPENDIX B Details of Models, Tools, and Techniques in SPI

SPI Approach used/Proposed	Frequency
Developed and Used and proposed 1. The hybrid GQM/TSP approach can be used to assess attainment of learning outcomes and demonstrate to students the significance of all aspects of software engineering project management. 2. Assessment Approach for Quantitative Process Management (A2QPM) included the assessment and analysis of the task management process 3. Measurement Oriented approach suggested for SPI with management cockpit on the top 4. DMAIC-Kaizen approach is proposed for process performance improvement. It is integration of ISO 9001 and Lean-Six Sigma (LSS) into CMMI-DEV 5. Fault-driven lightweight process improvement approach is proposed to decrease the number of faults Only used and proposed while developed by Others 1. Systems Modular Analysis (SMA) is proposed as a graphical modeling	8

approach to facilitate understanding of SPI models 2. Use of appreciative inquiry in problem-oriented organizations. 3. The combination of CMM management and organizational capabilities and the judicious application of Clean room technical practices represents a powerful process improvement paradigm	
SPI Frame work used/Proposed Developed and Used 1. **SPI-IF** implementation framework is presented that has the potential to assist SPI practitioners in the design of effective SPI implementation initiatives 2. Practical framework based on ISO is proposed for process improvement designed to support effective, iterative, fast process improvement by using existing techniques 3. PIASS (Process-Improvement Activity Support System) is an integrated environment that provides (1) tools necessary to make assessment of targeted software processes, and (2) a knowledge-base to store guidelines, experiences, and know-how that are necessary to precede SPI activities for a particular organization. Only used and developed by Others/ proposed 1. The meta-Measurement framework (M2P) for developing and deploying targeted assessment instruments. 4. Primer, Practical Process Improvement for Embedded Real-time Software, frame work proposed for software Configuration Mgt 2. Used MAP frame work (Management, Approach, and Perspective of SPI) and proposed for early in the initiation phase of the first SPI initiative to understand the most characteristic features of the SPI project. Only proposed as output • SPI stakeholder Competency Framework is proposed. The organizations can use this framework to design the profile of each role, to assign a role to each employee, to define recruiting profiles, to design training plans, to design succession plans, and to design competency-based compensations.	7
Techniques Used/Proposed Developed and Used • RE process Improvement validation technique is proposed and validated • Defect Logging and Defect Data Analysis (DLDA) technique Based on PSP to prevent mistakes faster. It is low cost, low risk technique Only used and developed by Others 1. Combining two existing techniques for fault analysis methods:	5

Orthogonal Defect Classification (ODC) and Faults-Slip-Through (FST) to provide useful input to test process improvement 2. Used several participation techniques like search conferences, survey feedback, autonomous work groups, quality circles, and learning meetings in SPI initiatives 3. Quality Function deployment (QFD) technique to align and prioritize process improvement based on organization's strategic goals	
Models used/Proposed Developed and Used and proposed 1. Documentation process maturity model based on CMM is developed and proposed 2. an empirical model is presented that investigates the effect on product defects of consistent adoption of the CMM practices 3. Release Management Process Model is suggested 4. Quality Distinction model developed and based on 15 CMMI processes for IT service providers capabilities 5. Model for improving the release planning process of an organization is applied and proposed based on CMMI 6. Brazilian Software Process Improvement (mps Br) Project reference model used to improve s/w development process based n ISO/IEC 12207 7. A Risk Management Maturity Model based on the six levels of capability of Capability Maturity Model Integration (CMMI) and the four dimensions of organizations, namely culture, risk management process, experience and business applications is developed and proposed 8. The benchmark Based process Model (BBASPM) is developed based on Software Engineering Process Reference Model (SEPRM) for small org and projects. BBASPM is developed as a superset of CMM, ISO 15504 and ISO 9001 9. Shark tooth model developed introducing CMMI area Requirement Mgt 10. Architecture Process Maturity Model for s/w product line Engineering; provides a methodology to evaluate the current maturity for the architecture dimension of the SPL in an organization 11. A model is proposed to explain the variation in the reliability of assessing SPICE-based processes. 12. Formal specification based product development model is proposed. It represents the CMMI KPAs compliance with formal specification development 13. Micro-Evaluation Model is presented with strengths and weakness. And proposed for assessment in VSEs 14. SPI implementation readiness model to know how much ready an organization is to implement SPI. Based on CMM/CMMI 15. Organizational Learning Evaluation Cycle OLEC model is developed	21

and proposed for organization learning 16. i3GO model is proposed based on boot strap for s/w process inspection improvement 17. ABCM model is proposed that is feasible to be applied to Software Development Process, combined activity-based costing (ABC), balanced scorecard (BSC) and capability maturity model (CMM) 18. Knowledge driven model for SPI (KSPI) based on IDEAL is developed and proposed 19. Organizational maturity Assessment Model of software product line engineering for evaluating the maturity of organizational dimension Only used and developed by Others 1. Use of Competisoft reference model for improving customer satisfaction. 2. Data Envelopment Analysis variable return to scale(DEA VRS) model is recommended to be used as the default technique for appropriately benchmarking software development tasks [	
Methodology Used/Proposed Developed and Used • Process and Project Alignment Methodology (ProPAM) methodology is proposed for software product development process. • Method is presented to discover process patterns based on project tasks • Combined Requirement Engineering methodology is proposed that consists of three steps: initiating the assessment, executing multiple inquiry cycles • The method for initial level assessment was developed based on the five elements: philosophy, process, techniques, tools, and training; based on IDEAL • Propose Iterative Improvement Process for conducting SPI within individual agile project teams • Requirements Elicitation, Analysis and Validation Method (REAVM)" is proposed for RE process improvement Only used and developed by Others • To get good SPI a Basic RE (BaRE) method is proposed for outsourcing technical infrastructure for RE process improvement • The PROFES methodology proposed for Product focus SPI • Method PmCOMPETISOFT proposed based on ISO/IEC 15504-4 and Scrum. A light weight process for improvement.	10

Only used • Methodology of characterizing s/w process based **on** Quality Improvement Paradigm (QIP) phase "Characterization"	
Tool Used/Proposed **Developed and Used** 1. Instrument developed for measurement of SPI success factors. Managers can use the instrument to guide SPI activities in their respective organizations and researchers can use it to build models to relate the facilitating factors to both learning processes and SPI outcomes 2. Decision tree is created that organizations could use as a guideline for the selection of an SPI methodology that meets their quality requirements 3. A catalogue is provided to deal with non-tech features in CMMI Supplier agreement Mgt Process area 4. National Swedish benchmark based on IBM European benchmark is established for assessment Only used and developed by Others • Tool used Inspection Capability Maturity Model (ICMM) for assessment of software inspection practices based on CMMI • S/w development environment ***Taba Workstation*** is installed to facilitate and accelerate the software processes definition, deployment, and improvement. T support SPI-KM strategy • Micro Evaluation tool is suggested for assessment in VSEs Only developed and used 1. Progress 4GL/RDBMS database app for collection of PSP data collection is proposed. For analysis PSP Error Data Analysis Tool developed.	8

APPENDIX C: Details of Low Frequency Problems

Problems	Total Frequency in number of occurrence
Lack of Change Mgt	2
Lack of SPI evidence	2
lack of a defined SPI implementation methodology	2
Lack of SPI awareness	3

Lack of overall Support	5
Lack of Sponsorship	2
Lack of Training and mentoring	2
lack of communication	2
Lack of expertise in implementing cultural changes	3
Un clear Goals	3
Insufficient assessment	2
Lack of Task Mgt	2
Documentation problems	2
Lack of standards	2
Low process priority	2
Large scale programs	2
Workload	2
Commercial Pressure	2
• Imposition • Negative/Bad experience • Risk of adding complexity • Concerns about moving to a 'one-size-fits-all' Methodology • Irrelevant objectives/ deliverables • poorly managed information • Budget Constraints • hardly transferred technology for new members • unclear role distributions among many stakeholders • Personality clashes • Direct inference from customer • Difficult Maintaining normal productivity during implementation • late impact of the SPI program on projects	(Mixed **Pro**blems each with frequency=1)

APPENDIX D: Details of SPI Success Factors		
Success Factor	Category	Frequency
• Managers actively monitor the progress of process improvement • Management Involvement • Management commitment • Management Sponsorship • Management Support • perceived personal and project management benefits	Management	**19**
• Concern for Measurement • Use of Metrics	Measurement	5
• Business Orientation • Business motivation • alignment with business goals • identification of business processes	Business motivation **and** goals	5
• Experienced staff • Staff Involvement • Staff specific • commitment of development staff • Quality of team work • Team spirit • Political strength of the champion • managing the human dimension of process improvement effort • Creating process action teams/external agents • how well the SPI fits the task environment of the developer • the people involved are respected	Staff	21
Staff time facilitate from time pressure	Time	3
• shared goals among stakeholders • collaboration among stakeholders • clearly stated and understood goals	Shared Goals	2
• process ownership • Process Maturity • Tested assessment process	Process related	4

• Organizational Culture • Organization commitment to SPI • Deployment (resources, personnel etc) • Support--group process introduction • no politics and turf guarding • Focus to SPI efforts	Organization specific	7
Training & mentoring	Training	4
• Resources availability • Resources brought to bear • Attention to deployment • Allocate required resources	Resources	6
• SPI awareness • Defined SPI implementation methodology/strategy • Solid SPI Implementation • sufficient understanding of the current progress of SPI efforts	SPI awareness and defined implementation methodology	7
• Reviews • Internal Audits • Inspection, project post mortem	Assessment	4
• Environment • SPI motivation and acceptance • explicit assignment of responsibility for SPI • Identification of best practices • Documentation of status quo • Workshops and regular surveys • Customer perception surveys • Incentive • Sense of urgency • Tailoring the improvement initiative	mixed	9 (each factor with frequency of one)
• Standardizing data • Standards & Procedures • Simplification of routine procedures	Standardization	3
• Importance of Tools • Appropriate choice of managerial tools	Tools	2
• Exploitation of existing knowledge (learning by experience)	Knowledge Mgt	5

• Exploration of new knowledge (learning by experimentation) • Knowledge and prior experience • mechanisms to efficiently manage and organize a large amount of complex information generated during SPI		
• Concern for quality • Pressure to improve quality	Quality	2

APPENDIX-E: Details of Future implications in empirical studies
Knowledge Mgt In the area of Knowledge Mgt following areas of work are identified in the empirical literature for future work
• Knowledge engineering techniques that constitute Knowledge Management Tools • The role of KMTs in software process improvement programs
To know about the relationship between the chosen knowledge creation strategies to the surrounding organizational structures and management culture such as how to approach organizational learning under different organizational circumstances, strategies to use when.
The possible combination of knowledge creation strategies
the need for more complex models of the knowledge creation and expansion processes
To construct a knowledge-base of critical success factors CSF and to develop a computational system to support SPI managers to make decisions aiming to enhance the definition and control of SPI strategies.
Product Focused improvement of Embedded Software processes (PROFES)
investigate product/process dependency models PPDs
maturity assessment of software product line engineering area requires more work
Measurement
analyze business impact of GQM measurement
Instrument development to measure organization pre-requisite for SPI success, by further refining the theory adding more variables and/or more interactions.
Performance measurement indicators such as cost, productivity, quality, and customer satisfaction should be evaluated. Those studies should include a reasonable number of other moderators, especially such as application domain, cultural factors, and enablers and disables of process improvement.
To investigate the new and improved measures of SPI success, comparison of measurement instruments, and validation of SPI success measures.
Use SMA (System Modular Analysis) for modeling other SPI models; other than CMM that is used in this study.
s/w Development & Maintainability
To investigate characteristics that affects development problem factors and associated s/w maintainability.
investigate how the software development process maturity impact the various project risk factors such

as project size, organizational environment, and lack of team expertise
Architectural view of studies is required for better s/w development
to investigate if and how training and guidance could help overcome the tension between appreciative inquiry and problem-oriented approaches
to construct a contingency model which can guide small software companies in the selection and application of software process as they evolve
Another future direction in research is to apply statistical analysis in order to determine the relationship and individual contribution to SPI success of practices used in the SPI implementation strategy
Risk mgt
To develop the common factors into a risk management tool to support SPI champions to deliver improvement
RE
the development of instruments for more objectively assessing and measuring the interactions between RE Process and other processes such as change management, peer review, and testing
What are the relevant and meaningful criteria to judge improvements in peer reviews, for example, as a result of better RE processes?
To assess actual change in the organization's culture with respect to the attitude towards rigorous RE processes
Hot topics of RE improvement in near future • elicit functional requirements" • "elicit nonfunctional requirements" • "review requirements" • "document developer requirements
extending the issues of requirement management to cover up the entire software lifecycle
Develop other CMMI-oriented system modules; such as system verification modules
Cost
For widespread use of Cost of quality CoSQ technique extended models are required. Specifically, current models should be extended on the cost breakdown of the components of the cost categories (prevention appraisal, external and internal failure costs). These models should also be validated by field experiments.
Conduct empirical studies to determine the relationship between the relative "perceived value" of each practice and how its implementation is justified by return on investment.
the quantitative analysis of cost and benefits in practical examples and comparison with other formal specification language
how to reduce the cost and time of SPICE assessment, while maintaining its accuracy
SPI Factors
To identify the attributes that can help the implementation of SPI
Future studies should aim to further this line of research and test the impact of capabilities on performance through an appropriate nomological net
Study the Impact of process consistency on productivity and cycle time.

potential relationship between performance improvement and the organizational learning infrastructure
Need to investigate the importance of contextual variables to several types of SPI problems and to validate the approaches proposed for solving them.
To find the motivators of SPI in different cultural contexts in small companies
To construct and validate a maturity-based model of SPI implementation factors.
Organizational Maturity
To examine whether organizations which reach higher levels in the CMM model have differing abilities than those at lower levels.
To study the time taken to move from one level of CMM to the next.
Fault Driven Approach
A specific area for change if (LPIA) Light weight process improvement is to be used over time is to agree on a fault classification scheme.
People Impact
An interesting case study would be to analyze organization with younger and more inexperienced programmers and their impact on SPI
Another short-term goal is to develop a competencies assessment system for SPI stakeholders based on self-evaluation and 360-degree evaluation.
To investigate that whether respondents are confident that SPI can be achieved by the engineering teams themselves (and without additional help from business management).
Software Configuration Mgt
In future we will analyze major software companies located in Islamabad, Lahore and Karachi to get the true national picture regarding adherence to SCM
Assessment
Future research can be conducted to show the relationship between Kappa values and the assessment context.
to investigate the factors that have an impact on the reliability of SPICE assessments
using the assessment to claim a portion of the software process improvement budget for measurement
To investigate that in smaller companies employee motivations may be more closely aligned with company goals than in larger companies
Mapping CMMI with other approaches
Requirements development, technical solutions, product integration, validation and verification are process areas that could be mapped to XP and Scrum practices.
To examine agile method other than XP and Scrum such as LSD, FDD, APM, Crystal and ASD are all such methods that could be assessed
The mapping approach can be used by organizations to set up a single Quality Management System marrying both the worlds of CMMI and the regulatory standards in the background
PSP
Tool support is required for PSP and future work should be carrying on this.
Mixed
an area of research for future Experience Mgt to find practical implementation of SPI in the Experience Mgt.
Use of proposed Poor Quality Model for more quality indicators. By determining the relation between indicators, secondary effects of poor quality indicators can be examined in future work

to investigate if and how training and guidance could help overcome the tension between appreciative inquiry and problem-oriented approaches
to construct a contingency model which can guide small software companies in the selection and application of software process as they evolve
Another future direction in research is to apply statistical analysis in order to determine the relationship and individual contribution to SPI success of practices used in the SPI implementation strategy

APPENDIX F: Detail of Research Methods and data collection methods used by studies.

Research Method	Data Collection Method with Frequencies
Case study Not Mentioned= 36	Questionnaire=6 Artifact= 7 Artifact+ Workshop=1 assessment data=2 audits result=1 Tool=1 Focus group=1 Interview=18 Interview + artifact=7 interview+ observation+ questionnaire=1 Interview+ Artifact+ Observation=3 Interview+ meeting+ Artifact=2 PIWs Post iteration workshop=1 Q+ interview=3 Questionnaire+ Artifact+ Interview=2 Questionnaire=6 Web accessible electronic process guide=1
Survey Not mentioned=2	Focus group =2 group-based Repertory Grid Technique=1 Interview=8 interview+ survey=1 interview+ observation=1 Q+ interview=4 Questionnaire=37 SEI repository=1
Experiment	Artifact=2 Questionnaire=1
Experience Report Not mention=23	appraisal data + interview=1 Artifact=1 Tool=1 Questionnaire=3

APPENDIX G: LIST OF PRIMARY STUDIES FOR SLR IN SPI		
S. No	Study ID	Title & Abstract
1.	4	Abrahamsson, P., K. Kautz, et al. (2006). Personal Software Process: Classroom Experiences from Finland Software Quality â€" ECSQ 2002, Springer Berlin / Heidelberg. **2349:** 175-185.
2.	5	Adam, S., J. Doerr, et al. (2009). Lessons Learned from Best Practice-Oriented Process Improvement in Requirements Engineering: A Glance into Current Industrial RE Application. Requirements Engineering Education and Training (REET), 2009 Fourth International Workshop on.
3.	6	Ahmed, F. and L. Capretz "An organizational maturity model of software product line engineering." Software Quality Journal **18**(2): 195-225.
4.	7	Ajit Ashok, S. Medical software: a regulatory process framework. Proceedings of the 3rd India software engineering conference. Mysore, India, ACM.
5.	9	Alagarsamy, K., S. Justus, et al. (2007). The Knowledge Based Software Process Improvement Program: A Rational Analysis. Proceedings of the International Conference on Software Engineering Advances, IEEE Computer Society.
6.	11	Allison, I. Organizational Factors Shaping Software Process Improvement in Small-Medium Sized Software Teams: A Multi-Case Analysis. Quality of Information and Communications Technology (QUATIC), 2010 Seventh International Conference on the.
7.	18	Andreas, B., D. Pieter, et al. (1998). Applications of Measurement in Product-Focused Process Improvement: A Comparative Industrial Case Study. Proceedings of the 5th International Symposium on Software Metrics, IEEE Computer Society.
8.	22	BÃ¶rjesson, A., L. Holmberg, et al. (2007). Use of Appreciative Inquiry in Successful Process Improvement Organizational Dynamics of Technology-Based Innovation: Diversifying the Research Agenda, Springer Boston. **235:** 181-196.
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12.	31	Bernd, F., D. Christian, et al. (2005). An Industrial Case Study of Implementing and Validating Defect Classification for Process Improvement and Quality Management. Proceedings of the 11th IEEE International Software Metrics Symposium, IEEE Computer Society
13.	32	Berry, M. and M. F. Vandenbroek (2001). A targeted assessment of the software measurement process. Software Metrics Symposium, 2001. METRICS 2001. Proceedings. Seventh International.

14.	33	Bhandari, I., M. Halliday, et al. (1993). "A Case Study of Software Process Improvement During Development." IEEE Trans. Softw. Eng. 19(12): 1157-1170.
15.	34	Bhavani, P. and M. Frank (2006). Validating Requirements Engineering Process Improvements - A Case Study. Proceedings of the 1st international workshop on Requirements Engineering Visualization, IEEE Computer Society.
16.	35	Bin Basri, S. and R. V. O'Connor Organizational commitment towards software process improvement an irish software vses case study. Information Technology (ITSim), 2010 International Symposium in.
17.	40	Cass, A., C. Volcker, et al. (2002). SPiCE in action - experiences in tailoring and extension. Euromicro Conference, 2002. Proceedings. 28th.
18.	41	Cater-Steel, A. and E. P. Fitzgerald (1997). Quality assurance certification: adoption by Australian software developers and its association with capability maturity. Proceedings of the Fourth Asia-Pacific Software Engineering and International Computer Science Conference, IEEE Computer Society.
19.	42	Cater-Steel, A. P. (2001). Process improvement in four small software companies. Software Engineering Conference, 2001. Proceedings. 2001 Australian.
20.	44	Cerpa, N., J. Pereira, et al. (2007). A Practitioner Experiment in Understanding Software Process Improvement Using Systems Modular Analysis Software Process Improvement, Springer Berlin / Heidelberg. 4764: 82-93.
21.	45	Chen, J.-C. and S.-J. Huang (2009). "An empirical analysis of the impact of software development problem factors on software maintainability." Journal of Systems and Software 82(6): 981-992.
22.	47	Christ, V. (2003). Certifying for CMM Level 2 and ISO9001 with XP@Scrum. Proceedings of the Conference on Agile Development, IEEE Computer Society.
23.	48	Chun-Hui, W. (2008). Exploring impacts of software development process maturity on project risk. Industrial Engineering and Engineering Management, 2008. IEEM 2008. IEEE International Conference on.
24.	52	Cohan, S. and H. Glazer (2009). An Agile Development Team's Quest for CMMI® Maturity Level 5. Agile Conference, 2009. AGILE '09.
25.	53	Coleman, G. (2005). An Empirical Study of Software Process in Practice. System Sciences, 2005. HICSS '05. Proceedings of the 38th Annual Hawaii International Conference on.
26.	54	Collofello, J. S. and N. Chi Heng (1999). Assessing the process maturity utilized in software engineering team project courses. Frontiers in Education Conference, 1999. FIE '99. 29th Annual.
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33.	63	Daniela, D., C. James, et al. (2005). "Requirements Engineering and Downstream Software Development: Findings from a Case Study." Empirical Softw. Engg. 10(3): 255-283.
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38.	70	Dooley, K., A. Subra, et al. (2001). "Maturity and its impact on new product development project performance." Research in Engineering Design 13(1): 23-29.
39.	71	Dyba, T. (2000). "An Instrument for Measuring the Key Factors of Success in Software Process Improvement." Empirical Software Engineering 5(4): 357-390.
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41.	73	El-Emam, K., D. Goldenson, et al. (2001). "Modelling the Likelihood of Software Process Improvement: An Exploratory Study." Empirical Software Engineering 6(3): 207-229.
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		and Architecture, IEEE Computer Society.
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