A Framework for Assisting the Design of Effective Implementation Strategies for Software Process Improvement

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CERTIFICATE OF AUTHORITY

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated and referenced in the thesis.

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List of Acronym

CBs	Critical Barrier
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CSFs	Critical Success Factors
IMM	Implementation Maturity Model
ISO	International Standard Organization
IT	Information Technology
KPA	Key Process Area
PA	Process Area
SCE	Software Contractor Evaluation
SEI	Software Engineering Institute
SMEs	Small and Medium Enterprises
SPA	Software Process Assessment
SPI	Software Process Improvement
SPI-IF	SPI Implementation Framework
SPI-IM	SPI Implementation Model

Dedication

To my uncle Abdul Saboor Khan and my parents, Ghulam Rasool Niazi and Zakia Khanum, for making this possible...

Abstract

This research addresses issues relating to the implementation of software process improvement (SPI) initiatives. A number of advances have been made in the development of software process improvement (SPI) standards and models, e.g. Capability Maturity Model (CMM), more recently CMMI, and ISO's SPICE. However, these advances have not been matched by equal advances in the adoption of these standards and models in software development which has resulted in limited success for many SPI efforts. The current problem with SPI is not a lack of standards or models, but rather a lack of an effective strategy to successfully implement these standards or models.

Despite the importance of the SPI implementation process, little empirical research has been carried out on developing ways in which to effectively implement SPI initiatives. I have focused on SPI implementation issues and designed three individual components in order to assist SPI practitioners in the design of effective SPI implementation initiatives. I have combined individual components under one SPI implementation framework (SPI-IF) using a bottom-up approach. The framework is based on results drawn from the SPI literature and an empirical study I have carried out. In the design of SPI-IF, the concept of critical success factors (CSFs) is used and extended. Thirty-four CSF interviews were conducted with Australian practitioners. In addition, 50 research articles (published experience reports and case studies) were selected and analysed in order to identify factors that play positive or negative roles in SPI implementation. The SPI-IF has three components: SPI implementation factors component, assessment

component and implementation component. It provides a practical structure with which to assess and implement SPI implementation initiatives.

In order to evaluate the software process improvement implementation framework, two practical evaluations were undertaken: three case studies and an expert panel review process. The case study method was used because this method provides valuable insights for problem solving, evaluation and strategy in the real world environment. An "expert panel review" process was also conducted in order to seek the opinions of SPI experts about the structure and components of the SPI-IF.

In order to provide more confidence in this study, three separate case studies were conducted at different companies. The results of the case studies showed that the SPI-IF is not only significant in the theoretical sense but also significant in a real world environment. Successful completion of the three case studies demonstrates the use of the SPI-IF in the real world environment. All the participants who used the SPI-IF were fully satisfied with the assessment results and overall performance of the framework.

The results of the expert panel review process showed that the SPI experts' general impression about 'ease of learning', 'user satisfaction' and 'structure of the SPI-IF' was positive. Overall, the experts were fully satisfied with the different components of SPI-IF. All the experts considered this piece of work as useful for the SPI practitioners. They have also confirmed the SPI-IF as a valuable framework that has the potential to assist SPI practitioners in the design of SPI implementation initiatives.

Chapter One: Introduction

1.1 Introduction

This Chapter introduces the problem domain in relation to software process improvement (SPI) implementation and summarises the contribution and aims of this research.

This chapter is organised as follows:

- In Section 1.2 the problem statement and motivation for the study is described
- In Section 1.3 the research questions and the aims of research are described
- In Section 1.4 the research contribution is described
- In Section 1.5 the thesis roadmap is provided

1.2 The problem statement and motivation for the study

Information Technology (IT) failure has been a common topic in the literature over the last 25 or more years with the annual CHAOS Report (Standish-Group, 2003) perhaps being the most celebrated regular report. Andrew Taylor (2000) reported that only 12.7% of IT projects were successful (130 of 1027 surveyed); worse, the success rate for development projects, which comprised 50% of the sample, was 2.3%. The CHAOS Report shows that on average the percentage of software projects completed on-time

and on-budget improved from 16.2% in 1995 (Standish-Group, 1995) to 34% in 2003 (Standish-Group, 2003). Despite the demonstrated improvement, nearly two-thirds of projects were still not successful in 2003. A recent study, conducted by a group of Fellows of the Royal Academy of Engineering and British Computer Society, shows that despite spending 22.6 billions pounds on IT projects in UK during 2003/2004, significant numbers of projects still fail to deliver key benefits on time and to target cost and specification (The-Royal-Academy-of-Engineering, 2004). In addition to such disappointing performance, some software projects result in complete failure (e.g. Airbus A320 (Randell, 1989), the London Ambulance Service (Finkelstein, 1993), and the explosion of the Ariane 5 (Lions, 1997)) or even the demise of organisations (Greyhound's TRIPS System (Tomsho, 1994), FoxMeyer's ERP project (Scott, 1999), Oxford Health's 'computer glitch' (Khasru, 2001) and One.Tel billing system (Paul, 2002)).

These problems are often seen as issues of software quality, which has accordingly received much attention in both academia and industry. The Department of Trade and Industry (DTI) in the UK commissioned two reports into software quality (Logica, 1988; Waterhouse, 1988) which resulted in quality management systems and certification to standards such as ISO9001 becoming popular means of providing some management control of the software development process during the early 1990s, particularly in Europe and Australia. However, mandatory ISO certification schemes in both UK and Australia produced a level of disenchantment in the business community, particularly in operators of small and medium enterprises (SMEs) who were concerned about the cost and effort required to acquire and maintain ISO certification. With this decrease in emphasis on ISO9000 certification, software developers sought alternative

means of maintaining their competitive advantage – of improving product quality and innovation, continuing to lower costs and becoming more customer oriented. There was an increasing realization that one of the fundamental problems is the inability to effectively manage the software process (Butler, 1995; Pitterman, 2000; Yamamura, 1999).

In order to address the effective management of software process different approaches have been developed, of which Software Process Improvement (SPI) is the one most often used. "SPI involves understanding existing processes and changing these processes to improve product quality and/or reduce costs and development time" (Sommerville, 1998:p638). In order to improve the quality of the product, the aim of SPI is to focus on improving software development processes, that is, to focus on the steps required to develop and maintain software (Humphrey, 1995). Several different models and standards have been developed for SPI, including the Capability Maturity Model (CMM) (Paulk *et al*, 1993), more recently the Capability Maturity Model Integration (SEI, 2002a) and ISO's SPICE (ISO/IEC-15504, 1998). Research shows that the effort put into these model and standards can assist in producing high quality software, reducing cost and time, and increasing productivity and employee satisfaction (Ashrafi, 2003; Butler, 1995; Jiang *et al*, 2004; Pitterman, 2000; Yamamura, 1999).

Despite these documented benefits, SPI initiatives exhibit low levels of adoption and limited success (Leung, 1999). Deployment is often not only multi-project, but multi-site and multi-customer type and the whole SPI initiative typically requires a long-term approach. It takes significant time to fully implement an SPI initiative (SEI, 2004). Such time frames mean that the SPI approach is often considered an expensive approach for many organizations (Leung, 1999) as they need to commit significant resources over an

extensive period of time. Even organizations willing to commit the resources and time do not always achieve their desired results. The failure rate of SPI initiatives is very high, estimated as 70% (Ngwenyama and Nielsen, 2003; SEI, 2002b). The significant investment and limited success are reasons for many organizations being reluctant to embark on a long path of systematic process improvement.

Despite the importance of SPI implementation process, little empirical research has been carried out on developing ways in which to effectively implement SPI programmes (Goldenson and Herbsleb, 1995; Leung, 1999). Much attention has been paid to developing standards and models for SPI. This suggests that the current problems with SPI are not a lack of standards or models, but rather a lack of an effective strategy to successfully implement these standards or models (Zahran, 1998). Studies show that 67% of SPI managers want guidance on 'how' to implement SPI activities, rather than 'what' SPI activities to actually implement (Herbsleb and Goldenson, 1996). Also, organizations typically adopt ad hoc methods instead of standard, systematic and rigorous methods in order to implement SPI initiatives (Zahran, 1998). So far no approach has been identified that could assist specifically in the design of effective SPI implementation initiatives. There is a great need to develop some mechanism that could assist SPI practitioners in the implementation of SPI initiatives. This has the potential to reduce SPI implementation time, cost and failure risks.

1.3 Research questions and aims of research

An examination of the SPI literature, together with an empirical study, highlights the need to develop a framework in order to assist practitioners in the design of effective SPI implementation initiatives. The aim of this research project is to empirically explore the viewpoints and experiences of practitioners regarding SPI implementation and to

develop a framework in order to assist practitioners in the design of effective SPI implementation strategies. This framework will be based on SPI literature and empirical analysis of practitioners' experiences and perceptions of factors that can have a positive or negative impact on the implementation of SPI.

I aim to narrow the gap between SPI research and practice in such a way that is accessible to both practitioners and researchers.

There are seven research questions that have motivated the work reported in this thesis:

RQ1. What factors, as identified in the literature, have a positive impact on implementing SPI?

RQ2. What factors, as identified in the real practice, have a positive impact on implementing SPI?

RQ3. Are there differences between the factors (with positive impact) identified through the literature and the real practice?

RQ4. What factors, as identified in the literature, have a negative impact on implementing SPI?

RQ5. What factors, as identified in the real practice, have a negative impact on implementing SPI?

RQ6. Are there differences between the factors (with negative impact) identified through the literature and the real practice?

RQ7. What are the necessary and sufficient phases/steps for the implementation of SPI programmes?

To answer these questions an empirical investigation has been conducted that has led to the development of an SPI implementation framework (SPI-IF) (Niazi *et al*, 2003b; Niazi *et al*, 2005a; Niazi *et al*, 2005b) which is the main contribution of this thesis. This is because empirical research enables rigorous experimentation by encouraging multiple analysis, from multiple perspectives using different techniques and, being based on experiences and direct data collection, it helps to compare what we believe to what we observe (Harrison *et al*, 1999; Perry *et al*, 2000). Also empirical research helps researchers move towards well-founded decisions (Perry et al, 2000). An empirical investigation of SPI implementation issues has provided valuable insights into the design of the SPI-IF.

1.4 Research contribution

I have built on the work of the Software Engineering Institute and the SPI literature to create the SPI-IF in order to assist practitioners in the design of effective SPI implementing strategies. An examination of the SPI literature, together with an empirical study, led me to design three individual components. I have pulled together individual components under one framework using a bottom-up approach already familiar to many practitioners and researchers. The SPI-IF is a specialised, cohesive and comprehensive framework that represents a new process view of the SPI implementation. The SPI-IF aims to present complex SPI implementation activities in a way that can be easily understood. The SPI-IF addresses problems of SPI implementation through a robust and transparent framework building strategy rarely known in SPI models and literature. So far no approach has been identified that could assist specifically in the design of effective SPI implementation initiatives.

The principal contribution of this research is the development of a framework that presents a new process view of the SPI implementation. In this thesis I show how the framework is built, evaluated and where possible improvements can be made to enable other researchers to build on my work and continue towards seeking methods to improve the SPI implementation process.

The other contributions are: identification of critical success factors (CSFs) and critical barriers (CBs) from the literature and the empirical study, the conduct of three separate case studies in the real world environment and an expert panel review process.

1.5 Thesis roadmap

The thesis is organised as follows. In Chapter 2 the relevant literature is reviewed. The concept of software quality is described in detail. Background and approaches to SPI are explained. Different empirical studies and experience reports are described. Limitations with empirical studies and experience reports are discussed in this chapter.

In Chapter 3, the design of the research process is presented. The approach adopted in the research is discussed and the rationale behind choosing the research design is explained. This chapter also examines the particular research methods and techniques used and their advantages and drawbacks.

In Chapter 4 an empirical study of SPI implementation factors is described. In order to effectively plan SPI implementation strategies, the objective of Chapter 4 is to provide practitioners with sufficient knowledge about the nature of issues that play a positive or negative role in the implementation of SPI programmes in order to assist them in effectively planning SPI implementation strategies. The literature (i.e. case studies, technical reports and journal articles) was analysed regarding factors that have a

positive or negative impact on the implementation of an SPI initiative. An empirical study was also conducted about factors that have a positive or negative impact on the implementation of a SPI initiative.

The SPI implementation framework is presented in Chapter 5. The two components of the framework are presented in this chapter, i.e. assessment component and implementation component. In the assessment component, the design of implementation maturity model (IMM) is presented. The objective of IMM is to guide organizations in assessing and improving their SPI implementation maturity or readiness. This model is adapted from CMMI (SEI, 2002a) and is based on CSFs and CBs identified through the literature and the empirical study. This model provides a practical structure with which to assess and improve SPI implementation maturity. In the implementation component, the design of SPI implementation model (SPI-IM) is presented. The objective of SPI-IM is to assist practitioners in effectively implementing SPI initiatives. This model has two dimensions - SPI implementation phase dimension and SPI implementation CSFs and CBs dimension.

In order to evaluate SPI-IF, three case studies were conducted. Chapter 6 describes these case studies. The intention is to observe the behaviour of SPI implementation framework in the real world environment. In order to provide more confidence in this evaluation, expert panel review process was also conducted. The objective of this evaluation is to seek opinions of SPI experts about the structure and different components of SPI-IF.

Chapter 7 provides the conclusions and thoughts on future work.

Chapter Two: Background

2.1. Introduction

This chapter gives an introduction to the domain of SPI and includes a review of SPI as an approach to improving software quality. This chapter also presents a review of work that has been done in the area of SPI.

The aim of this chapter is to provide background material and to put this research into context and to set the scene for the contribution that this thesis will make to SPI knowledge. The rest of this chapter is structured as follows:

- In Section 2.2 software quality is described.
- Software process is discussed in Section 2.3.
- Background to SPI is described in Section 2.4.
- In Section 2.5 different approaches to SPI are presented.
- Limitations of SPI are outlined in Section 2.6.
- In Section 2.7 different empirical studies of SPI are surveyed.
- Limitations with empirical studies are described in Section 2.8.
- Key experience reports are reviewed in Section 2.9.

- Limitations with key experience reports are described in Section 2.10.

- Finally, this chapter is concluded.

2.2 Software quality

Quality is a complex issue and there are many views of the term quality:

Gillies (1997) has stated that the ultimate goal of the manufacturing any product is to satisfy the people using the product and to realise the benefits expected from it. In other words, the people who use the product and the quality of the product have a close relationship.

The IEEE defines quality as "The degree to which a system, component, or process meets (1) specified requirements, and (2) customer or user needs or expectations" (IEEE, 1991:pp60). The ISO defines quality as: "The totality of features and characteristics of a product or service that bear on its ability to satisfy specified or implied needs" (ISO-9126, 1991:pp13). From these definitions it is clear that quality is related to the user satisfaction.

Accordingly, quality can be defined in terms of the technical properties of the artefact such as its maintainability and usability as well as from the perspective of the user, i.e. are the users satisfied with the artefact, does it address their needs and help them to work more effectively? In general, there are two main views on quality: one is technical and the other is people-oriented. In the technical perspective the focus is on product and process. This perspective reflects very much a software engineering view and is primarily concerned with increasing the rigour of the development process to make the product more robust and

maintainable. On the other hand, the user-oriented view focuses primarily on the satisfaction of users and on how useful the artefact is in its context of use.

A more complex analysis of the concept of quality is provided by Garvin (1984). Garvin proposes five perspectives in various domains as shown in Table 2.1. Among the three technical categories, the manufacturing view of quality is the most common amongst software engineers and lies at the heart of the sequential development methodologies of the traditional waterfall type (Gillies, 1997). Of the two people-oriented views, Garvin comments that the user-based definition is more prevalent, yet it has often been sacrificed in the past in favour of technical attributes.

Table 2.1 Major views of quality

Technical Views • *The transcendent view*: This is the view of quality that can be recognised but not defined. • *The product-based view*: This is the view where quality inherits characteristics of the product. • *The manufacturing view*: This view measures quality in terms of conformance to requirements.
People-oriented views • *The user-based view*: This can be summarised as 'fitness for purpose'. • *The value-based view*: This is ability to provide what the customer requires at a price that they can afford. Within software development, people, time and tools may all act as constraints upon the attainment of the desired level of quality.

Software quality has received much attention in both academia and industry. This is due to the role software plays in modern-day business and, to some extent, modern-day living. Software quality assurance group embraced a model that has 14 software quality

factors in three stages of the development life cycle: design, performance and adaptation (SQA, 1999). Although it is difficult to develop a piece of software that adheres to all of these factors, the model provides a good frame of reference to understand software quality.

Software developing organizations are realizing that quality software can be produced by effectively managing the software development process (Pitterman, 2000; Yamamura, 1999). Software Process Improvement (SPI) is the most widely used approach for addressing the effective management of the software development process. Research has shown that organizations using SPI approach can produce higher quality software, reduce development cost and time, and increase development productivity (Pitterman, 2000; Yamamura, 1999). The impact of SPI approach on software quality is described in the following studies:

- Yamamura (1999) results showed a definite correlation of employee satisfaction to process maturity, e.g. the average satisfaction was increased from 57% (before process improvement activities) to 83% (after process improvement activities).

- SPI program was very successful in Raytheon "since it started a process-improvement initiative in 1988, Raytheon's Equipment Division has improved its bottom line, increased productivity, and changed the corporate culture. Much of the savings came from reducing rework" (Dion, 1993:pp28). Over the period of four and a half years the company eliminated $15.8 million in rework costs.

- Diaz and Sligo (1997) showed the defect injection rate decreases by roughly half each time a project advances a CMM level, e.g. the CMM Level 2 project has a defect injection rate eight time greater than the CMM Level 5 project.

- Herbsleb and Goldenson's (1996) results showed a correlation between higher maturity and meeting schedules, meeting budgets, improving quality, improving productivity and improving customer satisfaction. For example, customer satisfaction increased from 80% (companies in CMM Level 1) to 100% (companies in CMM Level 3), ability to meet schedule increased from 40% (companies in CMM Level 1) to 80% (companies in CMM Level 3).

2.3 Software process

The term process has been used in many different contexts with many different intentions. In simple terms it can be defined as, an organised set of activities which transform inputs to outputs (Kotonya and Sommerville, 1998). Aliee (1996) characterised a process and described the following attributes of a process:

- States of a process
- Activities within a process
- Agents for performing every step of a process
- Products aiming to be produced by a process
- Resources being used through a process

Apart from some typical uses of the term process for indicating natural phenomena, such as a physical or a chemical process which can be well defined, there are other

important phenomena which have been modelled as a process. Examples of such processes are organisational processes, business processes and software processes.

Organisational processes involve the activities to be carried out to achieve the goals which an organisation has established for itself. An organisational process can be defined as: "a group of logically related tasks that use the resources of an organisation to provide defined results in support of the organisation's objectives" (Gladwin and Tumay, 1994). In a business process people are considered as the main agents in carrying out the activities. Both organisational and business processes involve human activity. With this in mind, a process can be defined as: "any set of unified activities that take an organisation from an initial objective to an achieved goal" (Spink, 1995).

Software processes are amongst the most complex processes and are influenced by the development methods for software products (Aliee, 1996). The term process in the context of software process has been defined as: "a set of partially ordered steps intended to reach a goal" (Feiler and Humphrey, 1993). Paulk *et al* (1993) have provided a more comprehensive definition of software process as "a set of activities, methods, practices and transformations that people use to develop and maintain software and the associated procedures" (e.g., project plans, design documents, code, test cases and user manuals). Sommerville (1998:p7) defined the term software process as "the set of activities and associated results which produce a software product". Sommerville also discussed four fundamental process activities, i.e. software specification, software development, software validation, software evaluation. However, Paulk *et al's* definition of software process is more complete because it recognises that a complete software process relies on activities, methods, practices and people. Paulk *et al's* definition of software process will be used in this research project.

2.4 Software process improvement

Attempts to improve software quality have been going on for several decades. Software organizations have been struggling with a questionable quality image for their products for a long time (Zahran, 1998). Software organizations are stretched more than they have ever been in the past. Customer satisfaction has also become the motto of many software organizations in order to survive with quality software (Paulk et al, 1994). Software quality has become more critical as software pervades our day-to-day lives (Pitterman, 2000; Yamamura, 1999). The ability to deliver quality software within budget and schedule continues to elude most software organizations (Ashrafi, 2003; Jiang *et al*, 2004; Paulk *et al*, 1994; Standish-Group, 2003). In order to effectively address the software quality issues different approaches have been developed, of which software process improvement is the one most widely used (SEI, 2004).

SPI provides organisations with a powerful means of assessing their current capabilities for developing software systems and, in doing so, identifying their strengths and weaknesses. Organisations are then in a position to embark on a programme of process improvement towards clearly defined and achievable goals which are devised specifically to demonstrate their achievement. The underlying theme of SPI is that by understanding and defining an organization's current software development processes, organizations can determine the areas that can be controlled and manipulated in order to achieve a particular product effect (Humphrey, 1995).

Fox and Frakes (1997) defined SPI as "a set of process oriented quality management systems that apply a unified set of theories, tools, methods and techniques in conjunction with attitudes, values and model problem solution". Rico (1997:p1) defined SPI as "the discipline of characterizing, defining, measuring, and improving software

management and engineering processes, leading to successful software engineering management, higher product quality, greater product innovation, faster cycle times, and lower development costs, simultaneously". Sommerville (1998:p638) states that "SPI involves understanding existing processes and changing these processes to improve product quality and/or reduce costs and development time". Sommerville goes on to say that "process improvement does not simply mean adopting particular methods or tools or using some model of a process which has been used elsewhere. Process improvement should always be seen as an activity that is specific to an organization or a part of a larger organization" (Sommerville, 1998:p638). In the definitions of Rico and Sommerville, the focus is to improve product quality while reducing cost and development time. These definitions seem to be more appropriate and complete to be used in this research project.

2.5 Approaches to software process improvement

2.5.1 Capability Maturity Model (CMM)

The Software Engineering Institute (SEI), founded in 1984, is a US government funded organization housed at Carnegie-Mellon University in Pittsburgh. The purpose of SEI is to establish protocols and methodologies in the field of software development.

In 1986, in response to a request from the US Department of Defence to provide a method of assessing the capability of contractors to produce software on time and within budget, the SEI began the development of a process maturity framework. The Capability Maturity Model (CMM) was one of the early developments of the SEI (Paulk et al, 1993) in order to improve organizations' software processes. The beginnings of the CMM were largely the work of Watts Humphrey who has written a first book on

CMM (Humphrey, 1989). After this the SEI began to refine the work with the help of Mark Paulk and his team of engineers and researchers.

The primary aim of the CMM is to determine an organisation's capability by measuring the degree to which processes are defined and managed. The CMM describes an evolutionary path from an immature, ad-hoc software process to an optimising, disciplined and mature process. The CMM is structured into five maturity levels ranging from level 1 to 5, i.e. 1, Initial; 2, Repeatable; 3, Defined; 4, Managed; 5, Optimizing (as shown in Figure 2.1). Paulk *et al* (1993:p5) defined maturity level as "a well-defined evolutionary plateau towards achieving a mature software process". They also defined software process maturity as "the extent to which a specific process is explicitly defined, managed, measured, controlled and effective" (Paulk *et al*, 1993:p4). Each maturity level expresses a different state of maturity in an organization. Level 1 corresponds to the lowest state of maturity and level 5 corresponds to the highest state of maturity. Each of the five levels is composed of several key process areas (see Figure 2.1) – for each key process area, several (usually three or four) goals are defined and more numerous key practices are identified under one of five sections, called 'common features'. The common features are attributes utilised in determining the effectiveness and repeatability of the implementation or institutionalisation of the key process area. For an organisation to reach a maturity level, they must satisfy the goals of the key process areas for that level and all lower levels. The key practices help an organisation understand how to achieve maturity goals and serve as examples of the activities to be addressed when undertaking a software process improvement programme.

An organisation can judge its process strengths, weaknesses, and maturity level by conducting an "appraisal". The capability of an organisation is determined via self-

assessments or evaluations prescribed by the SEI. The SEI has developed two surveys – the Software Contractor Evaluation (SCE) and the Software Process Assessment (SPA) – which compare and rate an organisation against the CMM. The SCE is an audit or appraisal performed by trained assessors to identify qualified contract software developers; the SPA is an assessment to help organisations evaluate their software process maturity and to identify key areas for improvement.

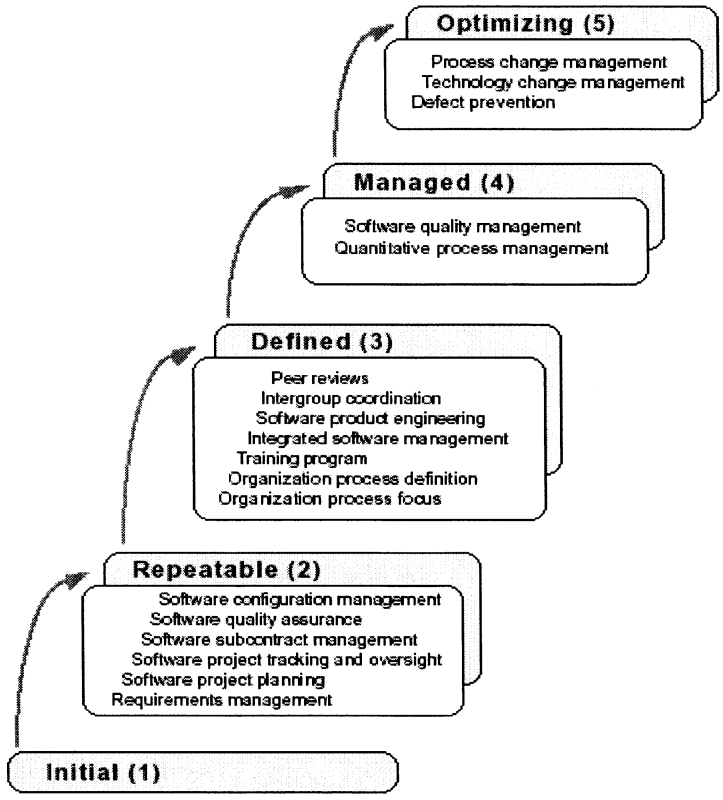


Figure 2.1 The Key Process Areas by Maturity Level (Paulk et al, 1993)

Overall, the CMM covers engineering, planning, managing and maintaining software processes. It is accepted as the de-facto standard in large companies in North America and is becoming increasingly popular in Europe. The CMM is a valuable model for SPI with defined levels and detailed definitions of key process areas and key practices. However, the model does not show how to implement those key practices and also does

not suggest effective implementation strategies. It also does not address issues relating to human resources such as selecting, hiring and motivating employees.

Many companies question the CMM because of lack of resources that small companies have at their disposal for SPI and they suggest that the CMM is more suitable for large organizations (Cater-Steel, 2001; Hareton and Terence, 2001). Some researchers have tailored the CMM to small projects (Hareton and Terence, 2001) others have applied it to a micro team with limited resources (Batista and Dias, 2000). Hareton and Terence (2001) argued that tailoring the CMM to small projects is necessary in order to encourage more organizations to use the CMM. They developed a process framework for small projects based on eight KPAs of the CMM and obtained positive results in software quality. Batista and Dias (2000) described a case study in which CMM is applied to a micro team of less that 10 people with limited resources. They concentrated primarily on the achievement of the objectives of KPA in level 2. The results obtained have shown a clear improvement of processes. This shows SPI can be achieved by a small team with limited resources.

2.5.2 Capability Maturity Model Integration (CMMI)

The CMMI model (SEI, 2002a) is the latest model from the Software Engineering Institute. The CMM Integration project was formed to sort out the problem of using multiple CMMs. As the name suggests, the CMMI is a model that combines three source models – the Capability Maturity Model for Software, Electronic Industries, the Alliance Interim Standard (EIA/IS) 731, and the Integrated Product Development Capability Maturity Model (IPD-CMM) - into a single improvement framework that accommodates multiple disciplines and is flexible enough to support two different representations (staged and continuous).

CMMI version 1.0 was released in August 2000 by SEI. It is important to note that CMMI was built on information from popular and well-regarded models together with the knowledge of the best systems and software development practices of high maturity CMM organizations that had been practising the model for more than a decade.

CMMI version 1.02 was released in December 2000 with the following objectives:

- To ensure that all of the products developed are consistent and compatible with the International Organization for Standardization (ISO/IEC-15504, 1998).
- To eliminate the redundancy and cost resulting from the use of separate and multiple CMMs.
- To be used to develop a framework to allow growth into other disciplines such as systems engineering, software acquisition and people.
- To provide an integrated set of common practices across systems engineering, software acquisition and people.

Like CMM, CMMI also has 5 maturity levels but Level 4 is renamed as "quantitatively managed". KPAs are renamed as process areas (PAs) in CMMI. CMM has 18 KPAs while CMMI has 25 PAs.

CMMI has two representations: staged and continuous. A CMMI model with a staged representation is shown in Figure 2.2. In the staged representation, maturity levels provide a recommended order for approaching process improvement in stages. As shown in Figure 2.2, maturity levels organize the process areas. Within the process areas are generic and specific goals as well as generic and specific practices.

A CMMI model with a continuous representation is shown in Figure 2.3. As shown, the specific goals organize specific practices and the generic goals organize generic practices. Each specific and generic practice corresponds to a capability level.

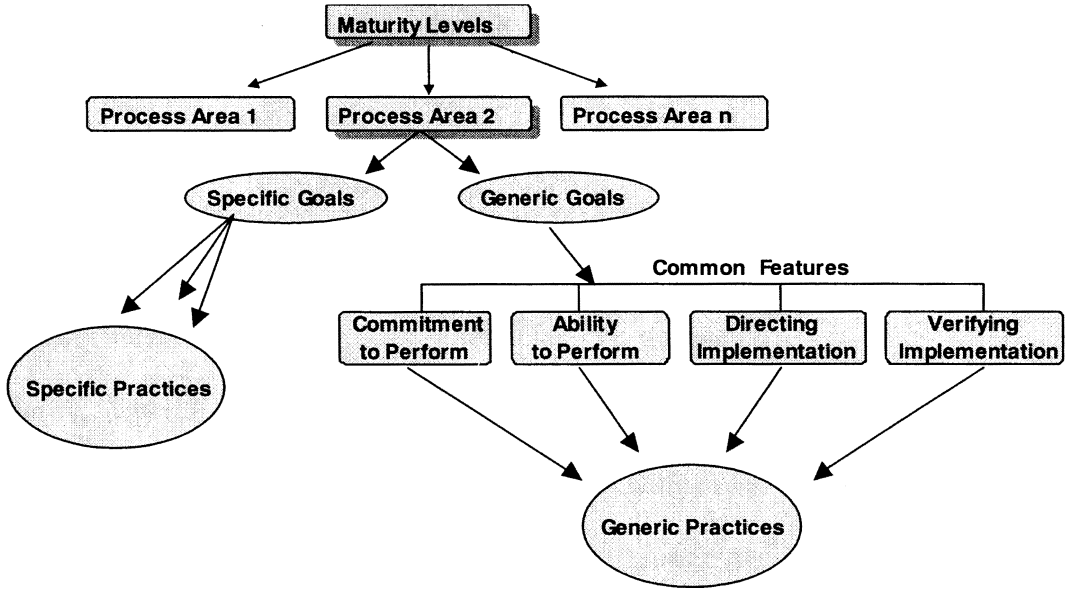


Figure 2.2 CMMI model with staged representation (SEI, 2002a)

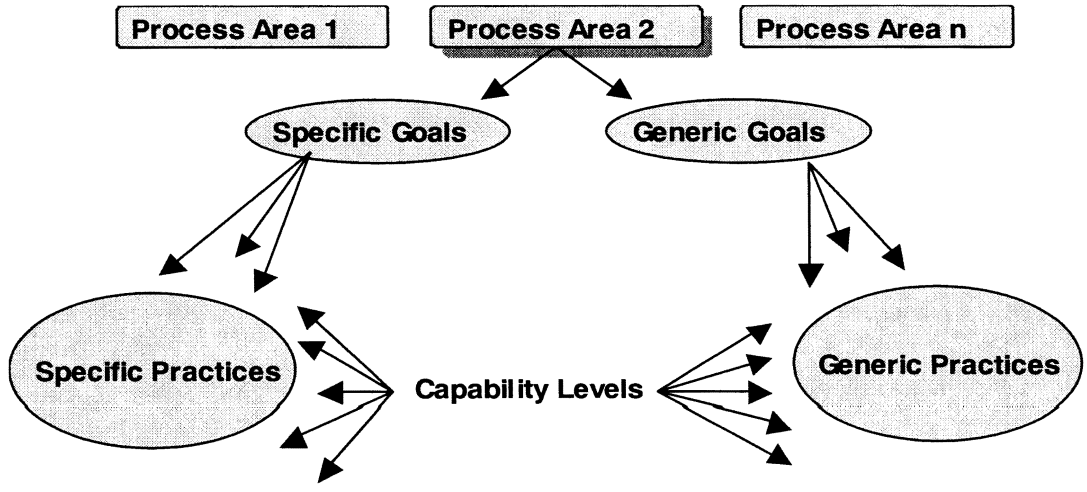


Figure 2.3 CMMI model with continuous representation (SEI, 2002a)

The CMMI is a valuable improvement framework with defined levels, process areas and key practices. However, this framework like its predecessor CMM does not show how to implement key practices neither does it suggest effective implementation strategies.

2.5.3 SPICE (ISO/IEC 15504)

SPICE is a set of international standards for software process assessment (ISO/IEC-15504, 1998). SPICE is intended to harmonize many different approaches to software process assessment and to provide an approach that encourages self-assessment. The intent of the standard is to deliver reliable and repeatable evaluations of process capability, providing results in a form that will permit valid comparisons between different assessments. This standard provides a mechanism for interchange of results of assessments based upon different process models, through the definition of a reference model for software processes and process capability. It has nine parts:

- Part 1: Concepts and introductory guide
- Part 2: A reference model for processes and process capability: defines a set of processes and a framework for evaluating the capability of the processes through assessment of process attributes structured into capability levels
- Part 3: Performing as assessment
- Part 4: Guide to performing assessments
- Part 5: An assessment model and indicator guidance
- Part 6: Guide to competency of assessors
- Part 7: Guide for use in process improvement

- Part 8: Guide for use in determining supplier process capability
- Part 9: Vocabulary

The key part of this standard is Part 2. The reference model in Part 2 documents a set of universal software engineering processes and its purpose is to provide a common basis for different software process assessment models and methods, ensuring that results of assessments can be reported in a common context.

Process capability is expressed in terms of process attributes which are grouped into capability levels – each level represents an incremental evolution in the management and control of the processes. The capability levels and associated process attributes are shown in Table 2.2.

Table 2.2 SPICE capability levels and process attributes

Capability Level	**Capability Description**	**Process Attributes**
Level 0	Incomplete process	–
Level 1	Performed process	Process performance
Level 2	Managed process	Performance management Work product management
Level 3	Established process	Process definition and tailoring Process resource
Level 4	Predictable process	Process measurement Process control
Level 5	Optimising process	Process change Continuous improvement

A process assessment is carried out by assessing the capability attributes of the selected processes – the assessment output includes a set of process profiles and, optionally, a

capability level rating for each process instance assessed. The process assessment is conducted either by a team with at least one qualified assessor or on a continuous basis using suitable tools for data collection and verified by a qualified assessor.

As mentioned earlier SPICE harmonises existing approaches to process improvement but does not recommend specific paths for improvement. It leaves the determination of a specific improvement path to the practising company.

2.5.4 ISO 9000

ISO 9000 is a series of quality system standards (ISO-9000, 2004). The ISO 9000 series of standards were developed with the intent of creating a set of common standards for quality management and quality assurance. The standards are generic in nature and can be applied to manufacturing and service industries regardless of an organization's size or the complexity of the product or service.

ISO 9001: Quality systems – Model for quality assurance in design/development, production, installation and servicing is the standard that is applicable to software development and maintenance (Ince, 1994). This model is used when conformance to specified requirements is to be assured by the supplier during design, development, production, installation and servicing. These requirements are not product specific and are aimed primarily at achieving customer satisfaction by avoiding nonconformity at all stages from design through servicing. It is a prescriptive model that encourages companies to examine their internal quality management systems. In 1991 the International Standards Organization published ISO 9000-3, "Quality Management and Quality Assurance Standards - Guidelines for the application of ISO 9001 to the

development, supply and maintenance of software" (ANSI/ASQC-Q9000-3, 1991). ISO 9000-3 interprets 9001 for software.

ISO 9001 2000 has replaced the old ISO 9001 1994 standard (ISO-9000, 2004). In addition, the old ISO 9001 1994 and ISO 9003 1994 quality standards have been discontinued. They are now obsolete.

ISO 9001 2000 is an effective standard for quality management but fails to address SPI implementation issues.

2.5.5 TRILLIUM

TRILLIUM is an assessment model developed in 1991 by Northern Telecom and Bell Northern Research (Francois, 2001). This model is based on SEI's CMM and has set of practices derived from a benchmarking exercise. In this model, there are eight capability areas that can span the five Trillium capability levels. Under each capability level different practices have been designed. This model has been designed for embedded software systems such as telecommunications systems, however it can also be applied to other segments of the software industry such as management information systems.

2.5.6 BOOTSTRAP

BOOTSTRAP is a methodology for the assessment and improvement of software process quality (Pasi, 2001). This methodology is mainly used in Europe. The main features of BOOTSTRAP methodology are: the assessment model, the underlying process model, the capability levels for evaluation, scoring and rating principles, and process improvement guidelines.

2.6 Limitations of software process improvement

For the last decade there have been many advances in standards and models to improve software development process. Research shows that the effort put into these models and standards can assist in producing high quality software, reducing cost and time, and increasing productivity (Ashrafi, 2003; Butler, 1995; Pitterman, 2000; Yamamura, 1999). However, these advances have not been matched by equal advances in the adoption of these standards and models in software development (Leung, 1999) which has resulted in limited success for many SPI efforts. Studies show that 67% of SPI managers want guidance on 'how' to implement SPI activities, rather than 'what' SPI activities to actually implement (Herbsleb and Goldenson, 1996). Despite the importance of the SPI implementation process, little empirical research has been carried out on developing ways in which to effectively implement SPI programmes. This suggests that the current problem with SPI is not a lack of a standard or model, but rather a lack of effective strategies to successfully implement these standards or models.

Some SPI models such as CMM are considered to be more suitable for large companies and smaller companies find it difficult to tailor some of the recommendations of CMM (Cater-Steel, 2001; Hareton and Terence, 2001; Jose *et al*, 2002; Leung, 1999). This is because larger companies have enough resources to invest. Leung argued that this issue of adaptability tends to prevent some companies from embarking upon SPI (Leung, 1999). Hareton and Terence (2001) argued that tailoring the CMM to small projects is necessary in order to encourage more organizations to use the CMM.

There are other difficulties that can limit the success of SPI initiatives in different companies, i.e. SPI is expensive, lack of immediate success, lack of support, lack of

resources and organizational politics. These limitations make it difficult for other companies to adopt SPI initiatives in order to improve software quality.

2.7 Empirical studies of software process improvement

This section presents a review of the key empirical studies conducted on the topic of SPI. The objective is to summarise and discuss the results of each study in order to better understand the problem context.

One of the first studies of factors necessary for SPI programmes was conducted by Goldenson and Herbsleb (1995). They conducted a survey of 138 individuals in 56 software organizations and identified the factors necessary for implementing a successful SPI programme. The results of this study suggest that:

- "Process maturity does indeed result in better product quality, ability to meet schedule commitments and other indicators of organizational performance".
- Over 80% of respondents believed that the "CMM has provided useful road-map direction about what process improvement ought to be tackled first".
- Only 10% thought that "their appraisals or the CMM caused them to neglect important process improvement issues". However, most respondents believed that "the money and effort they devoted to their appraisals were well spent and that the appraisals had a substantial positive impact on their organizations".
- 26 % of the respondents said: "nothing much has changed" since the appraisal.
- 49% said that there "has been a lot of disillusionment over the lack of improvement".

- 72 % reported that process improvement has often suffered due to time and resource limitations.

- 77 % said that process improvement had taken longer than expected and 68 % said that it had cost more than expected.

- 67 % of the respondents said that they need more guidance about exactly how to implement successful process improvement programs.

The authors identified a number of factors associated with successful SPI programmes, e.g. senior management commitment, staff involvement.

In this study factors associated with unsuccessful SPI programmes are also identified, e.g. organizational politics, belief that the SPI gets in the way of real work.

El Emam et al. (1999) also conducted a study that is a follow-up study to Goldenson and Herbsleb (1995) in order to investigate some of the important success factors and barriers for SPI. They have used data from 14 companies involved in the SPICE trials in order to identify which of the factors are most strongly related to the success of SPI efforts and which factors have no impact.

In order to confirm the findings of Goldenson and Herbsleb (1995), Stelzer and Werner (1999) have conducted a review of 56 software organizations that have either implemented an ISO 9000 quality system or that have conducted a CMM-based process improvement initiative. This study also assesses the relative importance of the factors. This research has been divided in two stages. In the first stage the authors have conducted an explorative study of factors that potentially affect organizational change in SPI. In the second stage the authors thoroughly analysed experience reports of 56

companies that had undertaken process improvement efforts in order to assess the significance of the factors identified in the first stage. 'Management commitment' and 'support' is the most important success factor of organizational change in SPI efforts. This factor is emphasized in 84% of the ISO cases and in 97% of the CMM cases. Staff involvement is ranked second and is mentioned in 84% of the ISO and also 84% of the CMM cases. The other factors are mentioned in between 52 and 72% of the ISO cases and in between 74% and 94% of the CMM cases. In the last the results of this research are compared with the findings of Goldenson and Herbsleb (1995).

Further studies have been conducted in order to find factors that impact SPI (Baddoo and Hall, 2002; Baddoo and Hall, 2003; Hall and Wilson, 1997; Rainer and Hall, 2002; Wilson and Hall, 1998). To highlight a few of these studies: a questionnaire survey of 85 UK companies (Rainer and Hall, 2002) identified the key success factors that can impact SPI implementation. The results show that the four factors that practitioners considered had a major impact on successfully implementing SPI are: reviews, standards and procedures, training and mentoring, and experienced staff. The authors have also identified four further factors (internal leadership, inspections, executive support and internal process ownership) that more mature companies considered had a major impact on successfully implementing SPI. In the study of Baddoo and Hall (2002; 2003), the authors present empirical findings analysing what motivates and de-motivates practitioners in SPI. The basic aim of these studies was to identify SPI motivators and de-motivators across developer, project manager and senior manager staff groups in order to provide insight into designing strategies that increase practitioner support for SPI. In this paper the similarities and differences of motivators and de-motivators for three groups of practitioners are presented. Authors have asserted

that such analysis will provide SPI managers with insight to develop targeted strategies for SPI implementation. Thirteen software companies were visited and 49 focus groups were conducted. The results of these studies show that there are more differences than similarities in motivators and de-motivators across practitioner groups. The authors have suggested that by identifying both similarities and differences, SPI managers can improve the implementation of SPI in their companies.

2.8 Limitations with empirical studies

The work I report in this thesis extends work previously done in the studies presented above. Due to the nature of CSFs it is possible that these CSFs may differ from manager to manager according to the individual's place in the organization's hierarchy and they may also differ in different geographical regions (Khandelwal and Ferguson, 1999; Rockart, 1979). So far I have not identified any empirical study that has been conducted with Australian practitioners in order to investigate what factors play positive or negative roles in the implementation of SPI programmes. Much of the existing literature provides anecdotal evidence of CSFs and CBs. In order to provide more certainty it is important to conduct empirical research that explores these factors - because empirical research enables rigorous experimentation by encouraging multiple analysis, from multiple perspectives using different techniques and, being based on experiences and direct data collection, it helps to compare what we believe to what we observe (Harrison et al, 1999; Perry et al, 2000). An empirical investigation of SPI implementation factors will provide SPI practitioners with valuable insights into the design of SPI implementation strategies.

Many of the studies mentioned above have adopted the questionnaire survey method for the identification of factors. A disadvantage of the questionnaire survey method is that

respondents are provided with a list of possible factors and asked to select from that list. This tends to pre-empt the factors investigated and to limit them to those reported in existing studies - respondents only focus on the factors provided in the list. It is also possible that respondents may misinterpret the factors provided in the questionnaire. In order to provide more confidence in the study it is important that practitioners' experiences and perceptions should be explored independently and without any suggestion from the researcher.

A thorough literature review revealed one topic of SPI missing, i.e. the existing empirical studies concentrate only on "what" activities to implement instead of "how" to implement these activities. Performing this research has convinced me that identification of only "what" activities to implement is not sufficient and that knowledge of "how" to implement is also required for successful implementation of SPI programmes (Herbsleb and Goldenson, 1996). Attention to the "how" to implement is crucial for the successful implementation of SPI initiatives.

2.9 Key experience reports of software process improvement

The research reported in this thesis focuses on implementation of SPI initiatives in real life environment. This section presents a review of the key experience reports and articles about SPI implementation. The objective is to better understand the SPI in real life context. The following reports are chosen because these reports described SPI initiatives in well known organizations. These reports are also frequently cited in the literature.

2.9.1 Hughes

Humphrey *et al* (1991) describe SPI experience at Hughes' software engineering division. They describe that in 2 years Hughes' software engineering division progressed from level 2 to level 3. One of the reasons for this success was 'management commitment' and the 'use of the available knowledge' by the SPI experts. Willis *et al* (1998) describe the SPI activities of Hughes Aircraft Company over the last 25 years. The focus in their paper is on the description of continuous improvement of the software process and the deployment of that improvement to all the 5000 software engineers of Hughes Aircraft. They mention that the reason for the survival and growth of the SPI programme was the 'strong support from the senior management'. Senior managers showed strong support by including process improvement in the organizational goals and by linking practitioners' incentives to organizational goals. Senior management also provided resources for SPI such as people, funding and the tools necessary to accomplish the tasks. Willis *et al* (1998) also describe that programme review is critical for SPI as it provides a communication forum to share lessons learned among different programs. These suggested changes were reviewed and approved by the software process team and thereby available to everyone in the company.

2.9.2 Motorola

Diaz and Sligo (1997) describe different factors that contributed to the success of SPI efforts at Motorola. 'Senior management support' was established through the provision of funds and resources for SPI activities and by rewarding practitioners for their SPI contribution. In addition to senior management commitment, individual project leaders and managers also needed to be committed to SPI. Diaz and Sligo (1997) state that process improvement working groups created were meeting every week in order to

address process, technology and people issues. In addition to these working group meetings, the chief software engineer also meets with new projects staff in order to ensure that level 5 principles are followed (Diaz and Sligo, 1997).

Fitzgerald and O'Kane (1999) examined how Motorola's Cellular Infrastructure Group achieved CMM level 4. The authors have identified 13 critical factors over a period of 5 years: dedicated project planning and tracking, management of subcontractors, institutionalised software quality assurance programme, software configuration management, comprehensive process definition and tailoring technique, strong and pervasive culture for SPI, training, strong cooperation, peer review, data driven culture, technology change programme fully deployed across whole organization, organization process improvement culture and defect prevention programme.

2.9.3 Oklahoma City Air Logistics Centre

Butler (1997) describes the SPI activities and lessons learned at the Oklahoma City Air Logistics Centre between 1990 and 1996. The Oklahoma City Air Logistics Centre has started its process improvement efforts in 1990 and its third assessment resulted in CMM level 4. The Oklahoma City Air Logistics Centre found different factors for successful SPI programmes: tailoring of priorities and goals to the needs of the particular organization, involvement of people in the SPI programme, sufficient training, communication and education, the need to choose lead assessors and process improvement must be seen as real work – it must be scheduled and tracked just as any other project. Butler (1997) also states that the management commitment and support was consistent throughout the SPI programme and process improvement success was not possible without high calibre leadership.

Lessons learned from the deployment of SPI by Oklahoma City Air Logistics Centre indicates that SPI must be considered as a real work and software practitioners must not be expected to do SPI in their own time (Herbsleb et al, 1994). Herbsleb *et al* (1994) also indicate that it is crucial to dedicate resources to SPI rather than expecting SPI activities to be done in spare time. They further mention "having SEPG membership of both full-time personnel and part-time personnel drawn from various projects is very important. The full time members provide continuity for the process improvement efforts, while the part-time members act as advisors, advocates, change agents and communications liaisons" (Herbsleb *et al*, 1994:p39).

2.9.4 Schlumberger

Wohlwend and Rosenbaum (1993:p219) describe the SPI efforts at Schlumberger and emphasize the importance of training: "in-house groups should be trained together to effect a cultural change". They also discuss management support for SPI: "the key behind the success of improvement effort lies with the management of the organization; if upper management is behind the improvement effort, then the improvement moves ahead" (Wohlwend and Rosenbaum, 1993:p218).

Lessons learned from the deployment of SPI by Schlumberger show that the support of middle management is important because they are often expected to make provision for SPI whilst meeting pre-existing deadlines (Herbsleb et al, 1994). This makes them unfriendly. One possible solution is to work with middle management first in order to reflect their expectations, time and resources to senior management (Herbsleb et al, 1994). Herbsleb *et al* (1994:p32) also describe the importance of SPI groups in the SPI efforts: "SPI depends on the critical role played by local SPI groups". They further state that SPI requires a cultural change that should spread throughout the business as SPI

cannot be separated from other parts of the business and must involve marketing, hardware, sales and manufacturing.

2.9.5 Space Shuttle Software Project

The Onboard Shuttle project adopted SPI in the 1970 in order to satisfy NASA's requirements for near zero-defect software. This project employed approximately 270 people. Specific teams were formed, in this project, in order to train and educate people (Billings et al, 1994; Paulk et al, 1994). "The curriculum team performed a training needs analysis and developed training objectives for 116 needs. The process team developed an on-line system that provided access to all training information on the project" (Paulk *et al*, 1994:p116). The mentoring programme was also part of the Onboard Shuttle quality improvement process and an informal mentoring programme was conducted in order to help and train new project members (Paulk et al, 1994). This project has also used process ownership teams that comprised the experienced people who performed the process. Executives in the Space Shuttle project had responsibility to ensure that staff are satisfied and that they are constantly focusing on the process improvement (Paulk et al, 1994).

2.9.6 Telcordia Technologies

Pitterman (2000) described the SPI programme at Telcordia Technologies and identified different factors that contributed to the success of SPI efforts. Pitterman indicates that senior management support was imperative for Telcordia's SPI programmes. In order to demonstrate to the developers that senior management was committed to the system's success and in order to supervise the system's quality effectively, Telcordia established a two-level management structure, i.e. the quality system's governing body and the quality system's implementation body. He also states that staff were actively involved

and the process specialists were in contact with the Telcordia product teams and customers in order to learn what was necessary to set up an effective quality system. Due to these communication lines, a sense of process ownership was quickly developed in all employees and in a short period of time making recommendations to improve the process became part of the culture at Telcordia (Pitterman, 2000). He states that, in the SPI programme, staff were very experienced and focused and could make decisions quickly without a lot of bureaucratic intervention. The quality and process control group was responsible for quality system training and mentoring. This group continually educated all members of the software organization about the quality method of operation and their responsibilities. Different working groups were established for SPI activities - i.e. strategic quality management team, tactical quality management team and the software engineering process group - and these groups played a critical role in the SPI efforts.

2.10 Limitations with key experience reports

A review of the experience reports revealed that no standard approach has been adopted for the implementation of SPI initiatives. Different organizations adopted different approaches, based on their own individual experiences, in order to implement SPI initiatives rather than following a standard SPI implementation approach. This can lead to a chaotic situation with no standard for SPI implementation practices (Zahran, 1998). The Software Engineering Institute has developed the IDEAL model (Jennifer and Chuck, 1997) for initiating, planning and guiding improvement actions. However, this model is explicitly linked to the CMM and is not generic enough to be useful for designing SPI implementation programmes using other SPI roadmaps or initiatives. So far I have not identified any standard approach that could assist specifically in the

design of effective SPI implementation initiatives. This topic needs to be investigated in order to assist SPI practitioners in designing effective SPI implementation strategies.

Most of the real life studies described what factors played the positive or negative role with no sufficient description of implementation strategies. It has also been revealed, through review of experience reports, that different advances have been made for the development of SPI standards and model but these advances have not been matched by equal advances in the adoption of these standards and models in software development (Leung, 1999) which has resulted in limited success for many SPI efforts. This suggests that the current problem with SPI is not the lack of a standard or model, but rather a lack of an effective strategy to successfully implement these standards or models.

A review of empirical studies and experience reports show that little attention has been paid to design some mechanism in order to assist SPI practitioners in the design of effective SPI implementation initiatives. Therefore, SPI implementation strategies lies at the very core of software engineering research and this thesis.

2.11 Summary

This chapter has examined the domain of SPI. A number of approaches have been described for SPI. Different empirical studies and experience reports of SPI have been described in order to better understand the problem context. Thorough literature review revealed what is missing in SPI, i.e. many standards and models exist for SPI but little attention has been paid to their effective implementation. Literature also shows that in real life different organizations adopted ad hoc methods instead of systematic and rigorous methods in order to implement SPI initiatives. So far no approach has been identified that could assist specifically in the design of effective SPI implementation

initiatives. Therefore, further research is needed in the domain of SPI implementation in order to reduce SPI implementation time and cost, higher SPI implementation quality and higher SPI practitioners' satisfaction.

Chapter Three: Research Methodology

3.1 Introduction

This chapter describes the research methodology, particularly, the use of research methods originated from social science in order to elicit and analyse views and perception of practitioners for SPI implementation. This chapter includes descriptions of, and a rationale for: research methods, samples, data sources, data analysis, and interpretation of data used in this study. Figure 3.1 provides a summary of sequence of events associated with the research design including the major stages and activities.

This chapter is organised as follows:

- Section 3.2 provides an introduction to empirical research.
- In Section 3.3 qualitative and quantitative research methods used in this thesis are described.
- In Section 3.4 choosing a research method is described.
- Section 3.5 discusses research design adopted. This section also describes the study sample, data collection methods and data analysis methods.
- In Section 3.6 limitation of research design are presented.

- In Section 3.7 University of Technology Sydney Ethics requirements are discussed.

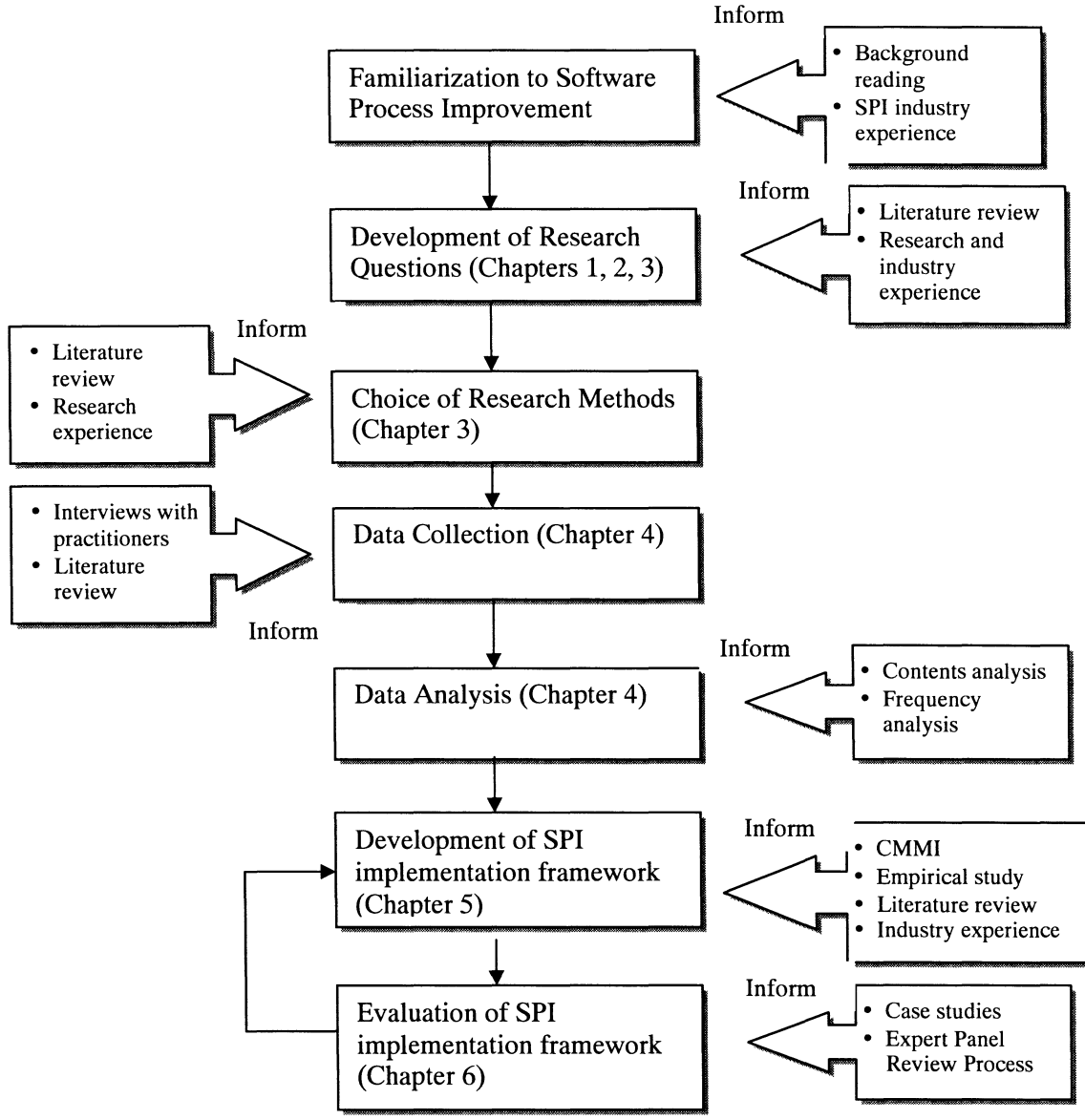


Figure 3.1 Research stages and activities

3.2 Empirical research

The American Heritage Dictionary of the English Language defines empirical as: relying on or derived from observation or experiment, verifiable or provable by means

of observation or experiment and guided by practical experience and not theory, especially in medicine. The Macquarie Dictionary defines empirical as: "1. taken from or guided by experience or experiment. 2. depending upon experience or observation rather than using science or theory".

These definitions tell us that empirical research is the type of research which is based on observed and measured phenomena that derives knowledge from experience rather than from theory.

In empirical research, the information, knowledge and understanding are gathered through experiences and direct data collection (Black, 1999). Empirical research is based on observation and experiences, therefore it reflects the world more fully than other research approaches (Harrison et al, 1999). Also, empirical research enables thorough experimentation by encouraging multiple analysis, from multiple perspectives using different techniques (Harrison et al, 1999). It is based on observed and measured phenomena and it derives knowledge from actual experience rather than from theory or belief. Empirical research also helps to build and confirm theories and to provide better knowledge of the software engineering discipline (Lehman and Belady, 1976).

There can be many forms of empirical research, e.g. case studies, surveys and prototyping exercises. Whichever form is used, the real spirit of empirical research is to learn something useful by comparing theory to reality and to improve these theories as a result (Perry et al, 2000). Empirical research involves the following steps (Perry et al, 2000):

- Formulating hypothesis/research questions
- Observing a situation

- Summarizing observations into data
- Analysing the data
- Drawing conclusion with respect to the tested hypothesis or research questions.

However, due to time constraints associated with a PhD program empirical research is sometimes difficult to conduct. This problem is further complicated by the fact that some companies do not want to participate, as they are reluctant to reveal information about their products, services and operations. Some companies do not want to participate because they have tight schedules and budgets and they do not want to let their practitioners participate in such studies. For these reasons it is difficult to carry out empirical research in the field of software engineering. There have been relatively few empirical studies conducted in some key areas of software engineering, such as perceptions and experiences of practitioners about SPI implementation. Adopting an empirical approach, therefore, can provide valuable insight into this important area of software engineering.

3.3 Qualitative versus quantitative research methods

3.3.1 Quantitative research methods

In quantitative research emphasis is on the collection and analysis of numeric data in order to explain or predict a phenomena of interest (Chong, 2001). Cavana et al. (2000) defined quantitative research as: "quantitative methods rely on the ability of the researcher to measure the phenomena under investigation and the use of statistics to analyse the raw data". Quantitative research is used mainly to test a theory by testing individual hypothesis. Such hypotheses are attempts to establish relationships between

variables and concepts. Concepts in quantitative research are described by distinct variables. "This type of research involves either identifying the characteristics of an observed phenomena or exploring possible correlations among two or more phenomena. In every case, descriptive research examines a situation as it is. It does not involve changing or modifying the situation under investigation, nor is it intended to detect cause-and-effect relationship" (Leedy and Omrod, 2001: pp191).

Quantitative research is about prediction, generalizing a sample to a larger group of subjects, and using numbers to prove or disprove a hypothesis. For a typical study using quantitative methods, researchers tend to draw a sample of persons at random from a broader population and generate data from this sample in order to generalise the conclusion to others. Quantitative methods of research are questionnaires and field and laboratory experiments. The data for quantitative research may come from tests, rating scales, checklists, questionnaires or other instruments administered to "subjects" in the research study itself. Examples of the quantitative data would be census data, student achievement records, and financial or demographic data. Occasionally, data gathered by qualitative methods such as interviews or field notes may be analysed numerically, thus yielding a combination of qualitative and quantitative methods in the same study.

The most common quantitative research methods are: questionnaire and survey research.

3.3.2 Qualitative research methods

Qualitative research differs from quantitative research by its way of generating information. It concentrates on a particular situation where depth is more important than generalisation. In qualitative research, research questions are posed rather than

hypothesised. In qualitative research the focus is on words and observations in order to express reality and attempts to describe people in natural situations. Qualitative research reveals people's values, mind maps, belief systems and rules of living in order to fully understand the respondent's reality (Cavana et al, 2000). Qualitative research methods are designed to study the complexities of human behaviours such as motivation, communication and understanding (Seaman, 1999). Human behaviour is a complex phenomena and requires qualitative research methods to study (Seaman, 1999).

Understanding the complex behaviours and messages is the central theme of qualitative research. In order to accurately reflect the behaviours and messages, qualitative research uses two techniques (Cavana et al, 2000). First, to report "in the voice of the source" by using actual words of the respondents. Second, to report the logic of interpretation used to come to a particular conclusion.

All qualitative studies have two things in common (Leedy and Ormrod, 2001), i.e. first, they focus on phenomena that occur in the real world; and second, they involve studying those phenomena in all their complexity. Qualitative research studies serve one of the following purposes (Peshkin, 1988):

- Description: They can describe the nature of certain processes, systems, people and situations.

- Interpretation: Qualitative studies enable a researcher to gain good understanding about the nature of a particular phenomenon, develop new concepts about the phenomenon and/or discover problems associated with those phenomena.

- Verification: They allow a researcher to test the validity of certain claims and theories in the real world environment.

- Evaluation: They provide a means to a researcher in order to judge particular policies and practices.

The most common qualitative research methods are: case study, interview, focus group, and observation.

3.4 Choosing a research method

In empirical research both qualitative and quantitative methods are used to gather information, knowledge and understanding through experience and direct data collection (Black, 1999). I took a scientific approach in this research where I collected and analysed empirical data using a combination of qualitative and quantitative methods in order to create and test a number of research questions. Qualitative and quantitative methods are complementary (Walker *et al*, 2003). Qualitative data can be converted through coding to become frequency data, and hence quantitative (Baddoo, 2001; Burnard, 1991; Seaman, 1999). Seaman (1999) adds that although this process of coding transforms qualitative data into quantitative data, it does not affect its subjectivity or objectivity. Bryman (1996) noted that the reverse can also occur. One of the examples in which quantitative research can facilitate qualitative research is by the selection of case studies for further research.

Finally, this overview of methods indicates that empirical methods help researchers move towards well-founded decisions (Perry et al, 2000). In line with recommendations, this research uses a combination of qualitative and quantitative methods for data collection and analysis. The description of research design described in Section 3.5,

involves the collection of qualitative data, through interviews, that is transformed to quantitative data (i.e. frequencies) in order to carry out statistical analyses.

3.5 Research design

This section explains how data is collected and analysed. This section also places the sample in context and explains how representative the data is of the population as a whole.

3.5.1 Sample profile

From November 2002 to December 2003 twenty-nine companies were visited and 34 interviews were conducted. Out of 34 interviews, one interview was conducted with each of the 24 companies and 2 interviews were conducted with 5 larger companies. The 224 letters of request were sent out to participants and only 29 companies (13%) responded. The sample profile is shown in Appendix A. The target population in this research was those software-producing companies that have initiated SPI programmes. Although I do not claim this is a statistically representative sample, Appendix A does show that companies in the study range from a small software house to large multinational companies and cover a wide range of application areas. It is also important to acknowledge that the data was collected from companies who were tackling real SPI implementation issues on a daily basis; therefore I have substantial confidence in the accuracy and validity of the data.

Thirty-four practitioners voluntarily participated in this study. By volunteering to participate they have become a self-selecting sample. Self-sampling though more practical than random sampling is often prone to bias (Krippendorf, 1980). In this research because the sample of companies form an original self-selected group (that is

software producing companies), it is important to ensure that one particular group is not over represented (Coolican, 1999). This research addresses the issue of over representation by using a sample of companies of varying complexities, size, nature of business, type of applications etc. A similar approach has been used by other researchers (Baddoo, 2001; Baddoo and Hall, 2002; Baddoo and Hall, 2003).

Sample size can be another source of bias. Generally, the larger the sample the less likely the sampling bias (Coolican, 1999). There are 29 participating companies in this sample of research. It is important to show that this sample is large enough to minimise the possibility of bias. However, it is difficult to determine the exact number of Australian software companies. This is because many smaller companies have closed down their business due to the recession. Another reason is that some companies are dedicated to software development only, whereas other companies have dedicated software development departments. Again it is suggested that the variety in company type, size, nature of business, age, type of applications etc limit the sample bias. A similar approach has been used by other researchers (Baddoo, 2001; Baddoo and Hall, 2002; Baddoo and Hall, 2003).

It is further important to acknowledge that the practitioners sampled within companies are representative of practitioners in organisations as a whole. A truly representative sample is impossible to attain and the researcher should try to remove as much of the sample bias as possible (Coolican, 1999). In this research, in order to make the sample fairly representative of SPI practitioners in particular organization, different groups of practitioners from each organisation self-selected to participate. The sample of practitioners involved in this research includes developers, business analysts, methodology analyst, technical directors, project managers and senior management.

In addition to the empirical study I also have analysed 50 published experience reports, case studies and articles in order to identify factors that can play a positive or negative role in the implementation of SPI programmes. These studies appeared to be of well-known organizations. Appendix C summarises published experience reports, case studies and papers organized according to the respondent companies. I consider these to be important publications because the 34 organizations include all the five organizations that have been awarded the IEEE Computer Society Award for Process Achievement.

3.5.2 Data collection methods

Data collection methods significantly influence the data analysis process, therefore, the data collection method needs to be carefully selected. In this research I have used CSF interviews and literature review for data collection. These methods are selected because they are best suited for the nature and type of data that this research analyses (Rockart, 1979).

3.5.2.1 Literature Review

SPI literature consists of case studies, experience reports and high-level software process texts. Most of the studies describe real life experiences of SPI implementation and provide a specific guidelines and recommendations for SPI implementation.

3.5.2.2 Application of literature review in this research

I have analysed 50 published experience reports, case studies and articles in order to identify factors that can play a positive or negative role in the implementation of SPI programmes. This literature analysis was entirely objective and only one researcher was involved. According to Leedy and Ormrod (2001) if the judgement of the literature is entirely objective then one rater is sufficient.

Each paper was reviewed carefully and a list of factors that played a positive or negative role in the SPI implementation was generated. There were three categories of papers. Firstly, papers in which the authors have described their SPI implementation experiences with lessons learned, e.g. how they achieved CMM level-3, why their SPI implementation programme was successful? etc. It was fairly simple to identify factors that played a positive or negative role in SPI implementation because often authors provided a summary of factors in the lessons learned. For example, in the experience of Oerlikon Aerospace, Laporte and Trudel (1998) state in lessons learned that "in addition to the senior management commitment it is essential that middle management and first line managers become strong supporters of the process improvement programme". In another example: Florence (2001) describes the lessons learned at The MITRE Corporation and states that "corporation had a software process training that supported Level 2 and Level 3. All employees engaged in software development were required to take process training appropriate to their software tasks".

Secondly, papers in which SPI implementation was discussed but authors did not provide any summary of factors. In this case, I have had to read each paper carefully to identify the factors that played positive or negative role. For example, in the study of Pitterman (2000) it was stated: "without high levels of senior management commitment to a quality system, most quality improvement efforts are doomed to fail". In another example it was stated: in discussing CMM in a small organization Paulk (1998) emphasized the creation of software engineering process groups: "a software engineering process group or some equivalent should be formed to coordinate process definition, improvement and deployment activities".

Thirdly, I also analysed a few papers in which the results of empirical studies were described. It was simple to identify factors from these studies. For example, El Emam et al. (1999) found time and resources as an important success factor for SPI. In another example I found: Hall et al. (2002b) present survey data characterizing the implementation of SPI in 85 UK companies and found that 89% of the respondents agreed to have proper resources for SPI: "it is important that SPI is properly resourced".

In order to reduce researcher's bias the inter-rater reliability was conducted in this process. Three research papers were selected at random and a colleague (PhD student), who was not familiar with the issues being discussed, was asked to identify CSFs that appeared in the research paper. The results were compared with previous results and no great disagreements were found. This PhD student has sufficient knowledge of SPI and methodology used.

All papers carried equal weight whether based on experienced reports, case studies or empirical studies. This is because I wanted to:

- identify aggregate factors that have been frequently cited in the literature
- compare aggregate factors identified through the literature with the empirical study in order to come up with common factors
- utilize these common factors in the development of the SPI implementation framework

Therefore, rather than using different empirical methods to rank CSFs and CBs, I have used the opinions of SPI experts to validate the literature findings. This two step process

has given confidence that a factor does indeed have an impact on SPI implementation if it is cited in both data sets.

3.5.2.3 CSFs interviews

The CSF interview (Bullen and Rockart, 1981; Rockart, 1979) is a unique opportunity to assist managers in better understanding their information needs. "The CSF interview often presents the initial occasion to interact with the manager on the types of information support that might be useful to her" (Bullen and Rockart, 1981). The original form of CSF interviews has been extended and used in the fields of information technology and information systems.

Different studies have confirmed the value of the CSF approach. For example:

- Huotari and Wilson (2001) reported a series of studies conducted in U.K. and Finland, in both academic and business institutions, and confirmed the value of the CSF approach in identifying organizational objectives and in relating the information needs of personnel to those objectives.

- Khandelwal and Ferguson (1999) used the concept of CSFs to determine the growth of IT in different geographic regions.

- Pellow and Wilson (1993) explored the potential of the CSF methodology in UK for assessing the information requirements of heads of university departments.

- Somers and Nelson (2001) describe the impact of CSFs across the stages of Enterprise Resources Planning implementation. Tyran and George (1993) identified a number of factors associated with expert system success.

A review of the CSF literature reveals that the concept has not been employed to any great degree in research on the topic of SPI implementation. Implementation of SPI programmes require real life experiences where one learns from mistakes and continuously improves the implementation process. CSFs are often identified after successful completion of certain activities. Therefore, these factors are near-to-real life experiences. Hence, the CSFs approach is useful in identifying important issues related to the implementation of SPI.

3.5.2.4 Application of CSF interviews in this research

In order to confirm the findings of literature and to have more confidence in the results, 34 CFS interviews were also conducted with three groups of practitioners. The practitioners participated in these interviews fall into the following categories:

- The first group was made up of designer/testers/programmer/analyst. Referred to as "developers".
- The second group was made up of team leader/project manager. Referred to as "managers".
- The third group was made up of senior managers/directors. Referred to as "senior managers".

Questioning was both open and close-ended with frequent probing to elaborate and clarify meaning. The interview questions were adapted from (Bullen and Rockart, 1981; Rainer and Hall, 2003; Rockart, 1979) and were chosen for the following reasons:

- The questions are best suited for the nature and type of questions that this research used.

- The questions can be adapted to achieve the objectives of this research's survey. The questions can be modified to specific questions relating to SPI implementation issues.

- The questions asked are short and to the point, this is important because participants are typically not willing to spend an excessive amount of time answering questions.

- The questions were used effectively and thus their effectiveness was proven (Huotari and Wilson, 2001; Khandelwal and Ferguson, 1999; Pellow and Wilson, 1993; Rainer and Hall, 2002; Reel, 1999).

A sample list of questions are shown in Appendix D. The negotiated interview duration was half an hour; however, the researcher and interviewee would determine the pace of the interview. The researcher did not rush the interview and allowed sufficient time for the interviewee to express his/her opinion effectively. Before the interview the researcher arranged the time and place with which the interviewees were comfortable. Most of the interviews took place in the interviewees' offices.

The interviews were held in the workplace and were subject to interruptions whether by incoming phone calls or from other staff. The researcher coped with this by switching off the recorder and then re-orientating the interviewee by repeating where the interview had broken off.

The researcher planned the interviews so as to meet the ethics requirements, i.e. protection of subjects from harm, deception and loss of privacy. The dignity and interest of participants was respected at all times. Approval from the host organizations was gained prior to conducting the research. The participants gave their written consent to

record their interviews. However, participants were given the option to switch the recorder off at any stage during the interview. The participants also agreed to the publication of results in the thesis, conferences and journal articles subject to confidentiality issues of maintaining secrecy for individuals and organizations. Additionally, participants were informed about the nature of the research, through a briefing document provided prior to the beginning of the research activity.

The following steps were followed during CSFs interviews:

- The objective of the interview was described with some explanation of the research project being under taken.
- Demographic questions were asked in order to determine the company type, nature of business and number of employees etc.
- Some questions were asked about interviewee's experience and knowledge of SPI implementation
- Questions were asked about: reasons for embarking SPI initiatives, how SPI initiatives were introduced, models and standards used, benefits achieved, software process assessment and maturity level of the company.
- The concept of CSFs was described to the interviewee
- The interviewee was asked to provide factors that can play a positive (CSFs) role or negative (CBs) role in the implementation of SPI programmes.
- When interviewee has finished providing all the CSFs and CBs then asked to provide his/her opinion about factors that are critical in the literature.

- The interviewee was asked to provide view about how these CSFs can be developed and how CBs can be avoided.

- The interviewee was also asked to provide view about how these CBs can be avoided.

The interviewing was found to demand considerable skills. These include avoiding putting one's own constructions into the interview, rather allowing interviewees to speak, determining the people to be interviewed, establishing objectives of the interviews, developing interview questions, employing effective listening techniques of reflecting back what a participant said, looking for opportunities to clarify meanings, and evaluating the interview. Basics skills were practiced, such as, introducing oneself, explaining the purpose of the interview, the presence of the tape recorder, and negotiating the length of the interview.

All interviews count equally regardless of company size, type, SPI maturity etc. The major reason for this is that I needed an aggregate list of CSFs and CBs to be used in the SPI implementation framework. Different categorizations of companies (e.g. mature versus immature companies, self-rated versus non-rated companies etc) are not required in this research project.

3.5.3 Data analysis methods

I have chosen the methods of data analysis according to the nature of collected data. The following methods were selected keeping in view the qualitative nature of data.

3.5.3.1 Frequency analysis

First way of organizing qualitative data is to group scores or values into frequencies (Black, 1999), because frequency analyses are helpful for treatment of descriptive information. Number of occurrences and percentages of each data variable can then be reported using these frequency tables. Frequencies are helpful for comparing and contrasting within groups of variables or across groups of variables and can be used for both nominal/ordinal as well as numeric data.

3.5.3.2 Application of frequency analysis in this research

Coding in empirical research is one method of extracting quantitative data from qualitative data in order to perform some statistical analysis (Seaman, 1999). In this research data from the literature and CSF interviews is categorised and coded in order to perform frequency analysis and also to perform some comparative analysis of SPI implementation CSFs within and between staff groups. I have used frequency analyses at two levels. Firstly, I measured the occurrence of key factors in a survey of the literature. I recorded the occurrence of a key factor in each article. By comparing the occurrences of a key factor in a number of articles against occurrences of other key factors in the same articles, I calculated the relative importance of each factor. For example, a percentage of x for factor y means that factor y is mentioned in x% of the literature, i.e. if a factor is mentioned in 10 out of 20 articles, it has an importance of 50% for comparative purposes. In this way I compared and ranked the factors. Secondly, I measured the occurrence of key factors in the empirical study. In order to analyse the CSF interview transcripts I recorded the occurrence of key factors in each CSF interview transcript. By comparing the occurrences of a key factor in a number of CSF interview transcripts against the occurrence of other key factors in the same CSF

interview transcript, I calculated the relative importance of each factor. Finally, conclusions are drawn regarding the factors that are critical in the literature and in the empirical study.

3.5.3.3 Content analysis

Content analysis is a research method that uses a set of procedures to make valid inferences from text (Michael and Lewis, 1994). Various authors provided definitions of content analysis. For example, Stone et al., (1966) state, "content analysis is any research technique for making inferences by systematically and objectively identifying specified characteristics within text". Krippendorff (1980) defines the method as follows: "content analysis is a research technique for making replicative and valid inferences from data to their context".

Content analysis can be used for many purposes, for example: (Michael and Lewis, 1994):

- Audit communication content against objectives
- Code open-ended questions in surveys
- Identify the intentions and other characteristics of the communicator
- Reflect cultural patterns of groups, institutional or societies
- Reveal the focus of individual, group, institutional or social attention
- Describe trends in communication content

Once data transcripts have been collected, the next task is to develop categories to be used in comparing and contrasting results.

Identification of categories is one of the important stages in analysing qualitative data (Creswell, 1994). Different researchers describe different approaches for establishing categories for qualitative data (Baddoo, 2001; Burnard, 1991). Baddoo (2001) describes the following steps for categorising qualitative data:

- Note important issues
- Read all the transcripts to identify themes from transcripts. Note down the themes and compare to the notes made during focus group sessions in order to reassure that the transcript being analysed is indeed a true reflection of the discussions in the focus group session
- Generate categories for responses
- Group similar categories together under a higher category heading. For example, motivators for SPI, time for SPI, money for SPI and people for SPI, are grouped under the higher category "resources" for SPI.
- Repeat the process until distinct sets of categories are obtained
- Assign codes to categories
- Construct a data matrix that reflects how categories appear in each transcript
- Verify categories using a triangulation approach
- Adjust categories to produce a final list

Baddoo's (2001) process is the most suitable for cases where one seeks to identify the frequencies of occurrence of category issues. This process is also suitable when extracting quantitative data from qualitative data in order to perform frequency analysis.

Burnard (1991) describes the following steps for categorising qualitative data obtained in the form of interview transcript:

- Make notes of the interview and identify general themes that appear
- Generate categories for relevant themes
- Analyse categories to identify clusters.
- Repeat this process until a tighter distinct set of categories is obtained
- Verify category system in order to improve its validity and reduce researcher bias
- Assign each category a colour and mark sections of the transcript with the relevant colour that reflects the category in question
- Take out all marked sections from the transcript

Burnard's (1991) process is suitable for cases where the researcher conducts the whole analysis process qualitatively and manually. This process is also appropriate when the researcher is not seeking to identify frequencies of occurrence of category issues.

In this research I am interested to measure the occurrence (i.e. frequency) of each factor in the literature and CSF interviews in order to determine the relative importance of each factor. Therefore, Baddoo's process seems to be more appropriate for this research.

3.5.3.4 Application of content analysis in this research

This research seeks to identify perceptions and experiences of practitioners about factors that play a positive and negative role in the implementation of SPI programmes. In order to identify categories or common themes for the implementation of SPI programmes, the following process has been adopted in this research (Baddoo, 2001; Burnard, 1991):

- Identifying themes for SPI implementation from transcripts: All the interview transcripts were read to identify the major themes for SPI implementation. These themes were noted down and compared to the notes made during the CSF interviews in order to reassure that the transcripts being analysed are indeed a true reflection of the discussion in the CSF interviews. This two step process also verifies that the transcription process has not changed the original data generated in the CSF interviews.

- Generate categories: All the CSF interview transcripts were read again to generate categories for responses. Different themes were grouped together under three categories, i.e. CSF, critical barrier and phases/steps needed for SPI implementation. For example, budget, funds etc were grouped together under CSF category "resources". Poor response, user unwillingness to involved etc were grouped together under critical barrier category "lack of support". Each category represents a CSF, a critical barrier or a phase/step necessary for SPI implementation.

In order to reduce researcher's bias the inter-rater reliability was conducted in this process. Three interview recordings were selected at random and one of the colleagues

(PhD student), who was not familiar with the issues being discussed, was asked to identify CSFs that appeared in the interviews. The results were compared with previous results performed by the researchers and no significant disagreements were found. This PhD student has sufficient knowledge of SPI and methodology used.

3.6 Limitation of research design

There are a number of limitations in this study. This study explored the experiences and perceptions of practitioners regarding SPI implementation. These perceptions and experiences have not been verified directly. This may mean that what practitioners say about critical factors may not necessarily be the critical factors for SPI implementation. Furthermore, practitioner's perceptions and opinions may not be accurate.

I did not categorise research papers, experience reports, case studies. Similarly I also did not categorise companies in the empirical study. This is because I wanted to identify aggregate factors that have been frequently cited in the literature and the empirical study.

However, I have high confidence in this research results based on opinion data (Baddoo and Hall, 2003; Dyba, 2000; El-Emam *et al*, 1999; Hall and Wilson, 1997; Hall and Wilson, 1998; Rainer and Hall, 2002; Stelzer and Werner, 1999) because:

- Data was collected from different practitioners who were dealing with SPI implementation issues on a daily basis
- Practitioners' experiences and perceptions were explored independently and without any suggestion from the researcher

- At the end of each CSF interview, I asked practitioners to rank from 1-5 their knowledge of SPI implementation. 77% of practitioners have chosen 4 and above. Only 23% have chosen 3 and below

- More than 50% of the companies have been involved in SPI programmes over the last five years

- Practitioners have cited those factors that have been used within the practitioners' company

- Though the software development industry is characterised by global competition and participation, this study is limited to Australian-based software development organizations. This helps eliminate the problem of interpersonal communication and probably cultural differences and tends to promote a more standardized group of organizations with respect to basic cultural differences

Among Australian-based software development organizations, only those that have attempted to improve their software processes were studied. Because this study is limited to the software industry, the gathered data reflects the perceptions of those individuals employed in this industry, and generalizations to other industries should be undertaken with extreme caution.

3.7 UTS ethics requirements

Before conducting this research an ethics application was approved by the UTS Ethics Committee. The researchers planned the interviews to meet the ethics requirements, i.e. protection of subjects from harm, deception and loss of privacy. The dignity and interest of participants was respected at all times. Approval from the host organizations was

gained prior to conducting the research. The participants also agreed to the publication of results in the thesis, conferences and journal articles subject to confidentiality issues of maintaining secrecy for individuals and organizations. Additionally, participants were informed about the nature of the research, through a briefing document provided prior to the beginning of the research activity.

3.8 Summary

In this research I explained how both qualitative and quantitative research methods are used to collect and analyse the data. I explained why different research methods are used and how they help to provide a context for the data. I also explained how representative the data is of the population as a whole. The use of a particular method requires knowledge of the data as each method has associated assumptions. I do not claim that the methods used are necessarily the only methods suited to my investigation. Results are presented with an understanding that experiments done in the real world are never perfect and many empirical studies, especially novel one, has flaws (Tichy, 1998). However, I explained that these methods are properly implemented in this research project.

Chapter Four: Empirical Study of Critical Success Factors and Critical Barriers for Software Process Improvement Implementation

4.1 Introduction

This chapter presents the results of an empirical study of SPI implementation critical success factors (CSFs) and critical barriers (CBs) in twenty-nine software companies. This study was conducted using CSFs interviews to investigate the experiences and opinions of 34 SPI practitioners. Furthermore, the experiences, opinions and views of practitioners through the literature (i.e. case studies, technical reports and journal's articles) were also analysed. The objective of this study is to summarise the factors that play a positive or negative role in the implementation of SPI programmes and to identify the CSFs and CBs. The ultimate aim of conducting this empirical study is to develop a SPI implementation framework (Chapter 5).

This chapter is organised as follows:

- The chapter aim is described in Section 4.2
- In Section 4.3 the concept of CSFs is explained
- In Sections 4.4 and 4.5 the CSFs and CBs identified through literature are discussed

- In Sections 4.6 and 4.7 CSFs and CBs identified through literature and an empirical study are presented, analysed and discussed

- This chapter is concluded in Section 4.8

4.2 Chapter aim

The aim of this chapter is to provide the reader with sufficient knowledge about the factors that play a positive or negative role in the implementation of SPI programmes. In order to identify these factors, an empirical study was conducted. In this empirical study, the concept of critical success factors (CSFs) (Rockart, 1979) was used. The findings of this empirical study drive the development of a SPI implementation framework (discussed in Chapter 5) (Niazi *et al*, 2003b; Niazi *et al*, 2005a).

The first six research questions, described in section 1.3, have motivated the work reported in this chapter.

4.3 Critical success factor (CSF) concept

The concept of CSFs was first introduced by Rockart (1979) as a mechanism to identify the information needs of chief executive officers. Rockart (1979) had based the CSF concept on the idea of success factors first discussed in the management literature by (Daniel, 1961). CSFs are defined as those few key areas where things must go right for a business to grow and they should receive constant and careful attention from management. If management does not pay attention to these areas the organizational performance is likely to suffer. The emphasis here is on "few" and "must go right". There are different things to which the attention of managers can be directed and it is imperative to focus on those things which are really important. CSFs are a small number

of important issues on which management should focus their attention. CFSs may differ from manager to manager according to the individual's place in the organization's hierarchy and they may also differ in different geographic regions and may change with the passage of time (Khandelwal and Ferguson, 1999; Rockart, 1979).

4.4 CSFs identified through literature

The following CSFs for the implementation of SPI programmes have been identified through the literature. A summary of these factors is provided in Appendix E.

4.4.1 Higher management support

There are several accounts that describe the importance of higher management support for SPI implementation. A few of the key studies are described below:

- Basili *et al* (2002) describe the 13 lessons learned from 25 years of process improvement experience at the NASA software engineering laboratory and emphasise senior management commitment for SPI: "having upper management support is important for continued success" (Basili *et al*, 2002:pp78).

- Butler (1995; 1997) describes the SPI activities of the Oklahoma City Air Logistics Centre and states that the management commitment and support was consistent throughout the SPI programme and that process improvement success was not possible without high calibre leadership.

- A survey of 138 individuals in 56 software organizations (Goldenson and Herbsleb, 1995) identified the factors necessary for implementing a successful SPI programme. The authors have identified a number of factors associated with successful SPI programmes and management commitment is one of them. In this

study the authors have argued that some organizations were successful and others were not and have stated that respondents from organizations with successful SPI efforts tended to agree that managers actively monitor the progress in their organizations.

- Humphrey *et al* (1991) describe a SPI experience at Hughes' software engineering division. In 2 years Hughes' software engineering division progressed from Level 2 to Level 3 of the CMM. Humphery *et al* identified management commitment as one of the factors for their success: "commitment to process improvement should be tied to the salary or promotion of senior management" (Humphrey *et al*, 1991:pp21).

- Paulk (1998) discuss how to use CMM for small organization and describe the senior management commitment as a crucial component for SPI: "bottom-up improvement, without sponsorship and coordination, leads to islands of excellence rather than predictably improved organizational capability" (Paulk, 1998:p356).

- According to Pitterman (2000) "without high levels of senior management commitment to a quality system, most quality improvement efforts are doomed to fail" (Pitterman, 2000:p90).

4.4.2 Staff involvement

According to Stezler and Mellis (1999) "staff involvement is the degree to which staff members participate in the improvement activities". Many studies have described the importance of staff involvement for SPI implementation.

- Dion (1992) describes the process improvement programme at Raytheon. He describes that their level of capability was slightly below Level 2 in 1988 and in three and half years he believes that they have achieved solid Level 3. During this period about 25% of software engineering staff was actively involved in process improvement activities.

- Johnson (1994) reports SPI experience at Corning Information Services and identified 5 critical success factors. One of the 5 CSFs is staff support: "The process improvement effort has been staffed by people who indicated interest in the effort, then worked with their supervisors to allocate the time and resources necessary to make their participation successful" (Johnson, 1994:p327).

- In the Space Shuttle Project (Paulk *et al*, 1994) staff willingly take responsibility in order to manage the process: "staff are the most effective focus of process management, since they are the closest to it and are best able to interpret process data. For instance, most quality assurance issues are resolved at lower levels of the Onboard Shuttle project" (Paulk *et al*, 1994:p117).

- In the study of Stelzer and Werner (1999) staff involvement is ranked as second most important factor to SPI success and is mentioned in 84% of the ISO and CMM cases respectively: "staff participation is essential in improvement activities because employees must adopt process innovations in their day-to-day activities. If staff members do not buy into the proposed changes then improvement initiative is useless" (Stelzer and Werner, 1999:p116).

- Westaway (1995) describes the importance of staff involvement in the SPI effort: "the most important part of this complex process of maturing an

organization are the individuals within the organization. If the people who make up this division had not done their best and worked well beyond normal requirements, we would not achieved a Level 2 or Level 3 status" (Westaway, 1995:p9).

4.4.3 Training and mentoring

Training and mentoring is also emerged as an important factor for SPI implementation.

- Fitzgerald and O'Kane (1999) examine how Motorola's Cellular Infrastructure Group achieved CMM level 4 and identified 13 critical factors. The authors have identified good training as one of the critical factors and state that Motorola considers employee training as critical and the training department of Motorola develops the annual training plans for all the employees.

- Fowler *et al* (1999) describe the lessons learned for SPI at Xerox and state that training for all levels of practitioners was critical to SPI success. The software engineering process group was responsible for SPI-related training. Fowler *et al* (1999) suggest that these trainings help those managers, to better understand SPI concepts, who had limited exposure to SPI concepts and experience.

- In the study of Rainer and Hall (2002), the authors have divided their sample of companies to the appraisal status of the company, i.e. formally appraised, self-rated or not rated. The most important factor identified is training and mentoring. The authors state that training and mentoring is identified as the most prominent factor not only because it is recognised by the most number of samples, but also because it is recognised by two sets of companies with successful SPI (Rainer and Hall, 2002).

- Willis *et al* (1998) describe the SPI activities of Hughes Aircraft Company. The twelve steps programme for SPI has been developed and step 6 is about training software practitioners. Hughes Aircraft has a formal training programme with 60 formal courses to train practitioners on SPI. Hughes training programme is considered as one of the assets of its SPI initiatives.

4.4.4 Staff time and resources

There are several studies that describe 'staff time and resources' an important factor for SPI implementation. A few of key studies are described below:

- Baddoo and Hall (2002) present empirical findings analysing what motivates UK practitioners in SPI. The authors have separated senior managers, project managers and developers into separate focus groups. The authors find all practitioners consider resources as a motivator for SPI, i.e. 24% occurrence in developers focus group, 31% occurrence in project managers focus group and 17% occurrence in senior managers focus group.

- Dion (1993) describes SPI activities at Raytheon's and discusses how changes in its software process resulted in reduced development costs. The Raytheon achieved SEI Level 3 in 5 years time and sufficient resources were provided: "the division has invested about $1.00 million in discretionary funds in process improvement each year. These funds have been used to support a staff of only one or two full-time personnel, plus many people working part time" (Dion, 1993:p31).

- Kaltio and Kinnula (2000) describe an industrial experience of deploying the defined software process at Nokia and report that it is necessary to allocate sufficient resources to the deployment of new processes.

4.4.5 Creating process action teams/ Change agents and opinion leaders

The following studies have highlighted the importance of process action teams:

- Billings *et al* (1994) describe the experience of Space Shuttle Onboard Software project and state that different teams were formed for the different processes and these teams were responsible for various SPI activities, i.e. documenting the process, collecting process metrics and benchmarking the process etc.

- In the analysis of three high maturity companies from Asia and North America that have implemented SPI programmes, Curtis (2000) states that these organizations have central groups in order to coordinate improvement activities with local improvement staff.

- Diaz and Sligo (1997) describe that process improvement working groups of senior practitioners were created during the SPI effort at Motorola. Diaz and Sligo further state that in addition to process improvement working group, another working groups was established with eight senior task leaders in order to take care of initial SPI activities.

- Herbsleb *et al* (1994) describe the SPI efforts at BULL HN Information Systems Inc and report on the creation of software engineering process group in order to coordinate process improvement efforts. Herbsleb *et al* also describe the SPI efforts at Schlumberger and state that SPI depends on the critical role played by

local SPI groups. While describing the lessons learned at Oklahoma City Air Logistics Centre, Herbsleb *et al* illustrate that "having SEPG membership of both full-time personnel and part-time personnel drawn from various projects is very important. The full time members provide continuity for the process improvement efforts, while the part-time members act as advisors, advocates, change agents and communications liaisons" (Herbsleb *et al*, 1994:p39)

4.5 Critical barriers (CBs) identified through literature

My aim of identifying critical barriers is to understand the nature of issues that undermine SPI implementation programmes. This section shows the list of critical barriers cited in the literature. A summary of these barriers is provided in Appendix E.

It is important to note that some CBs identified may be opposite of CSFs. This is because literature specifically identified these factors as CBs. Thus any factor that play positive and negative role are separately described.

4.5.1 Lack of resources

The following studies have identified 'lack of resources' as one of barriers for SPI implementation:

- Florence (2001) discusses the lessons learned in attempting to but not getting software CMM Level 4 at The MITRE corporation and states that the organization achieved CMM Level 3 because sufficient resources were provided but failed to achieve Level 4 because enough resources were not provided.

- In the study of (Goldenson and Herbsleb, 1995; Herbsleb and Goldenson, 1996) almost three-quarters (72 percent) report that process improvement has often suffered due to time and resource limitations.

- Kautz and Nielsen (2000) describe why implementation of SPI was not successful in one company than another company: "the project managers were hesitant to use resources from their own projects on any improvement activity" (Kautz and Nielsen, 2000:p4).

- In the experience of Oerlikon Aerospace, Laporte and Trudel (1998) describe five elements for successful implementation of SPI and state that it is important to estimate and provide resources otherwise frustration will end the organization's readiness to adopt the SPI programme.

4.5.2 Time pressure

There are several studies that describe 'time pressure' as a barrier for SPI implementation. A few of the key studies are described below:

- In the study of Baddoo *et al* (2000) time pressure is identified as one of the obstacles to SPI: "operational management feel that in the absence of all other obstacles, lack of time seems to be the overriding obstacle to SPI success in companies" (Baddoo *et al*, 2000:p376).

- Baddoo and Hall (2003) find that all groups of practitioners have cited time pressure as a de-motivator for SPI, i.e. 62% of developers, 44% of project managers and 58% of senior managers.

- Paulish and Carleton (1994) describe case studies for SPI measurement and illustrate time restriction as one of the SPI implementation problems.

4.5.3 Inexperienced staff/lack of knowledge

Inexperienced staff has also emerged as a critical barrier for SPI implementation.

- Kautz and Nielsen (2000) describe why implementation of SPI was not successful in one company: "the staff and technical director had no prior experience with SPI and its potential benefits" (Kautz and Nielsen, 2000:p4).

- Moitra (1998) describes the problems and difficulties of managing change for SPI and identifies inexperienced staff as one of the barriers for SPI: "the quality and process improvement people are often quite theoretical – they themselves do not understand quite well the existing software development processes and the context in which they are used" (Moitra, 1998:p202).

4.5.4 Organizational politics

There are several accounts that describe 'organizational politics' as a barrier for SPI implementation. A few of key studies are described below:

- El Emam *et al* (1999) have conducted a study of 14 companies in order to investigate some of the important success factors and barriers for SPI. They have identified "organizational politics" as one of the barriers for SPI.

- Moitra (1998) describes the problems and difficulties of managing change for SPI and identifies organizational politics as one of the barriers for SPI: "politics in organizations is probably one of the principal reasons why change

management efforts for process improvement initiatives fail" (Moitra, 1998:p201).

4.5.5 SPI gets in the way of real work

The following studies describe this barrier:

- In the study of 14 companies, El Emam *et al* (1999) have identified "SPI gets in the way of real work" as one of the barriers for SPI.

- Kautz and Nielsen (2000) describe why implementation of SPI was not successful in one company than another company: "all the innovative capabilities and competence of the project managers and the software developers were directed at creating new and better products. With regard to software processes, there was no innovative capability" (Kautz and Nielsen, 2000:p8). Kautz and Nielsen also illustrate that it was clear that product development was more important than process improvement.

4.5.6 Staff turnover

The following studies have discussed 'staff turnover' as a critical barrier:

- Hall *et al* (2002a) have conducted an empirical study with twelve software companies in order to identify different requirements process problems. They have conducted 45 focus groups containing 200 people. Their results show that staff retention is a problem for many of the companies.

- Paulish and Carleton (1994) describe case studies for SPI measurement and illustrate staff turn over as one of the SPI implementation problem.

- Wohlwend and Rosenbaum (1993) describe the SPI efforts at Schlumberger and identify the problem of permanent staff turnover of staff that work on improvement activities.

4.6 Analysis of results (Critical success factors)

In this section the results relating to RQ1 to RQ3 are discussed. This section shows the CSFs cited in the literature and empirical study and the frequency with which they occurred. The percentage shows the proportion of literature and practitioners that cited a particular CSF.

4.6.1 Critical Success Factors identified through literature

In order to answer RQ1, Table 4.1 shows the list of CSFs cited in the literature.

Table 4.1 CSFs identified through literature

Success Factors	Occurrence in literature (n=47)	
	Freq.	%
Senior management commitment	31	66
Staff involvement	24	51
Training and mentoring	23	49
Staff time and resources	18	38
Creating process action teams/ Change agents and opinion leaders	15	31
Reviews	14	30
Experienced staff	13	28
Clear and relevant SPI goals	12	26
Assignment of responsibility of SPI	12	26
Process ownership	11	23
Encouraging communication and collaboration or sharing best practices	10	21
Tailoring improvement initiatives	7	15
Reward schemes	7	15
Managing the SPI project	7	15
Providing enhanced understanding	7	15
Internal leadership	6	13
SPI people highly/well respected	5	11
Standards and procedures	4	9

The most frequently cited factor in the literature is senior management commitment, i.e. 66%. This suggests that management commitment can play a vital role in the implementation of SPI programs. Other frequently cited factors in the literature are staff involvement (51%), and training and mentoring (49%). It shows that practitioners in literature consider their involvement, and training and mentoring imperative for the successful implementation of SPI programs. The results also show that staff time and resources and creating process action teams are also important factors. More than 25% of the literature cited reviews, experienced staff, clear and relevant SPI goals and assigning of responsibilities as CSFs.

In the analysis of literature review, I have given equal weight to all types of papers. This is because I wanted to identify aggregate factors that have been frequently cited in the literature (for more details see Chapter 3, Section 3.5.2.2).

4.6.2 Critical Success Factors identified through an empirical study

In order to answer RQ2, Table 4.2 shows the list of CSFs cited in the CSF interviews.

Table 4.2 shows that, like the literature, the most frequently cited factors in the CSF interviews are training and senior management commitment, i.e. 68% to each. Two new CSFs – SPI awareness and defined SPI implementation methodology – have been identified in this empirical study which have not been identified in the literature. Other frequently cited factors are resources, staff involvement and experienced staff.

In the analysis of interviews data, I have given equal weights to all types of interviews regardless of practitioners' designation. The major reason for this is that I needed an aggregate list of CSFs and CBs to be used in the SPI implementation framework.

Different categorizations of practitioners (e.g. developers versus manager, manager versus senior manager etc) were not required in this research project. However, in order to check the significant difference between the opinions of different practitioners the chi-square test was conducted (Appendix G). It was found that there were more similarities than differences between the CSFs identified by different group of practitioners. This shows the level of agreement across all practitioners about CSFs of SPI implementation.

Table 4.2 CSFs identified through an empirical study

Success Factors	**Occurrence in CSF interviews (n=34)**	
	Freq.	**%**
Senior management commitment	23	68
Training	23	68
SPI Awareness	20	59
Allocation of resources	16	47
Experienced staff	13	38
Defined SPI implementation methodology	12	35
Staff involvement	11	32
Facilitation	9	27
Communication	5	15
Project management	5	15
Quality assurance	5	15
Formal documentation	3	9
Reviews	3	9
Automated tools	2	6
Company Culture	2	6
Customer satisfaction	2	6
External implementation agents	2	6
Logical sequence or order of SPI implementation	2	6
Measurement	2	6
Tailoring improvement initiatives	2	6
Formalised relationship between development team	1	3
Higher staff moral	1	3

4.6.3 Comparison of two data sets

Comparison of CSFs from the two data sets provides evidence that there are significant similarities but also some important differences between the findings of two sets. It is

suggested that by focusing on similarities, practitioners can improve the SPI implementation process. Focusing on similar CSFs across two data sets may offer SPI practitioners cost-effective opportunities in order to improve the SPI implementation process. This is because a small number of CSFs with high impact can be implemented that have a significant effect on the success of SPI implementation process.

CFSs are small number of important issues and may change with the passage of time (Khandelwal and Ferguson, 1999; Rockart, 1979). In order to analyse this change, I have divided the SPI literature into two data sets, i.e. 1991-1996 and 1997-to date (Appendix F) (Niazi *et al*, 2003a). The 'assignment of responsibility of SPI' was critical initially but more recently it was less critical. Similarly, 'training and mentoring' and 'experienced staff' became more critical recently. This is because SPI initiatives were in their infancy during the period of 1991-1996 therefore organizations needed responsible practitioners who could own these initiatives in order to successfully implement them. But later when SPI became more established organizations realised that experienced staff and training are an integral part of SPI implementation. This is because, during the infancy period of SPI initiatives, organizations realised that their managers and employees had a general idea of the SPI but did not have a complete understanding of the necessary details and also did not understand how their work adds to the organization mission and vision. Now when many organizations are touching higher levels of maturity, an important question to be asked would be: "what will be needed"? I have targeted this issue for further research. Through the recent empirical study two new CSFs – awareness and defined SPI implementation methodology – emerged which were not identified in the literature:

- Awareness of SPI is critical. This is because SPI is an expensive and long-term approach and it takes time to realise the real benefits of this approach (SEI, 2004). Hence, in order to get support of management and practitioners and to successfully continue SPI initiatives it is important to provide sufficient awareness of SPI in organizations. Awareness in this context refers to promoting, through awareness events, the long-term benefits of SPI among the higher management and the staff members of the organization.

- Defined[1] SPI implementation methodology has also emerged as a CSF. This is because little attention has been paid to the effective implementation of SPI initiatives (Goldenson and Herbsleb, 1995) and studies show that 67% of SPI managers want guidance on how to implement SPI activities, rather than what SPI activities to actually implement (Herbsleb and Goldenson, 1996). This new CSF suggests that in the opinion of practitioners defined SPI implementation methodology can play a vital role in the implementation of SPI programs.

In order to find significant differences between the two data sets (i.e. RQ3) the chi-square test has been conducted. I have found a number of significant differences between the two data sets (i.e. p value in Table 4.3 is highlighted for significant differences). I found 13 factors with significant differences. These factors can be divided into 2 categories, 'organizational' and 'technical'. Nine factors belong to category 'organizational', i.e. assignment of responsibility of SPI, clear and relevant SPI goals, creating process action teams/external agents, facilitation, internal leadership, process ownership, providing enhance understanding, reward schemes and SPI awareness. Some of the 'organizational' factors are cited only in the literature, i.e.

[1] This defined SPI implementation methodology should contain implementation plan, activities, practices, and procedures to be used during the SPI implementation process

assignment of responsibility of SPI, clear and relevant SPI goals etc. I suggest that these factors are not critical for the population who participated in the study, e.g. Australian practitioners. That's why these factors were not identified in the recent empirical study.

Table 4.3 CSFs identified through literature and CSF interviews

Success Factors	**Occurrence in literature (n=47)**			**Occurrence in CSF interviews (n=34)**			**Chi-square Test α = 0.05**		
	Freq	%	Rank	Freq	%	Rank	X^2	*df*	*p*
Assignment of responsibility of SPI	**12**	**26**	**8**	**0**	**0**	**0**	**10.191**	**1**	**0.001**
Clear and relevant SPI goals	**12**	**26**	**8**	**0**	**0**	**0**	**10.191**	**1**	**0.001**
Company culture	0	0	0	2	6	11	2.835	1	0.092
Creating process action teams/external agents	**15**	**32**	**5**	**2**	**6**	**11**	**8.062**	**1**	**0.005**
Customer satisfaction	0	0	0	2	6	11	2.835	1	0.092
Defined SPI implementation methodology	**0**	**0**	**0**	**12**	**35**	**5**	**19.473**	**1**	**0.000**
Encouraging communication and collaboration	10	21	10	5	15	9	0.564	1	0.452
Experienced staff	13	28	7	13	38	4	1.012	1	0.314
Facilitation	**0**	**0**	**0**	**9**	**27**	**7**	**13.996**	**1**	**0.000**
Formal documentation	**0**	**0**	**0**	**3**	**9**	**10**	**4.307**	**1**	**0.038**
Formalised relationship between development team	0	0	0	1	3	12	1.400	1	0.237
Higher staff moral	0	0	0	1	3	12	1.400	1	0.237
Internal leadership	**6**	**13**	**12**	**0**	**0**	**0**	**4.688**	**1**	**0.030**
Logical sequence/order of SPI implementation	0	0	0	2	6	11	2.835	1	0.092
Managing the SPI project	7	15	11	6	18	8	0.111	1	0.739
Measurement	0	0	0	2	6	11	2.835	1	0.092
Process ownership	**11**	**23**	**9**	**0**	**0**	**0**	**9.208**	**1**	**0.002**
Providing enhanced understanding	**7**	**15**	**11**	**0**	**0**	**0**	**5.543**	**1**	**0.019**
Quality assurance	**0**	**0**	**0**	**5**	**15**	**9**	**7.366**	**1**	**0.007**
Reviews	**14**	**30**	**6**	**3**	**9**	**10**	**5.228**	**1**	**0.022**
Reward schemes	**7**	**15**	**11**	**0**	**0**	**0**	**5.543**	**1**	**0.019**
Senior management commitment	31	66	1	23	68	1	0.025	1	0.874
SPI Awareness	**0**	**0**	**0**	**20**	**59**	**2**	**36.712**	**1**	**0.000**
SPI people highly/well respected	5	11	13	0	0	0	3.855	1	0.050
Staff involvement	24	51	2	11	32	6	2.815	1	0.093
Staff time and resources	18	38	4	16	47	3	0.622	1	0.430
Standards and procedures	4	9	14	0	0	0	3.044	1	0.081
Tailoring improvement initiatives	7	15	11	2	6	11	1.622	1	0.203
Training and mentoring	23	49	3	23	68	1	2.815	1	0.093
Tools/packages	0	0	0	2	6	11	2.835	1	0.092

Similarly, some organizational factors are only identified in the empirical study, i.e. facilitation and SPI awareness. This shows that now practitioners are aware that in order to successfully run and continue SPI initiatives it is important to provide sufficient knowledge of the benefits of SPI in the organization. Similarly, it could be inferred that practitioners need facilitation during the SPI implementation process.

Four factors belong to 'technical' category, i.e. defined SPI implementation methodology, formal documentation, quality assurance and reviews. The first three factors were only identified in the empirical study while the fourth one is found in both data sets. This shows that there is now a need to create a SPI implementation methodology that guides SPI practitioners in effectively implementing SPI programmes. This also shows that practitioners want defined documentation structures and quality assurance procedures for SPI implementation.

In order to further refine this analysis I have summarised the factors, identified through two data sets (see Figure 4.1). The results show that the two data sets in aggregate have cited 10 CSFs. These findings suggest that organizations should focus on these CSFs in order to successfully implement SPI programmes. I have confidence that these factors should indeed have a significant impact on SPI implementation as they are cited in both data sets.

In order to answer RQ3, it is clear from Figure 4.1 and Table 4.3 that there are both similarities and differences in CSFs between the two data sets. Using Figure 4.1, it is clear that 33% factors are common between the two data sets and 67% factors are only cited by an individual data set. Table 4.3 shows that, 13 factors (43%) have significant differences while 17 factors (57%) have no significant difference between two data sets.

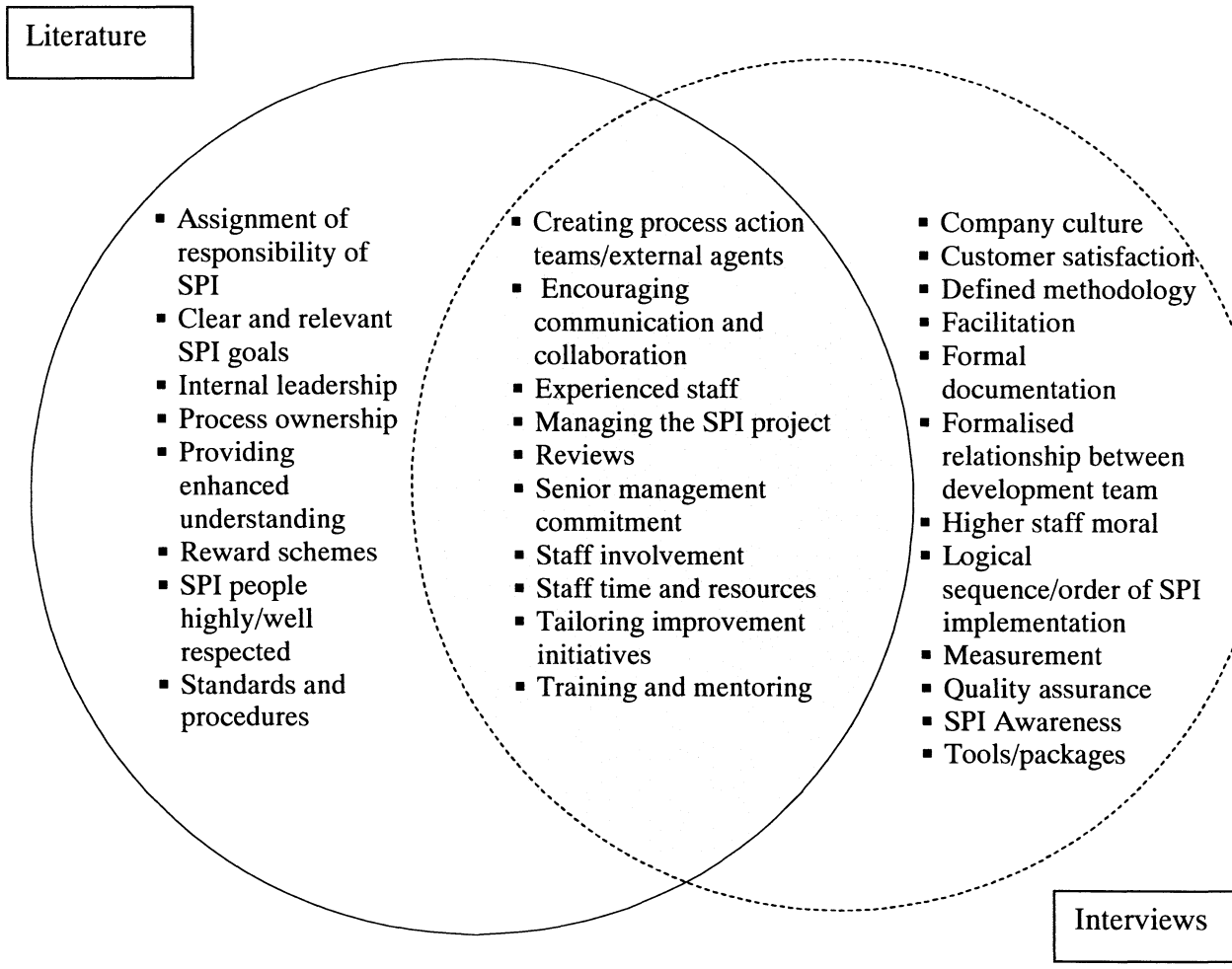


Figure 4.1 A summary of CSFs stated by literature and interviews. The CSFs are listed as a bullet point. The area in which both categories overlap represents common factors

4.7 Analysis of results (Critical barriers)

In this section the results relating to RQ4 to RQ6 are discussed. This section covers the CBs cited in the literature and the empirical study and the frequency with which they occurred. The percentage shows the proportion of literature and practitioners that cited a particular CB.

4.7.1 Critical Barriers identified through literature

In order to answer RQ4, table 4.4 shows the list of CBs cited in the literature. It shows, in literature, that most of the practitioners consider lack of resources a major critical barrier for the implementation of SPI. The results also suggest that in the opinion of practitioners time pressure and inexperienced staff can undermine the success of SPI implementation programs. It shows that practitioners in literature do not want organizational politics and staff turnover during the implementation of SPI programs.

Table 4.4 Critical Barriers identified through literature

Barriers	**Occurrence in literature (n=14)**	
	Freq	%
Lack of resources	7	50
Inexperienced staff/lack of knowledge	5	36
Time pressure	5	36
Organizational politics	4	29
SPI gets in the way of real work	4	29
Staff turnover	4	29
Lack of support	3	21
Changing the mindset of management and technical staff	2	14
Inertia	1	7
Negative/Bad experience	1	7
Paperwork required/formal procedures	1	7

4.7.2 Critical Barriers identified through an empirical study

In order to answer RQ5, Table 4.5 shows the list of CBs cited in the interviews. Lack of support is ranked highest in the interviews, i.e. 47%. The second highest barrier in the interviews is organizational politics, i.e. 41%. Two new critical barriers – lack of defined SPI implementation methodology and lack of SPI awareness – have been identified in the empirical study which have not been identified in the literature. The critical barrier 'lack of resources' is cited 35% in the interviews.

Table 4.5 Critical Barriers identified through an empirical study

Barriers	**Occurrence in interviews (n=34)**	
	Freq	%
Lack of support	16	47
Organizational politics	14	41
Lack of SPI awareness	13	38
Lack of defined SPI implementation methodology	12	35
Lack of resources	12	35
Inexperienced staff/lack of knowledge	9	27
Paperwork required/formal procedures	7	21
Time pressure	7	21
Lack of sponsorship	6	18
Lack of project management	3	9
Lack of tools	3	9
Lack of training	3	9
Negative/Bad experience	2	6
Lack of communication	2	6
SPI gets in the way of real work	2	6

As discussed in Section 3.5.2.4, all interviews count equally regardless of practitioners' designation. In order to check the significant difference between the opinions of different practitioners regarding CBs the chi-square test was conducted (Appendix G). It was found that there were more similarities than differences between the CBs identified by different group of practitioners.

4.7.3 Comparison of two data sets

Comparison of the CBs in the two data sets provides evidence that there are some clear similarities and differences between the findings of two sets (as shown in Table 4.6 and Figure 4.2). The results show that two data sets in aggregate have cited eight barriers. These findings suggest that organizations should focus on these common barriers in order to successfully implement SPI programmes because I have more confidence that a barrier should indeed have a significant impact on SPI implementation if it is cited in both data sets.

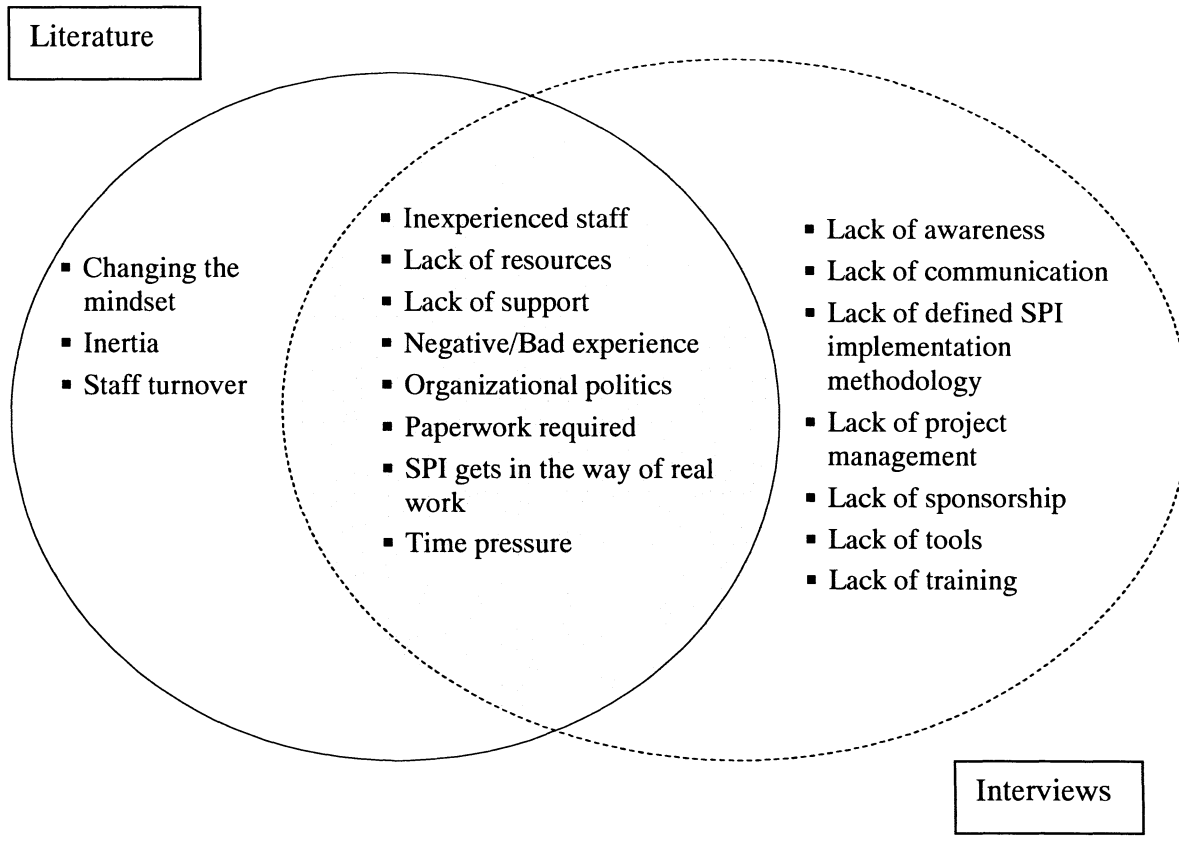


Figure 4.2 A summary of CBs stated by literature and interviews. The CBs are listed as a bullet point. The area in which both categories overlap represents common barriers

There are also a number of significant differences between the findings (i.e. *p* value in Table 4.6 is highlighted for significant differences). For example, 'changing the mindset of management and technical staff' and 'staff turnover' have not been cited in the empirical study but these barriers are present in the literature. Similarly, lack of awareness of SPI and lack of defined SPI implementation methodology are critical in the empirical study but have not been identified through the literature.

To answer RQ6, this is clear from Figure 4.2 that there are both similarities and differences in CBs between the two data sets. Out of these, 44% of the barriers are

common between the two data sets and 56% of the barriers are only cited by an individual data set. Table 4.6 shows that, 5 barriers (28%) have significant differences while 13 barriers (72%) have no significant difference between two data sets.

Table 4.6 Critical Barriers identified through literature and an empirical study

Barriers	**Occurrence in literature (n=14)**			**Occurrence in interviews (n=34)**			**Chi-square Test $\alpha = 0.05$**		
	Freq	%	Rank	Freq	%	Rank	X^2	*df*	*p*
Changing the mindset of management and technical staff	**2**	**14**	**5**	**0**	**0**	**0**	**5.068**	**1**	**0.024**
Inertia	1	7	6	0	0	0	2.480	1	0.115
Inexperienced staff/lack of knowledge	5	36	2	9	27	5	0.410	1	0.522
Lack of awareness	**0**	**0**	**0**	**13**	**38**	**3**	**7.341**	**1**	**0.007**
Lack of communication	0	0	0	2	6	7	0.859	1	0.354
Lack of defined SPI implementation methodology	**0**	**0**	**0**	**12**	**35**	**4**	**6.588**	**1**	**0.010**
Lack of project management	0	0	0	3	9	8	1.318	1	0.251
Lack of resources	7	50	1	12	35	4	0.897	1	0.344
Lack of sponsorship	0	0	0	6	18	7	2.824	1	0.093
Lack of support	3	21	4	16	47	1	2.724	1	0.099
Lack of tools	0	0	0	3	9	8	1.318	1	0.251
Lack of training	0	0	0	3	9	8	1.318	1	0.251
Negative/Bad experience	1	7	6	2	6	9	0.027	1	0.870
Organizational politics	4	29	3	14	41	2	0.672	1	0.412
Paperwork required/formal procedures	1	7	6	7	21	6	1.291	1	0.256
SPI gets in the way of real work	**4**	**29**	**3**	**2**	**6**	**9**	**4.667**	**1**	**0.031**
Staff turnover	**4**	**29**	**3**	**0**	**0**	**0**	**10.597**	**1**	**0.001**
Time pressure	5	36	2	7	21	6	1.210	1	0.271

4.8 Conclusion

This chapter has covered an empirical study and literature survey of CSFs and CBs that impact SPI implementation. I analysed the experiences, opinions and views of practitioners in order to identify factors that have a positive or negative impact on the

implementation of a SPI programs. I identified factors that are critical for successful implementation of SPI efforts. I suggest that focusing on these factors offers SPI practitioners short-term opportunities for implementing practices that impact SPI implementation process.

CSFs represent few key areas where management should focus their attention in order to successfully achieve the desired results (Rockart, 1979). In order to decide the criticality of a factor, I have used the following criteria:

- If a factor is cited in the literature with a frequency percentage of >=30%, then I treat that factor as a critical factor in the literature

- If a factor is cited by the respondents in the interviews with a frequency percentage of >=30%) then I treat that factor as a critical factor in this empirical study

A similar approach has been used by other researchers to identify important factors (Rainer and Hall, 2002). However, instead of having a 50% limit in this criteria, which is the more common approach, I have reduced this limit to 30%. This is because I wanted to have a sufficient number of implementation factors and with a 50% limit the identified implementation factors were not sufficient for the required research project.

These criteria have been designed, regardless of significant differences between the two data sets, in order to decide which factors and barriers are critical for SPI implementation. This is because in this research the focus is on the criticality of a specific implementation factor rather than the differences between two data sets. The objective is to use these CSFs and CBs in the SPI implementation framework.

Using these criteria, nine factors from two data sets have been identified that are generally considered critical for successfully implementing SPI. These factors are: allocation of resources, awareness, creating process action teams, defined SPI implementation methodology, experienced staff, higher management support, reviews, staff involvement, and training.

Using these criteria, for CBs, I have also identified seven barriers in both data sets. These barriers are: organizational politics, lack of support, lack of defined SPI implementation methodology, lack of awareness, lack of resources, inexperienced staff/lack of knowledge and time pressure.

I have summarised research results of this chapter in Table 4.7.

These findings drive the development of a SPI implementation framework (discussed in Chapter 5) (Niazi *et al*, 2005a). This chapter only contributes to the one component of the framework, i.e. SPI implementation factor component. The eventual research outcome is a framework for assisting the design of effective implementation strategies for SPI. The CSFs and CBs reported here provide the input to the other two components of the framework discussed in Chapter 5.

Table 4.7 Summary of results (CSFs and CBs) from literature and interviews

Research Question	Answer
RQ1. What factors, as identified in the literature, have a positive impact on implementing SPI?	• Senior management commitment • Staff involvement • Training and mentoring • Staff time and resources • Creating process action teams/ Change agents and opinion leaders • Reviews
RQ2. What factors, as identified in the real practice, have a positive impact on implementing SPI?	• Senior management commitment • Training • Awareness • Allocation of resources • Experienced staff • Defined SPI implementation methodology • Staff involvement
RQ3. Are there differences between the factors (with positive impact) identified through the literature and the real practice?	There are both similarities and differences in CSFs between the two data sets. Using Figure 4.1, it is clear that 33% factors are common between the two data sets and 67% factors are only cited by an individual data set. Table 4.3 shows that, 13 factors (43%) have significant differences while 17 factors (57%) have no significant difference between two data sets.
RQ4. What factors, as identified in the literature, have a negative impact on implementing SPI?	• Lack of resources • Inexperienced staff/lack of knowledge • Time pressure
RQ5. What factors, as identified in the real practice, have a negative impact on implementing SPI?	• Organizational politics • Lack of support • Lack of defined SPI implementation methodology • Lack of awareness • Lack of resources
RQ6. Are there differences between the factors (with negative impact) identified through the literature and the real practice?	There are both similarities and differences in CBs between the two data sets. Out of these, 44% barriers are common between the two data sets and 56% barriers are only cited by an individual data set. Table 4.6 shows that, 5 barriers (28%) have significant differences while 13 barriers (72%) have no significant difference between two data sets.

Chapter Five: A Framework for Assisting the Design of Effective Implementation Strategies for Software Process Improvement

5.1 Introduction

In this research project a Software Process Improvement Implementation Framework (SPI-IF) has been developed in order to assist SPI practitioners in the design of effective SPI implementation initiatives (Niazi *et al*, 2003b; Niazi *et al*, 2005a). The framework is based on the results drawn from SPI literature and an empirical study that has been carried out. This framework has three components, i.e. SPI implementation factors component (i.e. CSFs and CBs), assessment component (i.e. implementation maturity model) and implementation component (i.e. SPI implementation model). SPI-IF provides a very practical structure with which to assess and implement SPI implementation initiatives. The first component of the framework was discussed in Chapter 4. The objective of this chapter is to discuss the other two components of the framework.

This chapter is organised as follows:

- In Section 5.2 SPI-IF development process is described
- In Section 5.3 SPI-IF is described
- In Section 5.4 the assessment component is described

- In Section 5.5 the implementation component is presented
- This chapter is concluded in Section 5.6

5.2 Framework development process

An examination of the SPI literature, together with an empirical study, highlights the need to develop a strategy in order to assist practitioners in the design of effective SPI implementation initiatives. In order to address this need, seven research questions were developed (see Section 1.5).

An empirical investigation to answer these seven questions has led me to the development of the SPI-IF which is the major contribution of this research project. SPI-IF development was initiated by creating and agreeing its success criteria. Objectives were set to clarify the purpose of the framework and outline what the framework is expected to describe. These criteria guided development and are later used to help evaluate the framework.

The development of SPI-IF involved abstracting characteristics from three sources:

- SPI literature data
- Interview data
- CMMI architecture

These three sources led me to design three separate components of the SPI-IF.

Figure 5.1 outlines the stages involved in creating the SPI-IF. The first stage in SPI-IF development is to set the criteria for its success. These criteria govern and guide

subsequent framework building activities. The primary motivation for building these criteria for SPI-IF development emanates from my empirical research with 29 software development companies. In order to design the SPI-IF the following criteria were determined:

- **Ease of learning**

Complex models and standards are unlikely to be adopted by the organizations as they require a lot of resources, training and effort. The SPI-IF will have different levels of decomposition starting with the highest level in order to gradually lead the user through from a descriptive framework towards a more prescriptive solution. The structure of the SPI-IF will be flexible and easy to follow.

- **User satisfaction**

The end users need to be satisfied with the results of the SPI-IF. The end users of the SPI-IF will be able to use the product and will achieve specified goals according to their needs and expectations without any confusion and ambiguity.

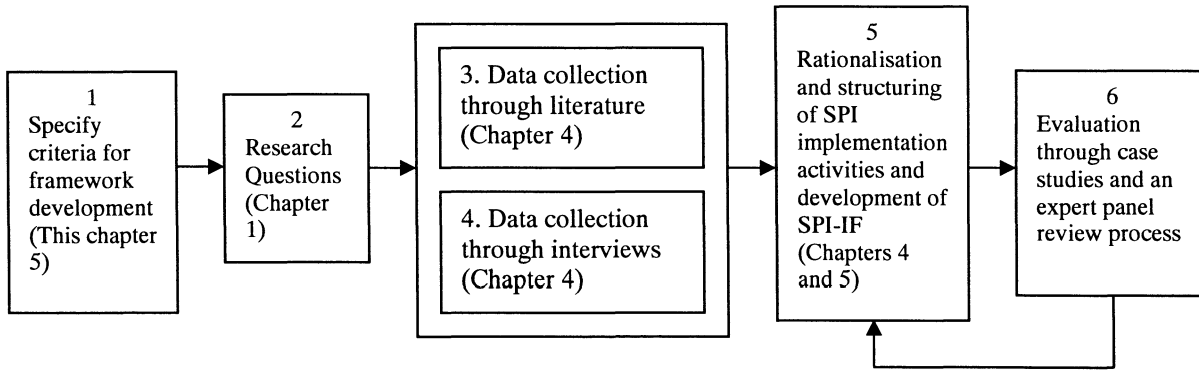


Figure 5.1 Activities involved in building the SPI-IF as conducted in this research

In order to address these criteria, seven research questions were developed in stage 2. Stages 3 and 4 are the stages where data is collected and analysed. Different CSFs and CBs were identified in these stages. These stages are discussed in Chapter 4. The existing literature concentrates only on 'what' activities to implement and 'how' to implement still needs to be considered. The interview questions were designed in such a way that the missing topic 'how to implement' should also be considered. During data collection it was not clear what form the SPI-IF would take, but my aim was to develop some mechanism that not only help SPI practitioners in 'what' to implement but also help in 'how' to implement. A list of factors was identified through literature and interviews. These important factors were grouped together under a 'factor component' of the SPI-IF (Chapter 4). In the interviews questions were asked about 'how one can develop these factors'. This led me to design different practices for each factor. Questions were also asked about 'how would you like to implement SPI initiatives?' This led me to design different SPI implementation phases. These SPI implementation phases, factors and practices are used in the 'implementation component' of the SPI-IF (Section 5.5). During interviews some practitioners discussed 'implementation readiness'. This prompted me to design an assessment instrument in order to assess the readiness of the organization for SPI implementation. I adapted the CMMI perspective and based on the results of empirical study developed the 'assessment component' of the SPI-IF (Section 5.4). There are many compelling reasons for using the CMMI as a basis for creating the 'assessment component':

- It is the most widely used SPI model (SEI, 2004)

- Research shows that the effort put into this model can assist in producing high quality software, reducing cost and time, and increasing productivity (Ashrafi, 2003; Jiang *et al*, 2004; Pitterman, 2000).

- It is a living model continuously being updated by the SEI (SEI, 2004)

- It is a normative model designed to be adapted

The CSFs and CBs identified through the empirical study are used as input to this component.

Stage 5 is the stage where I undertook a rationalisation and structuring of all SPI implementation activities and, based on empirical findings and existing literature, designed the three individual components (as discussed above). I have pulled together individual components under one framework using a bottom-up approach already familiar to many practitioners and researchers. The SPI-IF is a specialised, cohesive and comprehensive framework that represents a new process view of SPI implementation. The SPI-IF aims to present complex SPI implementation activities in a way that can be easily understood.

The final stage is covered in Chapter 6 where an evaluation of the framework is presented.

5.3 SPI Implementation Framework

During the empirical study and literature review two important issues of SPI implementation were discovered, i.e. "what" and "how". The first issue is about what is critical in the SPI implementation. The second issue is about how to implement SPI initiatives in the organizations.

In order to identify "what", it was important to identify a list of factors that are critical in SPI implementation. This was the starting point of this research. The critical SPI implementation factors were divided into two categories, i.e. critical success factors (CSFs) and critical barriers (CBs). In order to identify these factors, an empirical study was carried out about factors that have a positive or negative impact on the implementation of a SPI initiative (Niazi *et al*, 2003a; Niazi *et al*, 2004a). The empirical analysis of CSFs and CBs is presented in Chapter 4. The CSFs and CBs provide input to the other two components of the framework as shown in Figure 5.2.

Humphrey (1989) stressed the need for assessment as: "if you do not know where you are, a map will not help". Zahran (1998) described the risk of not following a defined assessment method: "different assessment teams could be adopting different approaches based on their own individual experiences, rather than following a standard approach to the assessment" (Zahran, 1998:p77). This risk can lead organizations to a chaotic situation with no standard for SPI implementation practices. In the appraisal of SPI models, e.g. CMMI, the software process maturity of the organizations is assessed. No attention, however, has been paid to assess the SPI implementation maturity of the organizations. The assessment of SPI implementation maturity can help organizations in successfully implementing SPI initiatives. This is because the readiness of the organizations for successfully implementing SPI initiatives could be judged through this SPI implementation maturity. I have focused on these issues and developed an implementation maturity model (IMM) (as shown in Figure 5.2), in the assessment component of the SPI-IF, in order to assess the SPI implementation maturity of the organizations (Niazi and Wilson, 2003; Niazi *et al*, 2005b). The CMMI perspective (SEI, 2002a) and the findings from current empirical study were used in the design of

IMM. The IMM has four SPI implementation maturity levels abstracted from CMMI. These maturity levels contain different CSFs and CBs identified through the literature and CSF interviews. Under each factor, different practices have been designed that guide how to assess and implement each factor. The IMM is described in Section 5.4.

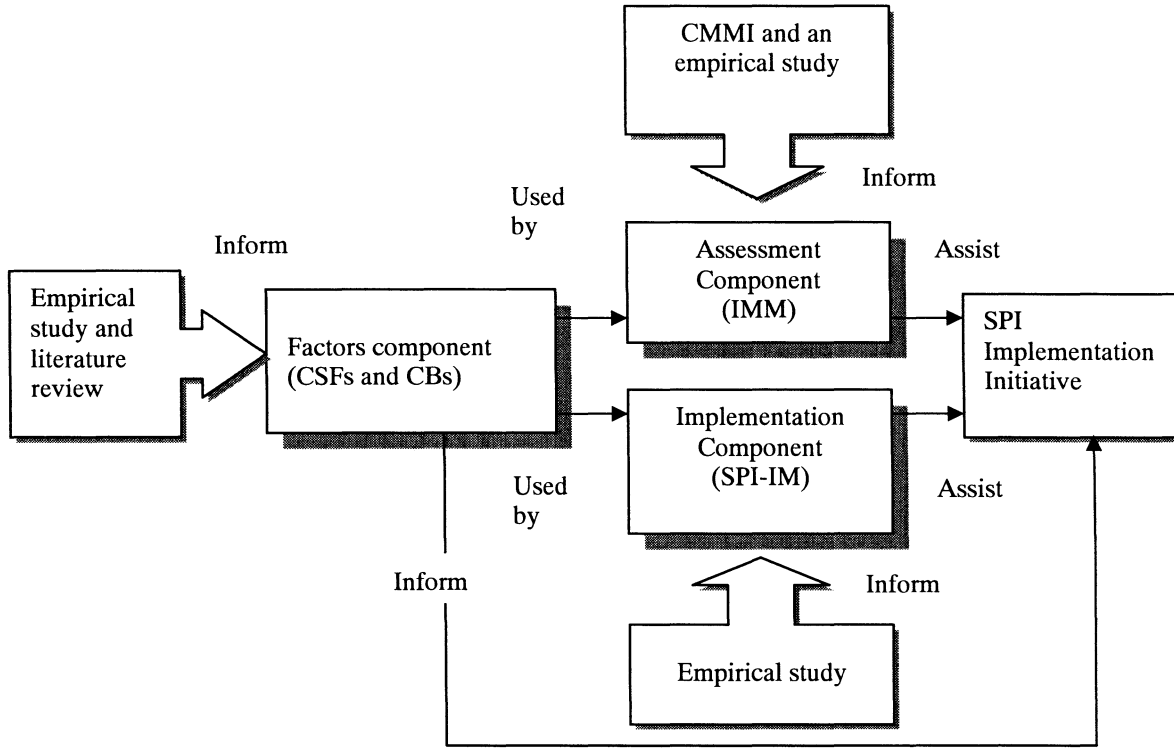


Figure 5.2 SPI implementation framework

Findings from the literature and the empirical study have also led to a second issue of SPI implementation, i.e. how to implement. The SPI implementation model (SPI-IM) was developed (as shown in Figure 5.2), in the implementation component of the SPI-IF, in order to assist organizations in successfully implementing SPI initiatives (Niazi *et al*, 2003c; Niazi *et al*, 2004b). During the empirical study it was suggested by the practitioners to use phase by phase approach for SPI implementation in order to reduce the implementation failure risks. The findings from the empirical study have led to the design of different phases for SPI implementation. Those phases were selected in the

SPI-IM, which were most frequently cited by practitioners. The CSFs and CBs were divided among different phases of the SPI-IM. In order to have more fine-grained activities within each phase of the SPI-IM, a list of practices were also designed for each CSF and CB. The SPI-IM is described in Section 5.5.

I have pulled together individual components under one framework using a bottom-up approach already familiar to many practitioners and researchers. The SPI-IF is a specialised and comprehensive framework that represents a new process view of the SPI implementation. The SPI-IF aims to present complex SPI implementation activities in a way that can be easily understood.

5.4 An assessment component

I have adapted CMMI (SEI, 2002a) perspective and developed a maturity model for SPI implementation (as shown in Figure 5.3) in order to guide organizations to assess and improve their SPI implementation maturity. The Figure 5.3 shows the relationship between maturity levels, CSFs and CBs and different implementation practices. It demonstrates how maturity levels indicate implementation capability and how CMMI perspective and empirical findings feed into these maturity levels, CSFs and CBs and implementation practices. Each maturity level (except level 1) is made up of CSFs and CBs. Each CSF and CB contains different practices.

The structure of this implementation maturity model (IMM) is built upon the following three dimensions:

- Maturity stage dimension
- CSFs and CBs dimension

- Assessment dimension

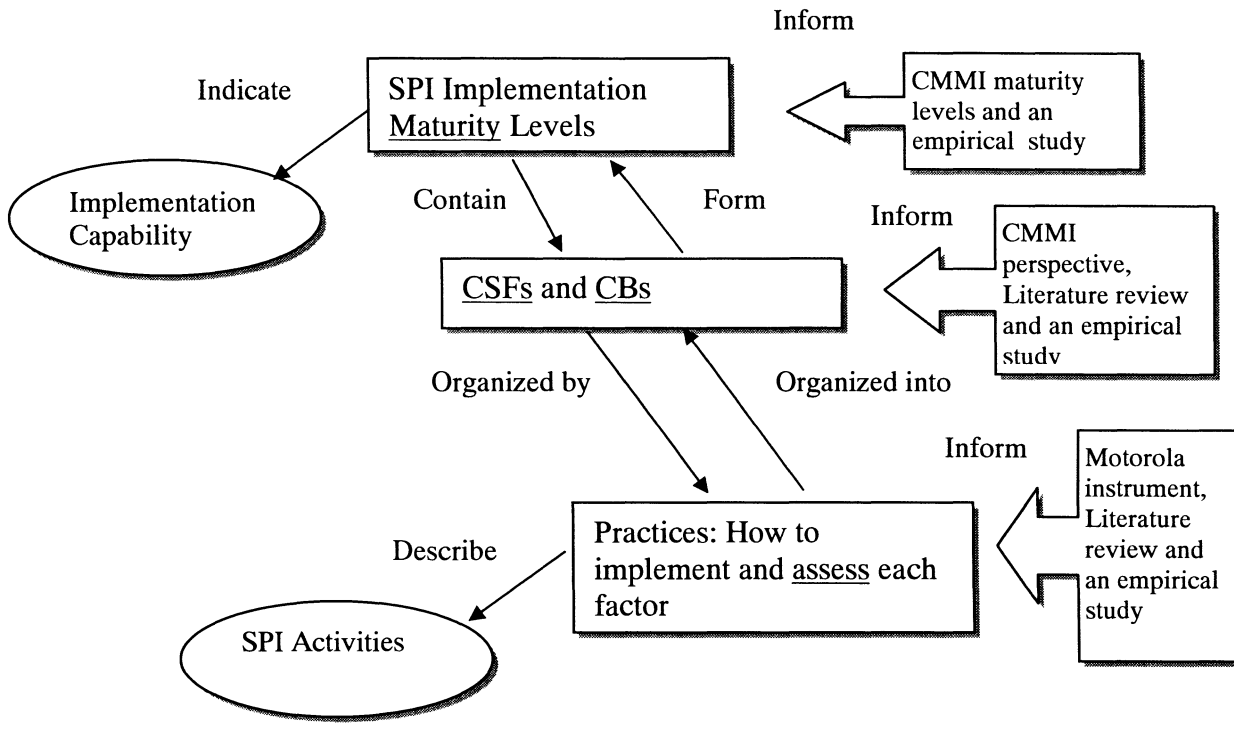


Figure 5.3 SPI implementation maturity model structure (Adapted from (Paulk *et al*, 1993; SEI, 2002a))

The primary motivation for building these dimensions for IMM emanates from CMMI perspective. As in CMMI, there are five maturity levels. Each maturity level contains different process areas. Each process area contains various practices. The CMMI stage representation and the categorisation of CSFs and CBs have led me to design different maturity levels for the implementation of SPI. These maturity levels contain different CSFs and CBs identified through literature and CSF interviews. Under each factor different practices have been designed that guide how to assess and implement each factor. The IMM in Figure 5.3 shows that organizations should address each factor in order to achieve a certain maturity level.

By maturity I mean an extent to which an implementation process is explicitly defined, managed and measured (SEI, 2002a). The maturity level is defined as a well-defined stage towards achieving a mature implementation process (SEI, 2002a).

5.4.1 Maturity stage dimension

The staged representation of CMMI is structured into five maturity levels ranging from level 1 to 5. For the IMM several adjustments to this stage structure are necessary to take account of SPI implementation characteristics (as shown in Figure 5.4):

- The level 1 has been adopted directly from CMMI. This is the level where the SPI implementation process is chaotic and few processes are defined.

- Awareness has emerged in the empirical study as an important factor for SPI implementation, i.e. cited in 59% of CSF interviews. SPI implementation is the process of adoption of new practices in the organization. In order to get support of management and practitioners, it is therefore important to promote awareness of SPI and to share knowledge among different practitioners. Awareness can be promoted through awareness sessions for practitioners to fully understand the benefits of SPI plus a series of working sessions for practitioners in order to define activities, goals and organisational strategy. Therefore, level 2 of the IMM is called 'aware'. I have defined level 2 as aware because SPI is an expensive long-term approach and it takes a long time to realise the real benefits. Hence, in order to successfully continue SPI initiatives it is important to provide sufficient awareness at the beginning of SPI implementation programmes. SPI implementation is not as beneficial without sufficient awareness of its benefits. Moitra (1998) has emphasised explanation and sharing of "how the improved

processes will help the individuals in terms of their efficiency, productivity and performance". The necessary investment of time and money and the need to overcome staff resistance are potential barriers to SPI implementation (Stelzer and Werner, 1999). These obstacles cannot be overcome without sufficient SPI awareness within the organization.

- Level 3 and level 4 of the IMM are adapted from CMMI level '3-Defined' and level '5-Optimising' respectively. In the IMM, level '3-Defined' is the level where SPI implementation processes are documented, standardized, and integrated into a standard implementation process for the organization. Level '4-Optimising' is the level where organizations establish structures for continuous improvement.

Although informed by CMMI, the IMM does not replicate the level '2-Managed' and level '4-Quantitatively Managed' of CMMI. This is because:

- In level '2-Managed' of CMMI, the focus is on project management. I have identified 'managing the SPI project' factor in this study that relates to project management. But this factor has been cited low in the literature (i.e. 15% of literature) and in the empirical study (i.e. 18% of interviews). I did not identify any other factor in this study that directly relates to project management.

- In level '4-Quantitatively Managed' of CMMI, the focus is on establishing quantitative measures of software process. Again in this study I did not find any factor that directly relates to this maturity level.

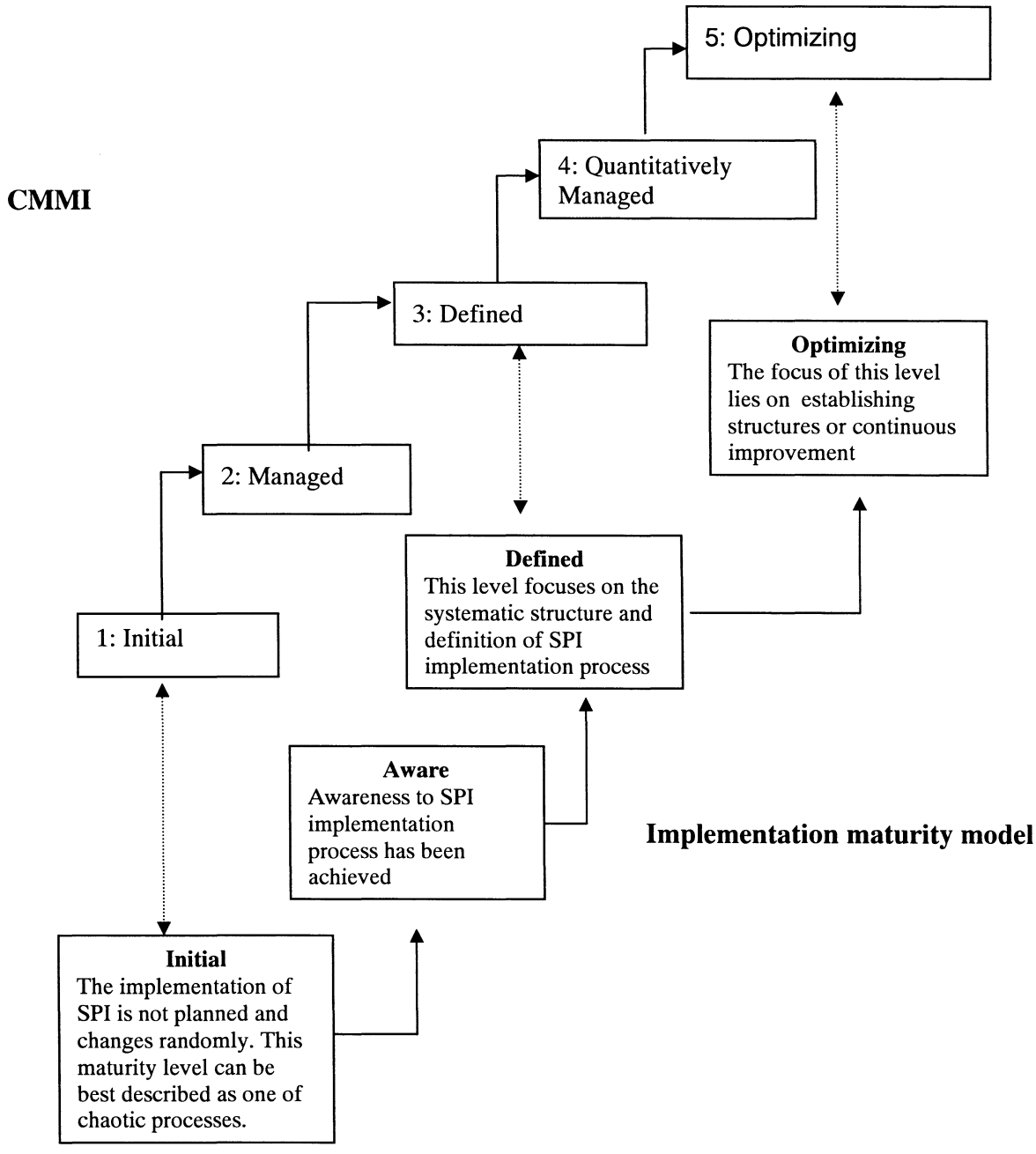


Figure 5.4 Maturity stage dimension as proposed by this research

These four maturity levels are sufficient for SPI implementation because these maturity levels are generated from factors which were collected from companies who were tackling real issues on a daily basis. It is not unusual to have fewer levels of process maturity than CMMI model. Other researchers have also designed fewer maturity levels than CMMI in areas of requirements process improvement and personal software

process (Humphrey, 1995; Sommerville *et al*, 1997; Sommerville *et al*, 1998). Sommerville et al (1997; 1998) have published the requirements engineering process maturity model which has been derived from the CMM and has three maturity levels, i.e. Level 1-Initial, Level 2-Repeatable and Level 3-Defined. This model can be used to assess current requirements engineering process and it provides a template for requirements engineering practice assessment. Similarly, Humphrey (1995) has designed a personal software process which has four process levels, i.e. PSP 0 - PSP 3.

5.4.2 CSFs and CBs dimension

The CMMI consists of 25 process areas (PAs) categorized across the five maturity levels. Software process maturity could be organised using these PAs (SEI, 2002a). Conducting this research has convinced me that the SPI implementation maturity would be best viewed in terms of CSFs rather than PAs. This is because:

- The implementation of SPI programmes requires real life experiences where one learns from mistakes and continuously improves the implementation process. CSFs are often identified after the successful completion of certain activities. Hence these factors are near-to real life experiences.

- Fitzgerald and O'Kane (1999) argued the importance of the CSF approach in SPI and emphasised the use of the CSF approach rather than the key process area approach: "the CMM assessment team at Motorola noted this richness, and therefore successful process improvement can be viewed in terms of CSFs rather than key process areas" (Fitzgerald and O'Kane, 1999:pp38). Somers and Nelson (2001) have also described the importance of the CSF approach in enterprise resource planning implementation: "Critical success

factors can be viewed as situated exemplars that help extend the boundaries of process improvement, and whose effect is much richer if viewed within the context of their importance in each stage of the implementation process".

- Different studies have confirmed the value of the CSF approach in the field of information technology (Huotari and Wilson, 2001; Khandelwal and Ferguson, 1999; Khandelwal and Natarajan, 2002; Pellow and Wilson, 1993; Somers and Nelson, 2001; Tyran and George, 1993). Therefore, the CSF approach can also be effective in the implementation of SPI.

Keeping these facts in view, different CSFs and CBs were identified from the literature and an empirical study. As CSFs are a small number of important issues on which management should focus their attention (Rockart, 1979), important criteria were applied to determine the criticality of a factor (Section 4.8).

The 25 PAs of CMMI can be split into four categories, i.e. process management, project management, engineering and support (SEI, 2002a). I have adapted this approach and categorised CSFs and CBs. This categorisation of CSFs and CBs has led me to design three categories, i.e. 'awareness', 'organizational' and 'support'. The three categories with the corresponding CSFs and CBs are shown in Table 5.1. The basis of this categorisation is the perceived coherence between the CSFs and CBs identified. It should also be pointed out that these factors and barriers are not necessarily mutually exclusive and there may be a certain degree of overlap among them.

The 'awareness' category contains CSFs and CBs that support SPI awareness activities in the organizations, e.g. senior management commitment, training, support and SPI awareness. The 'organizational' category contains CSFs and CBs relating to defining,

planning, resourcing, deploying and improving SPI implementation process. The 'support' category covers the activities that remove defects from SPI implementation process.

Table 5.1 Categories of CSFs and CBs

Category	CSFs	Critical Barriers
Awareness	• Senior management commitment • Training and mentoring • Staff involvement • Awareness of SPI	• Lack of awareness • Lack of support
Organizational	• Creating process action teams • Experienced staff • Staff time and resources • Defined SPI implementation methodology	• Lack of resources • Time pressure • Inexperienced staff • Org. politics • Lack of defined SPI implementation methodology
Support	• Reviews	

In order to have more confidence in this categorisation process, another researcher (co-supervisor) was asked to categorise the CSFs and CBS. The results were compared with previous results and no great disagreements were found. Furthermore, this categorisation process is evaluated at two levels, i.e. case studies and expert panel review process (Chapter 6).

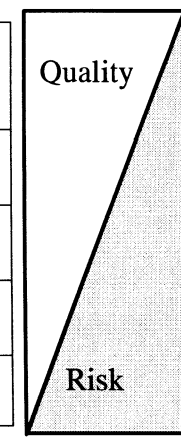
In order to divide these categories of CSFs and CBs among different levels of the IMM, I have used the perception of PAs division among different maturity levels of CMMI. The awareness category can be directly linked to maturity Level-2, i.e. "Aware" of the IMM. This is because the factors in this category can help to develop SPI awareness.

For example, one needs senior management commitment in order to initiate SPI awareness activities in the organization. Similarly, one also needs SPI training, support and staff involvement in order to establish the real benefits of SPI initiatives. The organizational category can be linked to maturity Level-3, i.e. "Defined", because the focus in this level is on the systematic structure and definition of SPI implementation process. The factors in the organizational category can be used to design systematic structures for SPI implementation. For example, defined SPI implementation methodology, allocation of resources and creating process teams etc can be used to define the SPI implementation process. Focus in Level-4 of the IMM is on continuous improvement; therefore the support category is linked with this level.

These factor categories may overlap and one should continuously monitor a previously implemented category. Thus, I named the current category as the "front-end category" and the previously implemented category as the "back-end category". The final allocation of factor categories among the four maturity levels of the IMM is shown in Table 5.2. There is no category for level '1-Initial' because this level is characterised as chaotic and ad hoc and it does not have to be achieved as such. Furthermore, CMMI also does not have any PA for level '1-Initial'.

Table 5.2 CSFs and CBs dimension

Maturity Stage	**Front-end category**	**Back-end category**
4 – Optimising	Support	Awareness, Organizational
3– Defined	Organizational	Awareness
2 – Aware	Awareness	
1 – Initial		



5.4.3 Assessment dimension

In this dimension each of the CSFs and CBs is measured to assess how well the factor has been implemented in practice. In order to measure the maturity of the SPI implementation process I have adapted an assessment instrument (as shown in Appendix H) that has been developed at Motorola (Daskalantonakis, 1994). There are many compelling reasons for adapting Motorola's instrument. It is a normative instrument designed to be adapted, it has been successfully tried and tested at Motorola and it has a limited set of activities. This instrument is used to assess the organization's current status relative to CMM and identify weak areas that need attention and improvement (Daskalantonakis, 1994). Diaz and Sligo (1997) describe the use of this instrument: "at Motorola Government Electronics Divisions, each project performs a quarterly SEI self-assessment. The project evaluates each KPA activity as a score between 1 and 10, which is then rolled into an average score for each KPA. Any KPA average score that falls below 7 is considered a weakness" (Diaz and Sligo, 1997:pp76). Motorola's assessment instrument has the following three evaluation dimensions (Daskalantonakis, 1994):

- *Approach*: Criteria here are the organization commitment and management support for the practice as well as the organization's ability to implement the practice.

- *Deployment*: The breadth and consistency of practice implementation across project areas are the key criteria here.

- *Results*: Criteria here are the breadth and consistency of positive results over time and across project areas.

For each CSF and CB, a list of practices (as shown in Appendix I) has been designed using the empirical study and the literature (El-Emam *et al*, 1999; Goldenson and Herbsleb, 1995; Johnson, 1994; Rainer and Hall, 2002; Stelzer and Werner, 1999; Zubrow *et al*, 1994). The following steps have been adapted for SPI implementation assessment (Beecham and Hall, 2003; Daskalantonakis, 1994):

- Step 1: For each practice of a CSF and a CB, a key participant who is involved in the SPI implementation effort calculates the 3-dimensional scores of the assessment instrument.

- Step 2: The 3-dimensional scores for each practice are added together and divided by 3 and rounded up. A score for each practice is ticked in the evaluation sheet (one example is shown in Table 5.3).

- Step 3: Repeat this procedure for each practice. Add together the score of each practice and average it to gain an overall score for each CSF and CB.

- Step 4: Relating the evaluation scores to SPI implementation: a score of 7 or higher for each CSF and CB will indicate that specific factor has been successfully implemented (Daskalantonakis, 1994). Any CSF or CB with an average score that falls below 7 is considered a weakness (Daskalantonakis, 1994).

- Step 5: In order to achieve any maturity level it is important that all those CSFs and CBs that belong to that maturity level should have an average score of 7 or above (Daskalantonakis, 1994). For example, in order to achieve SPI implementation maturity Level 2 it is important that all those CSFs and CBs that belong to Level 2 (e.g. Senior management commitment, Training and

mentoring, Staff involvement, Awareness, Lack of awareness, Lack of support) should have average score of 7 or above.

Table 5.3 Factor evaluation sheet

(5+8+8+7+7/No of practices) -> 35/5= Average core: 7

Training	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
P 1. Training is provided for developing the skills and knowledge needed to perform SPI implementation						√					
P 2. Sufficient resources and additional time to participate in SPI training will be provided to staff members.									√		
P 3. Training programme activities are reviewed on a periodic basis									√		
P 4. Organization has developed a written training policy for SPI to meet its training needs								√			
P 5. All future group or individual trainings of SPI are planned								√			

5.5 An implementation component

In this section a SPI implementation model (SPI-IM) is described. The objective of this section is to empirically explore the viewpoints and experiences of practitioners regarding SPI implementation and to develop a model in order to assist SPI practitioners in effectively implementing SPI initiatives. The empirical study was conducted with software practitioners in different organizations with the specific aim of:

- Establishing what their typical SPI implementation experiences are
- Identifying their major concerns about SPI implementation

- Exploring the different phases/steps necessary for the implementation of SPI programmes

The findings from the literature and the empirical study were used in the design of an SPI-IM (as shown in Figure 5.5). The Figure 5.5 shows the relation between implementation phases, CSFs and CBs and different implementation practices. It demonstrates how empirical findings feed into these phases, factors and implementation practices. The structure of this SPI-IM is built upon the following dimensions:

- SPI implementation phase dimension
- SPI implementation CSFs and CBs dimension

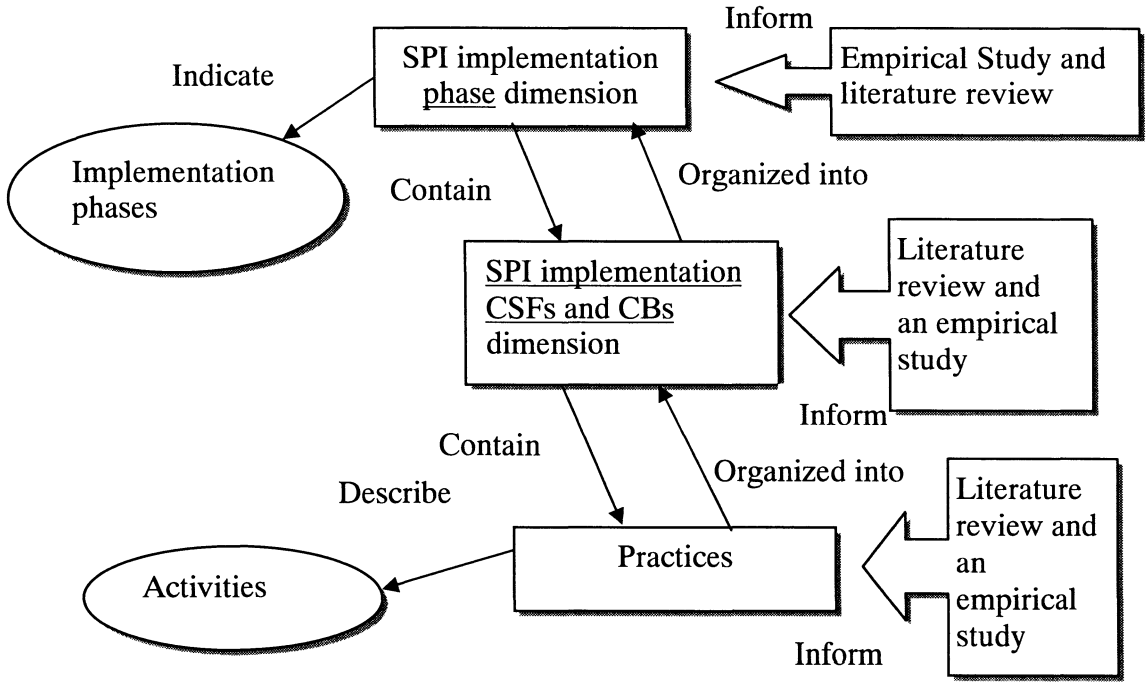


Figure 5.5 SPI implementation model

The primary motivation for building these two dimensions emanates from my empirical research with 29 software development companies. The empirical study has led me to design different phases for SPI implementation. Those phases are selected which were frequently cited by practitioners. These phases contain different CSFs and CBs identified through the literature and CSF interviews. In order to have more fine-grained activities within each phase of the SPI-IM, a list of practices were designed for each CSF and CB (Section 5.4.3 and Appendix I). The SPI-IM in Figure 5.5 shows that organizations should address each factor in order to successfully implement each phase of the model.

5.5.1 SPI implementation phase dimension

Using the content analysis of the recorded interviews, six phases for the implementation of SPI programmes were identified. In this section each phase is briefly described in turn and in the appropriate sequence. Figure 5.6 shows the SPI implementation phase dimension.

5.5.1.1 Awareness.

During interviews the practitioners felt the need for awareness of SPI programmes in order to fully understand the benefits of SPI. Practitioners said that as SPI implementation is the process of adoption of new practices in the organization, it is important to promote awareness activities of SPI and to share knowledge among different practitioners. Practitioners suggested involving all the staff members in these awareness programmes.

Awareness has been selected as an ongoing phase for the implementation of SPI programmes. This is because SPI is a long-term approach (SEI, 2004). Hence, in order

to get support of management and practitioners and to successfully continue SPI initiatives it is important to continuously provide sufficient SPI awareness during SPI implementation programmes.

5.5.1.2 Learning.

Learning appears as an important factor for SPI implementation success. For learning, practitioners emphasized training in SPI skills in order to achieve mastery of its use. This phase involves equipping the practitioners with the knowledge of the critical technologies which are required for SPI.

Different studies have confirmed training as an important source of learning for the implementation of SPI programmes (Billings *et al*, 1994; Butler, 1997; Dion, 1993; Fitzgerald and O'Kane, 1999; Fowler *et al*, 1999; Kaltio and Kinnula, 2000; Paulk, 1999; Pitterman, 2000; Westaway, 1995; Willis *et al*, 1998). Learning comprises acquiring and transferring knowledge of SPI activities. Managers and employees usually have a general idea of software process but they may not have complete understanding of the necessary details and also they may not understand how their work adds to the organization's mission and vision (Dyba, 2000). SPI can only be successfully implemented if staff members have enough understanding, guidance and knowledge of all the SPI activities (Hall and Wilson, 1997; Stelzer and Werner, 1999; Wilson and Hall, 1998).

5.5.1.3 Pilot implementation.

During interviews the practitioners advised first implementing SPI programs at a low level and seeing how successful it is within a particular department. A pilot implementation is important for practitioners in order to judge their existing SPI skills

and readiness. This is the phase where practitioners can decide how much resources, training and commitment is required in order to implement SPI practices across the organization.

The interviewees were mostly in agreement with the recommendations made by Hall and Wilson (1997; 1998) where they recommend "Start small and slow" for real quality improvement.

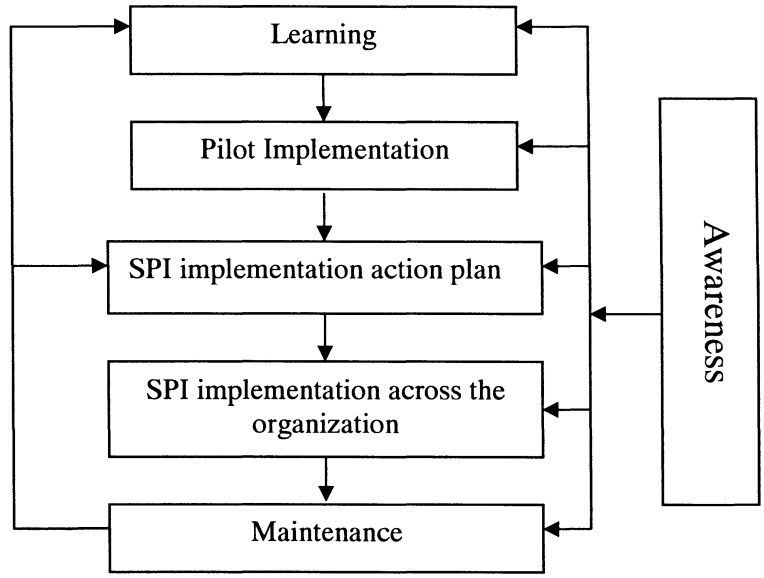


Figure 5.6 SPI implementation phase dimension

5.5.1.4 SPI implementation action plan.

Practitioners stressed the need for proper planning and management. They said after pilot implementation a proper plan with implementation activities, schedule, allocated resources, responsibilities, budget and milestone should be designed. This plan should be based on the results and experiences of the pilot implementation. The practitioners also suggested to design a defined SPI implementation methodology and this

implementation plan should be part of that implementation methodology. This defined SPI implementation methodology should contain implementation plan, activities, practices, and procedures to be used during the SPI implementation process.

SPI implementation without planning, defined SPI implementation methodology and project management leads to chaotic practices. Different studies emphasised managing the SPI project (Butler, 1997; Fitzgerald and O'Kane, 1999; Macfarlane, 1996; Paulk, 1999; Quenn, 1997; Stelzer and Werner, 1999). Often, the improvement projects have no specified requirements, project plan, or schedule (Stelzer and Werner, 1999). It was recommended by the practitioners to treat SPI as a real project that must be managed just as any other project.

5.5.1.5 Implementation across the organization.

After proper planning and using the pilot implementation experience, practitioners in interviews suggested implementing SPI practices in other areas/departments of the organization in order to have a uniform development approach and maturity across the organization. It is also important to illustrate the results of the pilot implementation to different departments in order to get support and confidence. In order to avoid risks and to implement SPI programmes more effectively, practitioners suggested project-by-project implementation. This is because each project experience can be reviewed to determine what was accomplished and how the organization can implement SPI programmes more effectively for future projects. Practitioners emphasised that senior management commitment plays a very important role in this phase. They also suggested providing sufficient resources for SPI implementation in this phase.

5.5.1.6 Maintenance.

The important theme in maintenance is to continuously monitor and support the previously implemented SPI activities. This maintenance will also help to refine the SPI implementation methodology. Practitioners suggested continuing awareness and training programmes to be incorporated into maintenance activities as practitioners often switch jobs.

SPI efforts do not have long lasting effects because practitioners often slide back to their old habits (Stelzer and Werner, 1999). It is therefore important to continuously provide them with feedback, guidance, motivation and reinforcement to stay involved in the improvement effort (Paulish and Carleton, 1994; Stelzer and Werner, 1999; Wohlwend and Rosenbaum, 1994).

5.5.2 SPI implementation CSFs and CBs dimension

A review of the CSF literature reveals that the CSF concept has not been employed to any great degree in research on the topic of SPI implementation. Literature also shows that little attention has been paid to developing ways in order to improve the SPI implementation process (Herbsleb and Goldenson, 1996). A few studies have identified key factors for SPI implementation (Goldenson and Herbsleb, 1995; Rainer and Hall, 2002) but these studies have not described how and where to use these factors. I believe that the identification of factors by themselves is not sufficient for the effective design of SPI implementation strategies but a holistic approach is required in order to successfully implement SPI programmes.

Keeping these facts in view different CSFs and CBs were identified through the literature and the empirical study. A frequency analysis technique was used in order to

calculate the relative importance of each factor (sections 4.6 and 4.7). As CSFs are a small number of important issues on which management should focus their attention (Rockart, 1979), I have only selected those factors that are critical either in both data sets or in any data set (section 4.8). I have divided CSFs and CBs among different phases of the SPI-IM as shown in Table 5.4.

In order to reduce researcher's bias, the inter-rater reliability was conducted in this distribution of CSFs and CBs to different phases of SPI-IM. Two other researchers were asked to distribute CSFs and CBs among different phases of the SPI-IM. The results were compared with previous results and an agreed list of factor distribution was generated as show in Table 5.4.

Table 5.4 suggests that practitioners should consider these CSFs and CBs in order to successfully implement each phase of the SPI-IM. For example, in the 'learning' phase it is important to have higher management support, SPI training and SPI awareness activities in order to provide sufficient knowledge about SPI and its benefits to the organization. Similarly, in the 'learning' phase adequate attention should be paid to avoiding barriers such as time pressure, lack of awareness, lack of support and lack of resources in order to prevent undermining of SPI implementation process.

In order to have more fine grained activities within each phase of the SPI-IM, a list of practices have been designed for each CSF and CB (Appendix I) using the empirical study and the literature (El-Emam *et al*, 1999; Goldenson and Herbsleb, 1995; Johnson, 1994; Rainer and Hall, 2002; Stelzer and Werner, 1999; Zubrow *et al*, 1994). These practices guide practitioners on how to implement each CSF and CB in practice.

Table 5.4 SPI implementation CSFs and CBs dimension

Phase	CSFs	CBs
Awareness	• Senior management commitment • Staff involvement • SPI awareness	• Organizational politics • Lack of awareness • Lack of support
Learning	• Senior management commitment • Training and mentoring • SPI awareness	• Time pressure • Lack of awareness • Lack of support • Lack of resources
Pilot Implementation	• Senior management commitment • Creating process action teams • Experienced staff • Defined SPI implementation methodology	• Inexperienced staff • Lack of defined SPI implementation methodology • Lack of support • Lack of resources
SPI implementation action plan	• Senior management commitment • Experienced staff • Defined SPI implementation methodology • Reviews	• Inexperienced staff • Time pressure
SPI implementation across the organization	• Senior management commitment • Staff time and resources • Staff involvement • Experienced staff • SPI awareness • Defined SPI implementation methodology	• Organizational politics • Time pressure • Inexperienced staff • Lack of defined SPI implementation methodology • Lack of support • Lack of resources • Lack of SPI awareness
Maintenance	• Senior management commitment • Reviews • Training and mentoring	• Inexperienced staff

5.6 Summary

In this chapter a SPI-IF is presented that has the potential to assist SPI practitioners in the design of effective SPI implementation initiatives. The basis of this framework is what I have studied in the SPI literature and an empirical study I have carried out. This

framework has three components, i.e. SPI implementation factors component, SPI assessment component and SPI implementation component. In order to effectively plan SPI implementation strategies, the objective of SPI implementation factors component is to summarise the factors that play a positive or negative role in the implementation of SPI programmes and to identify the key factors. The assessment component's objective is to provide an implementation maturity model in order to guide organizations in assessing and improving their SPI implementation maturity. In the implementation component the viewpoints and experiences of practitioners regarding SPI implementation are empirically explored and a model is developed in order to assist practitioners in effectively implementing SPI initiatives.

In the next chapter, in order to evaluate the SPI-IF, two practical evaluations are undertaken, i.e. case study and expert panel review process.

Chapter Six Evaluation of Software Process Improvement Implementation Framework

6.1 Introduction

In order to evaluate the software process improvement implementation framework (SPI-IF), presented in Chapter 5, two practical evaluation were undertaken, i.e. a case study and an expert panel review process. In this chapter the details of these evaluations are discussed and results are presented.

This chapter is organised as follows:

- The evaluation criteria are described in Section 6.2
- The limitation of evaluation is described in Section 6.3
- The case studies are described in Section 6.4
- In Sections 6.5 the SPI-IF is evaluated through expert panel review process
- This chapter is concluded in Section 6.6

6.2 Evaluation criteria

In order to evaluate the SPI-IF the following criteria have been decided. The primary motivation for building these criteria for SPI-IF evaluation emanates from the criteria designed for the development of SPI-IF (Section 5.2). These evaluation criteria are sufficient for SPI evaluation because these criteria can be used to judge the effectiveness and quality of the product and can help to highlight areas with any deficiency.

- **Ease of learning**

The objective is to analyse how easily SPI practitioners can interpret, use and understand the SPI-IF.

- **User satisfaction**

The objective is to analyse the level of user satisfaction with the results of the SPI-IF.

The evaluation of the end product is important in order to highlight areas where the end product has deficiencies. The evaluation aids in future planning and decision making. In the evaluation process the lessons learned and results are used to educate the future.

6.3 Limitations of evaluation

The SPI-IF has three components, i.e. SPI implementation factors component, assessment component and implementation component. It was not possible to evaluate the whole SPI-IF in these two evaluation methods because of the length of the PhD research period. However, two components of the SPI-IF (i.e. SPI implementation

factors component and assessment component) were fully evaluated in these two evaluation exercises.

I did not fully evaluate/implement the third component, i.e. SPI implementation component because one needs to evaluate this component by implementing it in an entire SPI project in an organization. SPI is a long-term approach and it takes time to fully implement a SPI initiative (SEI, 2004). The recent report of Software Engineering Institute shows number of months in order to move from one maturity level of CMM to the next one (SEI, 2004):

- Maturity level 1 to 2 is 22 months
- Maturity level 2 to 3 is 19 months
- Maturity level 3 to 4 is 25 months
- Maturity level 4 to 5 is 13 months

Therefore, it was not possible to implement/evaluate each phase of the implementation component (SPI-IM) within the time constraint of a PhD. However, as the 'factors component' is used in the 'implementation component' of SPI-IF (Figure 5.2) and the 'factors component' has been fully evaluated. Therefore, I can say that some parts of the third component (i.e. implementation component) were also evaluated through these evaluations.

6.4 Evaluation through case studies

The case study method was used because this method is said to be powerful for evaluation and can provide sufficient information in the real software industry

environment (Yin, 1993). The case study also provides valuable insights for problem solving, evaluation and strategy (Cooper and Schindler, 2001). Since the SPI-IF is more applicable to a real software industry environment, the case study research method is believed to be a more appropriate method for this situation. Real life case studies were necessary because they:

- Showed that the SPI-IF is suitable or will fit in the real world environment.
- Highlighted areas where the SPI-IF needs improvement.
- Showed the practicality and usability of the SPI-IF in use.

To provide more confidence in this evaluation, three separate case studies were conducted at three different companies. Companies were selected for case studies because they provided especially rich descriptions of their SPI efforts and because they agreed to release the case studies results.

Initially, I talked to each participant face-to-face, explained what the case study was about and handed out a hard copy of the SPI-IF. The participants also asked me through emails to solicit more information about the use of SPI-IF. One participant from each company, who was the key member of SPI team, was involved in each case study. The key participant communicated with me through email and face-to-face discussion for one month in order to get a thorough understanding of the SPI-IF. Before commencing these studies, SPI-IF training was also provided to the participants nominated for these case studies. In this training different components of the SPI-IF were explained and participants were encouraged to use this framework independently.

In each case study, a participant has used SPI-IF and assessed the SPI implementation maturity of his/her company independently without any suggestion or help from the researcher. At the end of each case study, a feedback session was conducted with the participant in order to provide feedback about SPI-IF. The questionnaire (Appendix J) designed for expert panel review process (Section 6.5) was used as a means to structure this feedback session. This questionnaire is divided into four parts, i.e. demographic, ease of learning, user satisfaction and structure of the IMM. Each feedback session was an informal discussion and the questionnaire was filled out by each participant. Each questionnaire was analysed qualitatively.

6.4.1 Case study at Company A[2]

Company A is an international company that provides consultancy and information technology services to both the private and public sector, employing 10,000 professionals in Asia Pacific, Canada, Europe and United Sates. The main purpose of the company is to enhance the efficiency and effectiveness of the Information Systems prevailing in the public and private sectors by applying relevant state-of-the-art technologies related to computer software, hardware and data communication.

The following are some of the major areas in which Company A can provide services to its clients:

- E-Business
- Enterprise Consulting
- Technology Consulting

[2] The company names are fictitious as it was their wish to remain anonymous

- Solution Delivery
- Application Portfolio Management/ Outsourcing
- Project Management

An SPI initiative has been initiated five years ago in Company A. The reasons for initiating the SPI programme were:

- To reduce software development cost
- To improve management visibility in software development
- To increase productivity
- To improve the quality of the software developed
- To meet customer requirements

The SPI programme was initiated by the research division of company A. The research division has developed a standard methodology for software development. During the development of this methodology special attention was given to the requirements of the ISO 9001 standard and the CMM model. Company A is ISO 9001 certified and is currently assessed at CMM level 3.

One participant who is the key member of SPI team has used IMM and assessed the implementation maturity of the Company A.

6.4.1.1 Assessment results at Company A

As discussed in Section 5.4.3, in order to measure the maturity of the SPI implementation process, I have adapted an assessment instrument that has been

developed, tried and tested at Motorola (Daskalantonakis, 1994). A score of 7 or higher for a CSF or CB indicates that a specific factor has been successfully implemented. Any CSF or CB with an average score below 7 is considered a weakness (Daskalantonakis, 1994).

The participant of company A has completed an SPI implementation assessment (as shown in Appendix K). The assessment results of Company A are summarised in Table 6.1. The key points of this assessment are as follows:

- It is clear that Company A stands at Level-1 'Initial' of IMM because two factors of Level-2 'Aware' are not fully implemented (i.e., score is < 7) in Company A. In order to achieve any maturity level it is important that all the CSFs and CBs that belong to that maturity level should have average score of 7 or above. Table 6.1 shows that in order to achieve Level-2 'Aware' of IMM the Company A needs to improve two factors, i.e. senior management commitment and staff involvement. Similarly, in order to achieve Level-3 'Defined' the Company A needs to improve 3 factors, i.e. Creating process action teams, Staff time and resources and Time pressure.

- It shows that Company A has well defined training and SPI awareness programmes.

- SPI activities have been assigned to experienced staff members.

- It is clear that a defined SPI implementation methodology is in use and Company A managed to avoid organizational politics. The defined SPI implementation methodology could be the reason that this company was assessed in CMM Level-3.

- Company A has established some processes in order to review the implementation processes

Table 6.1 Implementation scores for each CSF and CB at company A

Category	CSFs and CBs	Score	Status
Awareness	Senior management commitment	6.4	weak
	Training and mentoring	7.6	strong
	Staff involvement	6.2	weak
	Awareness of SPI	7.4	strong
	Lack of support	7.0	strong
Organizational	Creating process action teams	6.2	weak
	Experienced staff	7.4	strong
	Staff time and resources	5.0	weak
	Defined SPI implementation methodology	7.0	strong
	Time pressure	3.6	weak
	Organizational politics	7.0	strong
Support	Reviews	7.2	strong

Company A is a relatively high maturity company with CMM Level-3. It is surprising to see that Company A has not successfully implemented implementation factors such as 'senior management commitment', 'staff involvement', 'creating process action teams', 'staff time and resources' and 'time pressure'. As these factors are weak in company A therefore this company stands in Level-1 'Initial' of IMM.

6.4.1.2 Feedback at Company A

At the end of the case study the key participant, who used the IMM, was asked to provide feedback (in feedback session) in order to analyse the usability of the IMM. As discussed earlier, the questionnaire (Appendix J) designed for expert panel review

process (Section 6.5) was used as a means to structure this feedback process. All questions are on a Likert scale from 1-4. In order to measure the usability of the IMM, the following two criteria were used:

- ***Ease of learning***

Different questions were asked about ease of learning. It was found that the participant's general impression of learning of IMM was positive. The participant at Company A indicated the following items are easy to learn:

- The representation of the IMM
- The use of IMM
- Distribution of three factors' categories among four levels of IMM
- Practices designed for each CSF and CB
- Assessment method

- ***User satisfaction***

The participant at Company A has shown full satisfaction about the following items:

- The generality of IMM
- Practices designed for each CSF and CB
- The usefulness of the model for the software industry
- The usefulness of the 5 practices designed for each CSF and CB
- The usefulness of assessment method

Overall, the participant was fully satisfied with the use of IMM. The participant agreed with the results of assessment, i.e. the participant mentioned that "now we know the weak factors and through 5 practices, designed for each CSF and CB, we will improve these weak factors". In response to "If the IMM is available for my job, I predict that I would use it on regular basis in the future", the participant selected "strongly agreed". The participant was also fully satisfied with the structure of the IMM.

In particular, one aspect that the participant considered important is the development of a complete tool that can be used to perform different activities of the SPI-IF. The participant said that this tool will facilitate the SPI practitioners in assessing organizations' SPI implementation maturity. This tool should be capable of:

- Recoding the results of assessment of each CSF and CB
- Identifying weak and strong factors
- Guiding SPI practitioners in successfully assessing the organizations' SPI implementation maturity
- Generating different assessment documents

Automated tool support is a productive way to enhance the visibility of processes, to identify processes weakness and to better understand the processes. A tool can also be used to observe the behaviour of different activities and their interactions. The participant suggested that this tool will speed up the process of SPI implementation assessment.

6.4.2 Case study at Company B

Company B is an international company that provides consultancy and information technology services to both the private and public sector, employing more than 2000 professionals in Australia and worldwide. The core business of the company is to provide services in software development, system integration, business innovation and business process improvement.

The following are some of the major areas in which Company B can provide services to its clients:

- Business and IT services
- Business consulting services
- Infrastructure services
- Financing
- E-Business
- Project Management

The company delivers complex software systems to a number of clients. The SPI programme was initiated five years ago in Company B. The main reasons for initiating the SPI programmes were to:

- Reduce development cost and time to market
- Increase productivity and quality of the product

Company B adopted a CMM model for its SPI programme. According to self assessment results, the organization's process maturity was found to be in CMM Level 1. The process teams undertook different SPI actions in order to achieve level 2, i.e. working on requirements management, software project planning and software quality assurance etc. Using CMM-based assessment in 2001, the process maturity was found to be in CMM level 2 with traces of Level 3. Now company B is working to achieve level 3.

6.4.2.1 Assessment results at Company B

One participant who is the key member of SPI team has used IMM and measured the implementation maturity of Company B (as shown in Appendix L). The assessment scores of Company B are summarised in Table 6.2.

- It is clear that Company B stands at Level-1 'Initial' of IMM because four factors of Level-2 'Aware' are not fully implemented in the Company B. Table 6.2 shows that in order to achieve Level-2 'Aware' of IMM the Company B needs to improve four factors, i.e. training and mentoring, staff involvement, awareness of SPI and lack of support.

- In order to achieve Level-3 'Defined' and Level-4 'Optimising' the Company B needs to improve five factors, i.e. creating process action teams, experienced staff, staff time and resources, time pressure and reviews.

- It also shows that the Company B has enough senior management support for SPI programmes.

- It is clear from Table 6.2 that a defined SPI implementation methodology is in use and Company B managed to avoid organizational politics.

Table 6.2 Implementation scores for each CSF and CB at company B

Category	CSFs and CBs	Score	Status
Awareness	Senior management commitment	7.2	strong
	Training and mentoring	6.4	weak
	Staff involvement	5.8	weak
	Awareness of SPI	6.8	weak
	Lack of support	6.0	weak
Organizational	Creating process action teams	6.8	weak
	Experienced staff	6.4	weak
	Staff time and resources	4.4	weak
	Defined SPI implementation methodology	7.0	strong
	Time pressure	5.0	Weak
	Organizational politics	7.2	Strong
Support	Reviews	6.8	Weak

6.4.2.2 Feedback at Company B

- ***Ease of learning***

The participant of Company B was positive about ease of learning of IMM, i.e. for 6 questions (out of 8) she has selected 'very' on a Likert scale. She fully agreed with the ease of learning of different components of the IMM:

i. Clear representation of IMM

ii. Consistency of IMM

iii. Distribution of CSFs and CBs among different categories

iv. Five practices designed for each CSF and CB

v. Assessment method.

- ***User satisfaction***

The participant at Company B has shown full satisfaction regarding all the components of the IMM. According to the participant "the assessment method is very well defined. The individual practices within the CSFs and CBs are all very appropriately distributed". When asked "the assessment results are according to her expectations", she fully agreed with the assessment results. She agreed that staff members of her organization are facing problems which were identified by IMM, e.g. time pressure, lack of resources, lack of support and lack of staff involvement. She added that "IMM is a very structured method of assessing and improving organizations' SPI implementation maturity."

6.4.3 Case study at Company C

Company C provides telecommunication services and employing more than 2000 professionals in Australia and worldwide. The core business of the company is to provide cutting-edge communications, information and entertainment services. The company provides a broad range of communications services including mobile, national and long distance services, local telephony, international telephony, business network services, Internet and satellite services and subscription television.

The SPI programme was initiated in Company C three years ago. The reasons for initiating the SPI programmes are:

- To reduce software development cost
- To reduce time-to-market
- To increase productivity

- To improve the quality of the software developed

- To automate the production of relevant development documentation

In 2002 this Company C was assessed at CMM level 2.

6.4.3.1 Assessment results at Company C

One participant who is the key member of SPI team has used IMM and assessed the implementation maturity of Company C (as shown in Appendix M). The assessment scores of Company C are summarised in Table 6.3.

Table 6.3 Implementation scores for each CSF and CB at company C

Category	CSFs and CBs	Score	Status
Awareness	Senior management commitment	6.0	Weak
	Training and mentoring	4.4	Weak
	Staff involvement	7.0	Strong
	Awareness of SPI	6.2	Weak
	Lack of support	6.0	Weak
Organizational	Creating process action teams	7.4	Strong
	Experienced staff	6.4	Weak
	Staff time and resources	6.0	Weak
	Defined SPI implementation methodology	7.0	Strong
	Time pressure	5.0	Weak
	Organizational politics	6.0	Weak
Support	Reviews	6.2	Weak

- It is clear that Company C stands in Level-1 'Initial' of IMM because four factors of Level-2 'aware' are not fully implemented in the Company C. Table 6.3 shows that in order to achieve Level-2 'Aware' of IMM the Company C

needs to improve four factors, i.e. senior management support, training and mentoring, awareness of SPI and lack of support.

- In order to achieve Level-3 'Defined' and Level-4 'Optimising' the Company C needs to improve five factors, i.e. experienced staff, staff time and resources, time pressure, organizational politics and reviews.

- It also shows that the Company C has experienced staff for SPI programmes.

- It is clear from Table 6.3 that a defined SPI implementation methodology is in use and Company C has created teams for SPI activities.

6.4.3.2 Feedback at Company C

- ***Ease of learning***

The participant of Company C was fully satisfied with the ease of learning of IMM. The participant appreciated practices designed for each CSF and CB and their distribution among different CSFs and CBs. She appreciated the assessment method designed for SPI implementation maturity assessment. However, the participant has identified the need of some training for this assessment method.

- ***User satisfaction***

The participant at Company C has shown interest and satisfaction with the IMM. The participant was willing to use IMM on regular basis in the future. The participant was also satisfied with the assessment results of her company. However, the participant identified the need for an automated tool to be used in the assessment method. She said that "it is difficult to calculate the score manually for each CSF and CB. An automated tool will help to speed-up this process and also to keep assessment record".

6.4.4 Discussion

In order to evaluate the SPI-IF, it is essential to discuss a few important points which will lead towards the evaluation of the SPI-IF.

The CMM is structured into five maturity levels ranging from level 1 to 5. Each maturity level expresses a different state of software development maturity in an organization. Level-1 corresponds to the lowest state of software development maturity while level-5 corresponds to the highest state of software development maturity. In order to clarify the evaluation points, it is important to discuss the following:

- Higher levels of CMM (level 3 and above) indicate that the company has well defined processes for the implementation of SPI initiatives. This is because the company has successfully implemented CMM.

- Lower levels of CMM (level 2 and below) indicate that the company does not have well defined processes for the implementation of SPI initiatives. This is because the company is struggling to successfully implement CMM.

Keeping in view these two points, the companies in higher CMM levels should have less implementation issues than companies in lower CMM levels. As in the SPI-IF the implementation maturity of the companies is measured through assessing different implementation factors. So the evaluation criterion is:

- Companies in higher CMM level should have successfully implemented more implementation factors than companies in lower CMM level.

In order to address this evaluation point, it is important to compare the results of the three case studies. As discussed earlier Company A is at CMM Level-3 and Companies

B and C are at CMM Level-2 respectively. According to the 'Evaluation point' Company A should have successfully implemented more implementation factors than Companies B and C. The results of the three case studies are summarised into Table 6.4.

Table 6.4 Summary of results of companies A, B and C

Assessment issue	**Company A (CMM Level-3)**	**Company B (CMM Level-2)**	**Company C (CMM Level-2)**
Weak implementation factors in IMM Level-2 'Aware'	• Senior management commitment • Staff involvement	• Awareness of SPI • Lack of support • Staff involvement • Training and mentoring	• Awareness of SPI • Lack of support • Senior management commitment • Training and mentoring
Weak implementation factors in IMM Level-3 'Defined'	• Creating process action teams • Staff time and resources • Time pressure	• Creating process action teams • Experienced staff • Staff time and resources • Time pressure	• Experienced staff • Staff time and resources • Time pressure • Organizational politics
Weak implementation factors in IMM Level-4 'Optimising'	• Nil	• Reviews	• Reviews
Total Weak implementation factors	**5**	**9**	**9**

It is clear from Table 6.4 that Company A has only two weak factors in IMM level-2, while Companies B and C have four weak factors in IMM Level-2. For IMM Level-3, Company A has three weak factors while Companies B and C have four weak factors. Table 6.4 shows that Company A has successfully implemented more implementation factors than Companies B and C. This also shows that Company A has less weak implementation factors (i.e. five) than Companies B and C (i.e. nine).

As discussed earlier Company B is at CMM Level-2 and Company C is also at CMM Level-2. In order to compare the results of companies in the same maturity level, it is important to compare the results of the case studies conducted at Company B and C respectively. This will provide opportunity to identify common weak factors of companies in the same maturity level. The results of two case studies are summarised into Table 6.4. Table 6.4 shows that both companies have nine weak factors. It also shows that 78% (i.e. seven factors) of the weak factors are common between the two companies.

Comparison of weak factors of the three companies provides evidence that there are some clear similarities and differences between the findings of three data sets. The factors 'time pressure' and 'staff time and resources' are common among three companies. This shows that companies both at lower and higher levels of CMM need to improve these two common factors. In the literature different studies have discussed 'time pressure' and 'staff time and resources' as barriers for SPI implementation. For example, Baddoo and Hall (2003) present empirical findings analysing what de-motivates UK practitioners in SPI. The authors have separated senior managers, project managers and developers into separate focus groups. The authors state that all the groups of practitioners have cited time pressure as a de-motivator for SPI, i.e. 62% of developers cited, 44% of project managers cited and 58% of senior managers cited. In the study of Goldenson and Herbsleb (1995) "almost three-quarters (72%) report that process improvement has often suffered due to time and resource limitations". Paulish and Carleton (1994) also describe case studies for SPI measurement and illustrate time restriction as one of the SPI implementation problem.

Table 6.4 also shows factors that are common between companies of lower CMM level (i.e. CMM level 2). For example, the companies at lower CMM level are having problems of 'awareness of SPI', 'experienced staff', 'lack of support', 'training and mentoring' and 'reviews'. These factors need to be addressed in order to successfully implement SPI initiatives.

6.4.5 Case studies lessons learned

Three case studies were conducted in order to evaluate the SPI-IF in the real world environment. The lessons learned from these three case studies are summarised as follows:

- The IMM can be used effectively to identify SPI implementation issues with a goal of increasing implementation maturity.

- All the participants agreed that the IMM is clear, easy to use and specifically geared to assess the organizations' SPI implementation maturity. However, some training needs to be provided for the assessment method of the IMM.

- Despite all the differences, i.e. company type, application domain and CMM maturity level, each of the three companies was able to successfully use the IMM without any confusion and ambiguity in order to assess their SPI implementation maturity.

- All the participants who used IMM were fully satisfied with the assessment results and overall performance of the model.

- All the participants have recognised the SPI implementation issues that the IMM has identified for their companies and they agreed with those issues.

- All the participants expressed an interest to use the IMM in order to provide solutions for the identified SPI implementation issues.

- The five practices designed for each CSF and CB are simple to use and unambiguous.

- The assessment method provides an entry point through which the participant can effectively judge the weak and strong implementation factors.

- All the participants agreed that IMM is general enough and can be applied to most companies.

- It was agreed by all the participants that the use of IMM would have a positive impact in improving their SPI implementation process.

- The IMM is capable of determining the current state of the SPI implementation process that is practiced regularly in an organization.

- The participants were willing to use IMM on a regular basis in the future.

- The IMM is not only significant in the theoretical work but also significant in the real world environment.

- The participants emphasised the importance of having automated tool support available in order to facilitate SPI practitioners in assessing organizations' SPI implementation maturity.

- Although the participants required a tool to support all the activities of the IMM, they were still willing to use the IMM without tool support. This shows the significance of the IMM.

Although the participants were friendly and co-operative in using IMM, it was inappropriate at some times for the researcher to push them to contribute due to their work responsibilities and time constraints.

6.5 Evaluation through expert panel review process

In addition to three case studies the "expert panel review" process was also conducted to further evaluate the SPI-IF in order to have a more comprehensive understanding of issues relating to the effectiveness of SPI-IF. The expert panel review process was used in order to seek opinions of SPI experts about the structure and components of SPI-IF. Thirty letters of requests were sent out to well known SPI experts all over the world inviting them to participate in this evaluation and only 6 SPI experts (20%) responded. Although I do not claim this is a statistically representative sample, Table 6.5 does show that all experts have many years of SPI experience and they also have more than sufficient knowledge of SPI implementation. It is further important to acknowledge that the opinions of those experts were solicited who were tackling real SPI implementation issues on a daily basis. These experts were selected on the basis of their experience in the SPI industry and/or list of publications in the area of SPI. Some experts have published books on SPI and others were key members of the Software Engineering Institute. The experts' profile is shown in Table 6.5.

In order to seek SPI experts' opinion about SPI-IF, an on-line questionnaire was designed (as shown in Appendix J). In this questionnaire some questions were taken from (Beecham and Hall, 2003; Rainer and Hall, 2002) and tailored to fit into this research project goal.

Table 6.5 SPI experts' profile

SPI expert	Job title	Experience of SPI (years)	Knowledge of SPI implementation (Low 1 - 4 High)	Practical experience of SPI implementation (Low 1 - 4 High)
1	Consultant	40	3	2
2	Senior project manager	37	4	4
3	Senior systems scientist	23	4	4
4	Senior Business Analyst/Quality Assure	13	3	3
5	Senior consultant	15	3	3
6	Consultant	25	4	3

This questionnaire is divided into four parts, i.e. demographic, ease of learning, user satisfaction and structure of the IMM. Before sending out this questionnaire to the SPI experts, drafts questionnaire were reviewed by two researchers (supervisors). These researchers were asked to critically evaluate the questions against four issues being investigated. Based on their feedback, some questions were re-written in order to better capture the required data. All questions are on a likert scale from 1-4. The on-line questionnaire was tested by two researchers before sending requests to the experts.

In order to evaluate the SPI-IF, each SPI experts was asked to evaluate SPI-IF against the following three criteria:

- Ease of learning
- User Satisfaction

- Structure of SPI-IF

The third criterion 'structure of SPI-IF' is also included in the evaluation through SPI experts. This is because SPI experts can provide valuable suggestions in order to further refine the structure of SPI-IF and to make it more complete.

A summary of the main insights derived from the data collected are presented below:

6.5.1 Ease of learning

It was found that the SPI experts' general impression about 'ease of learning' of SPI-IF was positive. The questions asked were relating to three important aspects of the SPI-IF, i.e. five practices designed for each CSF and CB, distribution of CSFs and CBs among different categories and an assessment method.

For practices the experts were asked "how easy is it to understand the 5 practices designed for each CSF and CB"? All the experts have chosen 3 or 4 on Likert scale except one who has chosen 2 on likert scale. This shows that the practices designed for each CSF and CB are simple to understand. This was also observed in the case studies where participants did not have any problem in understanding and learning these practices.

For distribution of CSFs and CBs among different categories the experts were asked "how easy is it to understand the distribution of CSFs and CBs among different categories"? Four experts have selected 3 or 4 on likert scale while 2 experts have selected 2 on likert scale. These results are encouraging and show that the majority of experts agreed with the categorisation of CSFs and CBs.

The assessment method is an important component of the SPI-IF. It was asked "how easy is it to understand the assessment method"? All the experts have chosen 3 or 4 on likert scale. This shows that the all the experts fully understand the use of assessment method. This was also observed during case studies that participants quickly learned how to use assessment method.

6.5.2 User satisfaction

Overall, the experts were fully satisfied with the different components of SPI-IF. The questions were asked about four important areas:

Firstly, the experts were asked "how useful would it be to the software industry to use this model"? All the experts have the opinion that it would be useful for the software industry to use this model. These results are encouraging in that all the experts consider this piece of work as useful and elegant for the software industry.

Secondly, they were asked about the usefulness of the assessment method. All the experts have selected 3 or 4 on likert scale. It has been illustrated through these results that assessment method is a useful tool in order to assess the SPI implementation maturity of the companies.

Thirdly, the experts were asked "using the Implementation Maturity Model would improve our SPI implementation process". Again results are encouraging and all the experts have selected 3 or 4 on likert scale. This shows that in their opinion the IMM is a valuable model and has the potential to assist SPI practitioners in the design of SPI implementation initiatives.

Lastly, they were asked "if the Implementation Maturity Model were available for my job, I predict that I would use it on regular basis in the future". Four experts have selected 3 or 4, one has selected 2 and one has no opinion. This shows that if IMM is available to the experts then they will use it on regular basis.

6.5.3 Structure of IMM

The questions were also asked about the structure of IMM. The objective here was to identify any deficiencies with the structure of IMM and how to improve those deficiencies. The questions were asked about four important areas:

Firstly, I was interested to validate the distribution of CSFs and CBs among three categories (i.e. awareness, organizational and support). The experts were asked to provide comments relating to the distribution of CSFs and CBs among these categories. All the experts agreed with this distribution except two. One expert suggested to move factor "senior management commitment" from category "awareness" to category "organizational". The second expert suggested to move factor "lack of support" from category "awareness" to category "organizational". Since "awareness" category is used in Level-2 "aware" of the IMM and this is the first SPI implementation maturity level that companies need to achieve (section 5.4.1). Therefore, management support should be available from the very beginning of the SPI implementation initiatives. Similarly support from the staff members should also be available form the very beginning. The second thing is that awareness of SPI cannot be developed without support from the management and staff.

Secondly, the experts were asked to provide any comments relating to the distribution of 5 practices to different CSFs and CBs. Majority of the experts agreed with the existing

distribution. One expert suggested moving practice "staff members are aware of the benefits of SPI implementation" from factor "lack of support" to factor "awareness". I think one can avoid lack of support barrier if all the staff members are aware of the benefits of SPI. This is the reason I assigned this practice to factor "lack of support". Another expert suggested moving two practices "a mechanism has been established to monitor the progress of each process action team" and "a mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned" from factor "experienced staff" to factor "creating process action teams". As some practices have been assigned to more than one factor, thus these practices have already been assigned to the suggested factor.

Thirdly, the experts were asked to provide any comments relating to the four maturity levels. Different comments were provided. For example, some comments are:

1. Having four levels seems practical. Experience in using the model will validate or correct this

2. The maturity levels are very well defined

3. You probably do need something to capture quantitative feedback on the impact of SPI similar to Quantitatively Managed. Learning is ineffective without feedback.

4. I suggest you rename Level 3 to "systematic" (rather than defined)

These comments are positive and validate this research. The point number 3 is a valuable suggestion. The categorisation of CSFs and CBs has led me to design four maturity levels for SPI implementation. I did not adapt the maturity level "Quantitatively Managed" of CMMI because in "Quantitatively Managed" the focus is

on establishing quantitative measures of software process. In the empirical study I did not find any factor that directly relates to this maturity level. In addition to that the participants of the three case studies, who used IMM in the real world environment, also did not identify this issue. Thus these 4 maturity levels are sufficient for SPI implementation because these maturity levels are generated from factors which were collected from practitioners who were tackling real issues on a daily basis. However, I consider this suggestion important to capture quantitative feedback in order to provide actual performance results of the IMM. I will consider this suggestion in my future work by developing some mechanism in order to capture quantitative feedback.

Lastly, the experts were asked to provide any comments relating to the assessment method. Again different comments were provided. These comments are:

1. More detailed examples would help understand the assessment method and provide reasonable level of competence

2. The assessment method is clear and concise. It should be reasonably repeatable from assessment to assessment.

3. The assessment method is very well defined

It is clear from these comments that the assessment method is well defined and according to user satisfaction.

6.6 Conclusion

In this chapter two components of the SPI-IF have been evaluated using two practical methods, i.e. case study and expert panel review process. SPI-IF performed exceptionally well in these evaluations. However, in case studies, one aspect that the

participants considered important is the development of a complete tool which can be used to facilitate SPI practitioners in assessing organizations' SPI implementation maturity. It was suggested that this tool should be capable of recoding the results of assessment, identifying weak and strong factors and generating different assessment documents. I have considered this suggestion and will develop a tool for SPI-IF in my future work. Some minor changes were suggested by SPI experts in the distribution of 5 practices to each CSF and CB. Similarly, it was suggested to develop some mechanism in order to capture quantitative feedback. I will also consider these suggestions in my future work.

Like any other model and standard, the SPI-IF is also a dynamic framework that will be extended and evolved based on feedback and input from three case studies and the expert panel review process. I envisage that in future I will be able to create more refined version of the SPI-IF based on its use in software industry.

Chapter 7 Conclusions

7.1 Introduction

This Chapter summarises the results obtained in the thesis in relation to SPI implementation, drives up conclusions, and prospects on the future related research that could be conducted.

This chapter is organised as follows:

- In Section 7.2 the summary of statistical results is presented
- In Section 7.3 summary of deliverables is discussed
- In Section 7.4 a critique of methodology followed in this research is presented
- In Section 7.5 future work is described
- Reflection on research is provided in Section 7.6
- Concluding remarks are provided in Section 7.7

7.2 Summary of statistical results

Seven research questions motivated the work described in this thesis. The summary of the results are organized with respect to these research questions as follows:

RQ1. What factors, as identified in the literature, have a positive impact on implementing SPI?

RQ2. What factors, as identified in the real practice, have a positive impact on implementing SPI?

In the empirical study of CSFs, nine factors were identified from the literature and interviews that are generally considered critical for successfully implementing SPI. These factors were: allocation of resources, SPI awareness, creating process action teams, defined SPI implementation methodology, experienced staff, higher management support, reviews, staff involvement, and training. Out of these nine factors, six factors were cited in both data sets. The results suggest that organizations should focus on these common CSFs in order to successfully implement SPI programs. The two new CSFs – "SPI awareness" and "defined SPI implementation methodology" – were identified in the interviews which were not cited in the literature. It is suggested that organizations should also focus on two new CSFs in order to effectively implement SPI programmes because different practitioners who were tackling real issues on a daily basis frequently cited these factors.

RQ3. Are there differences between the factors (with positive impact) identified through the literature and the real practice?

The chi-square test showed a number of significant differences between the two data sets. I found 13 factors with significant differences. These factors can be divided into 2 categories, 'organizational' and 'technical'. Nine factors belonged to category 'organizational'. Some organizational factors were only cited in the empirical study, e.g. 'facilitation' and 'SPI awareness'. This shows that now practitioners are aware that in

order to successfully implement and continue SPI initiatives it is important to provide sufficient knowledge of the benefits of SPI in the organization. This also shows that practitioners need facilitation during the SPI implementation process.

Four factors belonged to 'technical' category, e.g. 'defined SPI implementation methodology', 'formal documentation', 'quality assurance' and 'reviews'. The first three factors were only cited in the empirical study while the fourth one was cited in both data sets. This shows that there is a need to create a SPI implementation methodology that guides SPI practitioners in effectively implementing SPI programmes. This also shows that practitioners need defined documentation structures and quality assurance procedures for SPI implementation.

In summary, there were both similarities and differences in CSFs between the two data sets. 33% factors were common between the two data sets and 67% factors were only cited by an individual data set. Thirteen factors (43%) have significant differences while 17 factors (57%) have no significant difference between two data sets.

RQ4. What factors, as identified in the literature, have a negative impact on implementing SPI?

RQ5. What factors, as identified in the real practice, have a negative impact on implementing SPI?

Seven barriers were identified from the literature and interviews. These barriers are: organizational politics, lack of support, lack of defined SPI implementation methodology, lack of awareness, lack of resources, inexperienced staff/lack of knowledge and time pressure.

RQ6. Are there differences between the factors (with negative impact) identified through the literature and the real practice?

There were a number of significant differences between the findings. For example, 'lack of awareness of SPI' and 'lack of defined SPI implementation methodology' were critical in the empirical study but were not identified through the literature. This is because Australian practitioners were more concerned about SPI awareness activities and implementation methodology.

There were both similarities and differences in CBs between the two data sets. Out of these, 44% barriers were common between the two data sets and 56% barriers were only cited by an individual data set. Five barriers (28%) have significant differences while 13 barriers (72%) have no significant difference between two data sets.

RQ7. What are the necessary and sufficient phases/steps for the implementation of SPI programmes?

Using the content analysis of the transcribed interviews, the following six phases for the implementation of SPI programmes were identified:

- SPI awareness
- Learning
- Pilot implementation
- SPI implementation action plan
- SPI implementation across the organization

- Maintenance

Those phases were selected which were most frequently cited by practitioners.

7.3 Summary of deliverables

This research has met its objectives with respect to providing a framework in order to assist practitioners in the design of effective SPI implementation initiatives. In order to design this framework some criteria were decided for its success. My aim was to develop a framework that not only assists SPI practitioners in 'what' to implement but also assists in 'how' to implement. An examination of the SPI literature, together with an empirical study, led me to design three components. I have pulled together individual components under one framework using a bottom-up approach already familiar to many practitioners and researchers. The SPI-IF is a specialised, cohesive and comprehensive framework that represents a new process view of the SPI implementation.

In this thesis I have shown how the SPI-IF is designed, developed and evaluated. The results of the evaluation showed that the SPI-IF is not only significant in the theoretical sense but also significant in the real world environment. Successful completion of the three case studies demonstrates usefulness of the SPI-IF in the real world environment. The results showed that the SPI-IF is a valuable framework and has the potential to assist SPI practitioners in the design of effective SPI implementation initiatives.

The SPI approach in general has four stages: software process assessment, selection of an improvement model/standard, designing of an SPI implementation initiative and implementation of an improvement model/standard (Paulish and Carleton, 1994; Zahran, 1998). All the stages are important for successful implementation of SPI programmes. But, performing this research has convinced me that among all these four

stages the 'design of SPI implementation initiatives' is a critical stage. This is because no matter how good the SPI model or standard is, an ineffective SPI implementation initiative can significantly affect the success of SPI efforts (Niazi *et al*, 2005a; Niazi *et al*, 2005b).

To summarize how SPI-IF can assist practitioners in the design of effective SPI implementation initiatives each component of the SPI-IF, in this section, has been reviewed with respect to its role in the design of SPI implementation initiatives. Figure 7.1 shows each component of the SPI-IF with its input to the SPI implementation initiatives.

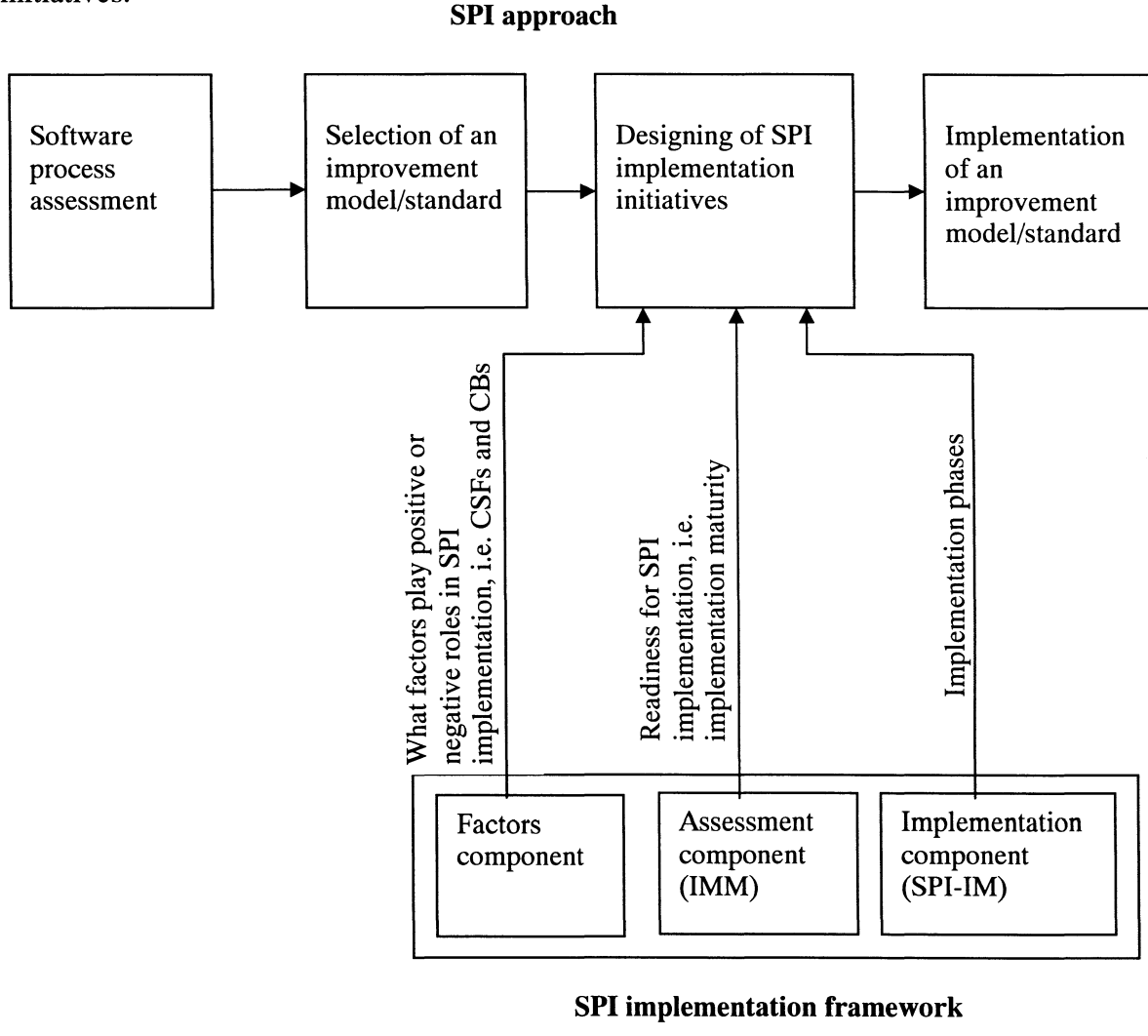


Figure 7.1 SPI-IF assisting the design of SPI implementation initiatives

The objective of the factors component is to summarise the factors that play a positive or negative role in the implementation of SPI programmes and to identify the key factors. In the study of CSFs, nine factors were identified from two data sets (literature and interviews) that are generally considered critical for successfully implementing SPI. In the study of CBs, seven barriers were identified in both data sets. It is suggested that SPI practitioners should focus on these CSFs and CBs in the design of effective SPI implementation initiatives. These factors are important to address because different practitioners who were tackling SPI implementation real issues on a daily basis frequently cited these factors. These factors have also been used within the practitioners' company.

The second component, assessment, guides organizations in assessing and improving their SPI implementation maturity. Through this component, one can measure the readiness of organizations to implement SPI initiatives. It is important that organizations should know about their SPI implementation readiness in order to reduce the risk of an implementation failure. The assessment component guides the organizations in how to improve and assess their SPI implementation maturity. The information about SPI implementation maturity is important during the design of SPI implementation initiatives. This is because the organizations can then design SPI implementation initiatives according to the results of SPI implementation maturity. For example, if an organization is not mature enough to implement a SPI implementation initiative then the SPI implementation initiative should be designed in such a way to tackle the identified implementation issues first and then plan the implementation process. There is a saying that suggests "do not try to fix it unless you understand it" (Whitten *et al*, 2001:p88). The assessment component provides the SPI practitioners with a more thorough

understanding of the SPI implementation issues that can undermine the SPI implementation initiative.

The objective of third component, implementation, is to assist practitioners in effectively implementing SPI initiatives. During the empirical study it was suggested by practitioners that any SPI initiative should be implemented phase by phase in order to achieve the desired results. They have suggested using phase by phase approach in order to reduce the implementation failure risks. Six phases were identified in this component that can be used to effectively implement SPI initiatives. These phases serve as a standard implementation procedure for any SPI initiative. It was suggested by practitioners to design different activities within each phase of this component according to the required model or standard used in the organizations. This component provides different SPI implementation phases to the SPI implementation initiative.

The inputs provided by the three components of the SPI-IF can assist SPI practitioners in the design of effective SPI implementation initiatives. This is because the evaluation results showed that SPI-IF has the potential to assist SPI practitioners in the design of effective SPI implementation initiatives. These results are very encouraging in that all the experts consider this piece of work as useful and elegant for the software industry.

7.4 Critique of methodology

There are a number of limitations in this study. This section presents the limitations identified in this research. It also identifies issues that should be done differently if this research needs to be repeated.

7.4.1 The use of perception data only

This study explored the perceptions of practitioners regarding SPI implementation. These perceptions have not been verified directly. This may mean that what practitioners say about critical factors may not necessarily be the critical factors for SPI implementation. Furthermore, practitioner's perceptions may not be accurate. In an ideal world the perception data would be supplemented by real-life experience data collected through observation. The design of the study would be improved if the critical factors were directly identified after the successful completion of SPI implementation initiatives.

The collection of real-life experience data on such a large scale would have been difficult to achieve. This is because the observation of how each SPI initiative operated could be undertaken over a long period of time. Also, because of the highly sensitive nature of the data of some of the companies in this research, access to real-life experience data would have been difficult to attain. Without access to observe all SPI implementation initiatives, the reporting of real-life experience data would have been prejudiced and less representative of the SPI initiatives being run in different companies.

However, I have high confidence in this research results based on opinion data because:

- Data was collected from different practitioners who were dealing with SPI implementation issues on a daily basis
- Practitioners' experiences and perceptions were explored independently and without any suggestion from the researcher

- At the end of each CSF interview, I asked practitioners to rank from 1-5 their knowledge of SPI implementation. 77% of practitioners have chosen 4 and above. Only 23% have chosen 3 and below

- More than 50% of the companies have been involved in SPI programmes over the last five years

7.4.2 Sample categorisation

There were three categories of papers. Firstly, papers in which the authors have described their SPI implementation experiences with lessons learned, i.e. how they achieved CMM level-3, why their SPI implementation programme was successful? Secondly, papers in which SPI implementation was discussed but authors did not provide any summary of factors. Thirdly, the papers in which the results of empirical studies were described.

All papers count equally whether based on experienced reports, case studies or empirical studies. Similarly, all interviews count equally regardless of company size, type, SPI maturity etc. This is because I wanted to:

- identify aggregate factors that have been frequently cited in the literature and interviews

- compare aggregate factors identified through the literature with the interviews in order to come up with common factors

- use these common factors in the SPI implementation framework

Therefore, rather than categorising different research papers, I have used the opinions of SPI experts (interviews) to validate the literature findings. This two steps process has given confidence that a factor does indeed have an impact on SPI implementation if it is cited in both data sets.

In an ideal situation each category of paper would need to be analysed separately. This is because the analysis process can be improved and can increase the confidence of the researcher on the results. It also helps to compare the different categories of papers and to observe the significant difference between them. In case of interviews it would be better to categories and then analyse the data of different companies. Different categorisations of companies (e.g. mature versus immature companies, self-rated versus non-rated companies etc) can provide better views of different critical factors for SPI implementation.

7.4.3 Using close-ended questions instead of open-ended questions

Although using closed questions has the disadvantage of pre-empting the factors reported in this study, the use of closed questions would have strengthened the validity of the results. This is because open-ended questions require one to record the answers and then transcribe the data. This transcription process may leads to biased results. Often the analysis of the results for open-ended questions is complex and difficult to judge the confirming levels of agreement and disagreement between participants. The other disadvantage is that collecting and analysing this type of open-ended data is more time consuming.

In order to reduce researcher's bias the inter-rater reliability was conducted in this process. Three interview recordings were selected at random and a colleague, who was

not familiar with the issues being discussed, was asked to identify CSFs that appeared in the recordings. The results were compared with previous results and no great disagreements were found.

7.4.4 Group interviews as opposed to one-to-one interviews

One-to-one interviews are normally time consuming and would reduce the number of participants who could take part in the study. Also, one-to-one interviews would isolate the interviewees and restrict them to expressing issues that are common in the organization. Group interviews would have provided very rich data and would have made it simple to judge the confirming levels of agreement and disagreement between participants. It would have also helped to identify the factors that are not only critical at individual levels but also at company levels.

7.4.5 Evaluation using three case studies

Although the evaluation results of three large-scale case studies showed that SPI-IF has the potential to assist SPI practitioners in the design of effective SPI implementation initiatives, it would have been better to see the behaviour of the SPI-IF applied to two companies, one in CMM(I) level-1 and other in CMM(I) level-5. It would have been given me much more rich data to analyse the behaviour of SPI-IF in the real world environment. In addition to the large-scale case studies it would have been ideal to use SPI-IF in small and medium organizations in order to observe its behaviour in these types of organizations. These evaluations would help to further refine the design of SPI-IF.

7.4.6 The expert panel review questionnaire

Although the process of using an expert panel to evaluate the SPI-IF proved very helpful in highlighting some of the framework's strengths and weaknesses, using the expert panel questionnaire to evaluate SPI-IF, in this process, provided paper-based evaluation rather than practical evaluation. Also, having designed the survey instrument myself and then validating by supervisors, there may be some bias in the design of the questions. Ideally this form of validation should be conducted by a group or individual who has no investment in the results (Beecham, 2004).

Often questionnaire surveys are used for large samples. This was not the main motivation for using questionnaire as I was more interested in the quality of the sample rather than quantity. Thirty letters of requests were sent out for participation to well-known SPI experts all over the world and only 6 SPI experts (20%) responded. Although I do not claim this is a statistically representative sample, all experts had many years of SPI experience and they also had sufficient knowledge of SPI implementation. It is further important to acknowledge that the opinions of those experts were solicited who were tackling real SPI implementation issues on a daily basis.

7.5 Further work

The SPI-IF is a dynamic framework that will be extended and evolved based on feedback received from three case studies and the expert panel review process. In order to get real value from this research, follow-up work is necessary as the findings of the empirical study are not ends in themselves (Potts, 1993). The evaluation of the SPI-IF provided a foundation for future work.

In particular, one aspect that emerged as important, is the development of a complete tool which can be used to facilitate the SPI practitioners, and to improve the overall SPI implementation assessment process and generating different kinds of assessment documents. The need for tool development was felt by the participants who tested SPI-IF in the real world environment. Automated tool support is a productive way to enhance the visibility of processes, to identify process weaknesses and to better understand the processes. A tool can also be used to observe the behaviour of different activities and their interactions. The participants during the case studies have suggested that this tool will speed up the process of SPI implementation assessment. They also suggested that this tool should be capable of: recoding the results of assessment, identifying weak and strong factors, guiding SPI practitioners in successfully assessing the organizations' SPI implementation maturity and generating different assessment documents.

Similarly some suggestions were provided by the SPI experts in order to further refine the SPI-IF. For example, one expert suggested that "we need something to capture quantitative feedback on the impact of SPI". Other experts suggested some minor changes in the distribution of 5 practices to each CSF and CB. These suggestions are valuable and I will consider these suggestions in my future work in order to further refine the SPI-IF.

Although the SPI-IF has been evaluated and tested with the case studies and through expert panel review process, further evaluation of the capability of the SPI-IF will require further large-scale case studies. In addition to the large-scale case studies I am also planning to use SPI-IF in small and medium organizations in order to observe its behaviour towards these types of organizations. These studies will certainly result in

further refinement of the SPI-IF. It will be better to see the behaviour of the SPI-IF in a case where it will be applied to two companies, one in CMM(I) level-1 and other in CMM(I) level-5. It is hope that I will be able to continue development of SPI-IF in order to improve it and make it more complete.

The evaluation results show that SPI-IF has potential to assist SPI practitioners in the design of effective SPI implementation initiatives. Thus, I recommend organizations to use SPI-IF in order to effectively design SPI implementation initiatives.

7.6 Reflection on research

I am very much convinced that research is all about discovering something one does not know. I learned that there could be many things that one does not know but one could find out by conducting a systemic investigation. I learned the whole research process: research design, sampling, data collection, data analysis and reports. It was clear to me that research is a cyclic process of reading, asking questions, re-searching, reading, asking more questions, and so on. The research process made it clear that the researcher is not who knows the right answers but one who struggles to find out the right research questions. I learnt that a researcher examines data critically in order to get valid and reliable data. I also learnt that a researcher looks for explanations, relationships, comparisons, justifications, predictions, generalizations and theories.

7.7 Concluding remarks

The validated framework (SPI-IF) presented in this thesis adds to the knowledge of framework development process and software process improvement. The SPI-IF addresses problems of SPI implementation through a robust and transparent framework building strategy rarely known in SPI models and literature. So far no strategic and

systematic approach has been identified that could assist specifically in the design of effective SPI implementation initiatives.

My contribution to knowledge is the development of framework that presents a new process view of the SPI implementation. The SPI-IF is a dynamic framework that should enable other researchers to build on my work and continue towards seeking methods to improve the SPI implementation process.

This work has led me to the publication of several research papers as listed in Appendix N.

End

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Appendix A: Participant company information

Company	Scope	Age (yrs)	Size	Softwar e size	Primary function	SPI in operation (yrs)
1	Australian	3	38	14	Software	< 1
2	Multi-national	21-50	>2000	DK	Services	> 5
3	Multi-national	>50	>2000	101-500	Services	> 5
4	Multi-national	11-20	>2000	501-2000	Services	1-2
5	Australian	6-10	<10	<10	Software	> 5
6	Australian	21-50	11-100	30	Software/Services	3-5
7	Multi-national	21-50	>2000	DK	Software/Services	> 5
8	Multi-national	>50	501-2000	26-100	Software	> 5
9	Multi-national	>50	>2000	>2000	Software/Services	>5
10	Australian	>50	101-500	11-25	Services	3-5
11	Multi-national	>50	>2000	>2000	Financial services	3-5
12	Australian	<5	<10	<10	Software/Services	1-2
13	Multi-national	>50	>2000	DK	Software/Hardware / Services	>5
14	Multi-national	11-20	>2000	>2000	Software/Services	3-5
15	Australian	21-50	>2000	101-500	Software/Services	1-2
16	Multi-national	21-50	>2000	>2000	Software/Services	>5
17	Multi-national	11-20	>2000	11-25	Beverages	>5
18	Multi-national	>50	>2000	101-500	Software	>5
19	Australian	11-20	11-100	11-25	Software	1-2
20	Australian	21-50	>2000	DK	Investment Management	>5
21	Multi-national	<5	11-100	11-25	Software	1-2
22	Australian	11-20	11-100	11-25	Software	3-5
23	Multi-national	6-10	101-500	26-100	Software	3-5
24	Australian	<5	<10	<10	Software/services	3-5
25	Australian	6-10	>2000	101-500	Services	>5
26	Australian	6-10	11-100	26-100	Services	>5
27	Australian	>50	101-500	<10	Services	1-2
28	Multi-national	>50	>2000	11-25	Beverages	>5
29	Multi-national	>50	>2000	501-2000	Software/Hardware	>5

Appendix B: Letter of request for CSF interviews

Dear Sir/Madam

We should like to invite you to participate in the research project 'A framework for guiding the design of effective implementation strategies for software process improvement (SPI)' being conducted by Mahmood Niazi, Faculty of Information Technology, Building 10 City Campus of the University of Technology, Sydney, for the purpose of his Doctorate degree (PhD).

The aim of this research is to survey the viewpoints and experiences of IT practitioners regarding the factors that can play a positive or negative role in the implementation of SPI programs and to develop a framework that will assist practitioners in designing effective SPI implementation strategies. For this purpose, we should like to conduct an interview with you that will not take more than half an hour. As results become available, we shall provide you with copies of relevant papers and documents. We believe that these results will assist you in the design of effective SPI implementation strategies.

All information gathered at the interview is for research purposes only. Such information will be treated in the STRICTEST CONFIDENCE and any publication from this study will present information in aggregate form such that individual organizations or individual respondents participating in the research cannot be identified.

Your participation in this research is entirely voluntary and will involve participating in an interview that will require about half an hour of your time.

You can contact Mahmood Niazi at 61-2-9514 4441 or email mkniazi@it.uts.edu.au; or his supervisor Associate Professor David Wilson at 61-2-9514 1832 or email

davidw@it.uts.edu.au if you have any concerns about the research. You are free to withdraw your participation from this research project at any time you wish and without giving a reason.

We should appreciate if you would agree to participate in this research. To do so, please reply to this letter advising your availability or telephone number to arrange a time for the interview. We shall send you the list of interview questions prior to the interview.

Yours sincerely

Mahmood Niazi

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Appendix C: Experience reports, case studies and papers

Organization	References	Organization	References
Advanced information services	(Ferguson et al, 1999)	Ogden Air Logistics Centre	(Paul and Webb, 1995)
AVX Ltd	(Sweeney and Bustard, 1997)	Oklahoma City Air Logistics Centre	(Butler, 1995; Butler, 1997; Herbsleb et al, 1994)
Boeing's Space Transportation Systems	(Yamamura, 1999; Yamamura and Wigle, 1997)	Raytheon	(Dion, 1992; Dion, 1993)
Bull HN	(Herbsleb et al, 1994)	Rolls-Royce	(Nolan, 1999)
Corning Information Services	(Johnson, 1994)	Sacramento Air Logistics Centre	(Westaway, 1995)
Eastman Kodak Comp.	(Weigers, 1998)	Schlumberger	(Herbsleb et al, 1994; Wohlwend and Rosenbaum, 1993; Wohlwend and Rosenbaum, 1994)
Fastrak Training Inc.	(Quenn, 1997)	SEI	(Goldenson and Herbsleb, 1995; Herbsleb and Goldenson, 1996; Paulk, 1998; Paulk, 1999)
High-Tech Measurement	(Kautz and Nielsen, 2000)	Siemens	(Paulish and Carleton 1994)
Hughes	(Herbsleb et al, 1994; Humphery et al, 1991; Willis et al, 1998)	SINTEF Telecom and Informatics	(Dyba, 2000)
Lucent Technologies	(Moitra, 1998)	Space Shuttle Software Project	(Billings et al, 1994; Curtis, 2000; Paulk et al, 1994)
MITRE Corporation	(Florence, 2001)	Sybase	(Macfarlane, 1996)
Motorola	(Diaz and Sligo, 1997; Fitzgerald and O'Kane, 1999)	Tata Consulting Services	(Curtis, 2000)
Master Systems	(Rifkin, 2001)	Texas Instruments	(Herbsleb et al, 1994)
NASA SEL	(Basili et al, 2002)	Telcordia Technologies	(Curtis, 2000; Pitterman, 2000)
Network Products	(Kautz and Nielsen, 2000)	Trident Data Systems	(Reel, 1999)
Nokia	(Kaltio and Kinnula, 2000)	University of Hertfordshire	(Baddoo and Hall, 2002; Baddoo and Hall, 2003; Baddoo *et al*, 2000; Hall *et al*, 2002a; Hall *et al*, 2002b; Rainer and Hall, 2002; Rainer and Hall, 2003)
Oerlikon Aerospace	(Laporte and Trudel, 1998)	Xerox	(Fowler et al, 1999)

Appendix D: List of CSF interview questions

- Interview Number
- Company number
- Interviewee name:
- Interviewee job title:
- E-mail address:
- Phone
- Company:
- Address:
- Date of interview:
- What is the primary business function of your company?
- What is the scope of your company?
- How long established is your company?
- What type of products or services does your company provide?
- What is your total IT experience?
- Your knowledge of SPI implementation

  High 5 ---------- 4 ---------- 3 ---------- 2 ---------- 1 Low

- Has your experience of SPI implementation been positive?

  Agree 5 ---------- 4 ---------- 3 ---------- 2 ---------- 1 Disagree

- Software Process Improvement is an effective approach to improving the quality of the software product.

  Agree 5 ---------- 4 ---------- 3 ---------- 2 ---------- 1 Disagree

- Implementing an effective SPI programme is difficult.

  Agree 5 ---------- 4 ---------- 3 ---------- 2 ---------- 1 Disagree

- Has your company attempted to improve its approach to software development?
- How long has your process improvement programme been in operation?

- How was the improvement programme introduced?
- Why did your company embark on a process improvement programme?
- Which of process improvement models does your company use
- Has your company been formally assessed against the process improvement models?
    - If yes, what were the results?
- Has your company been informally assessed against the process improvement models?
    - If yes, what were the results?
- What do you think what are the critical success factors for the implementation of SPI programmes?
- How can one develop these CSFs?
- Some discussion about factors identified through literature
- What do you think what are the critical barriers for the implementation of SPI programmes?
- How can one overcome or avoid these barriers?
- Some discussion about barriers identified through literature
- What do you think what phases or steps are necessary for the implementation of SPI programmes?
- Some discussion about these phases

Appendix E: Summary of CSFs and CBs Identified through literature

Papers/case studies or experience reports

No	Reference	No	Reference
1	Baddoo et al., 2000	27	Lapasaar et al., 2001
2	Baddoo and Hall, 2002	28	Laporte and Trudel, 1998
3	Baddoo and Hall, 2003	29	Macfarlane, 1996
4	Basili et al. 2002	30	Moitra, 1998
5	Billings et al., 1994	31	Nolan, 1999
6	Butler, 1995	32	Paulish and Carleton 1994
7	Butler, 1997	33	Paulk et al., 1993
8	Curtis, 2000	34	Paulk et al. 1995
9	Diaz and Sligo, 1997	35	Paulk, 1998
10	Dion 1992	36	Paulk, 1999
11	Dion 1993	37	Pitterman, 2000
12	Dyba, 2000	38	Quann, 1997
13	El Emam et al., 1999	39	Rainer and Hall, 2002a
14	Ferguson et al. 1999	40	Rainer and Hall, 2002b
15	Fitzgerald and O'Kane, 1999	41	Reel, 1999
16	Florence, 2001	42	Rifkin, 2001
17	Fowler et al., 1999	43	Stelzer and Mellis, 1998
18	Goldenson and Herbsleb, 1995	44	Sweeney and Bustard, 1997
19	Hall et al, 2002a	45	Tanaka et al. 1995
20	Hall et al., 2002b	46	Weigers 1998b
21	Herbsleb et al., 1994	47	Westaway, 1995
22	Herbsleb and Goldenson, 1996	48	Willis et at, 1998
23	Humphery et al. 1991	49	Wohlwend and Rosenbaum, 1993
24	Johnson 1994	50	Yamamura, 1999
25	Kaltio and Kinnula, 2000		
26	Kautz and Nielsen, 2000		

Summary of CSFs

Success Factors	Papers/case studies or experience reports																																														
	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
Senior management commitment	Y	Y		Y	Y		Y	Y		Y	Y			Y		Y	Y	Y	Y	Y	Y		Y		Y	Y			Y	Y		Y		Y	Y	Y	Y			Y	Y		Y	Y	Y	Y		
Clear and relevant SPI goals					Y	Y				Y	Y	Y				Y	Y		Y															Y	Y			Y		Y								
Staff involvement				Y	Y		Y	Y		Y	Y			Y		Y	Y	Y	Y		Y		Y		Y		Y			Y	Y			Y				Y		Y	Y			Y		Y	Y	
Process ownership	Y	Y	Y										Y				Y													Y			Y	Y		Y	Y										Y	
Staff time and resources	Y			Y			Y		Y		Y			Y		Y	Y	Y	Y		Y	Y	Y	Y	Y				Y						Y										Y			
Training and mentoring		Y	Y		Y				Y				Y	Y	Y		Y					Y			Y		Y	Y		Y		Y	Y	Y	Y	Y	Y						Y	Y	Y	Y		
SPI people highly/well respected											Y					Y	Y		Y								Y																					
Encouraging communication and collaboration or sharing best practices	Y		Y		Y		Y								Y												Y						Y							Y					Y	Y		
Experienced staff	Y																Y			Y		Y			Y					Y			Y	Y	Y	Y	Y	Y								Y		
Creating process action teams/ Change agents and opinion leaders			Y		Y	Y	Y											Y		Y		Y	Y		Y						Y	Y		Y						Y		Y			Y			
Tailoring improvement initiatives													Y				Y					Y										Y							Y	Y					Y			
Reward schemes	Y						Y									Y									Y		Y						Y		Y													
Managing the SPI project					Y								Y													Y	Y						Y		Y					Y								
Providing enhanced understanding					Y		Y			Y								Y									Y													Y					Y			
Reviews			Y		Y		Y						Y								Y				Y					Y			Y		Y	Y	Y						Y	Y	Y			
Standards and procedures						Y																									Y					Y	Y											
Assignment of responsibility of SPI			Y			Y					Y		Y			Y			Y						Y	Y				Y				Y										Y	Y			
Internal leadership							Y										Y	Y																Y		Y				Y								

Summary of CBs

Barriers	Papers/case studies or experience reports													
	1	3	13	16	18	20	22	26	28	30	32	37	41	49
Lack of resources	Y	Y		Y	Y		Y	Y	Y					
Time pressure	Y	Y			Y		Y				Y			
Inexperienced staff/lack of knowledge	Y	Y						Y		Y			Y	
Organizational politics			Y		Y		Y			Y				
SPI gets in the way of real work			Y		Y		Y	Y						
Staff turnover					Y	Y					Y			Y
Lack of support		Y	Y	Y										
Changing the mindset of management and technical staff				Y								Y		
Inertia		Y												
Negative/Bad experience		Y												
Paperwork required					Y									

Appendix F: CSFs in different periods of time

Papers, case studies or experience reports

No	Reference	No	Reference
1	Baddoo et al., 2000	27	Lapasaar et al., 2001
2	Baddoo and Hall, 2002	28	Laporte and Trudel, 1998
3	Baddoo and Hall, 2003	29	Macfarlane, 1996
4	Basili et al. 2002	30	Moitra, 1998
5	Billings et al., 1994	31	Nolan, 1999
6	Butler, 1995	32	Paulish and Carleton 1994
7	Butler, 1997	33	Paulk et al., 1994
8	Curtis, 2000	34	Paulk et al. 1995
9	Diaz and Sligo, 1997	35	Paulk, 1998
10	Dion 1992	36	Paulk, 1999
11	Dion 1993	37	Pitterman, 2000
12	Dyba, 2000	38	Quann, 1997
13	El Emam et al., 1999	39	Rainer and Hall, 2002a
14	Ferguson et al. 1999	40	Rainer and Hall, 2002b
15	Fitzgerald and O'Kane, 1999	41	Reel, 1999
16	Florence, 2001	42	Rifkin, 2001
17	Fowler et al., 1999	43	Stelzer and Mellis, 1998
18	Goldenson and Herbsleb, 1995	44	Sweeney and Bustard, 1997
19	Hall et al, 2002a	45	Tanaka et al. 1995
20	Hall et al., 2002b	46	Weigers 1998b
21	Herbsleb et al., 1994	47	Westaway, 1995
22	Herbsleb and Goldenson, 1996	48	Willis et at, 1998
23	Humphery et al. 1991	49	Wohlwend and Rosenbaum, 1993
24	Johnson 1994	50	Yamamura, 1999
25	Kaltio and Kinnula, 2000		
26	Kautz and Nielsen, 2000		

CSFs identified during 1991-1996

Success Factors	5	6	10	11	21	18	22	23	24	29	32	33	34	45	47	49
Assignment of responsibility of SPI	Y					Y	Y			Y		Y			Y	
Clear and relevant SPI goals						Y	Y									
Creating process action teams/ Change agents and opinion leaders	Y				Y			Y					Y	Y		
Encouraging communication and collaboration or sharing best practices	Y															Y
Experienced staff								Y				Y				Y
Internal leadership					Y											
Managing the SPI project										Y						
Process ownership	Y											Y				
Providing enhanced understanding					Y											
Reviews	Y								Y			Y			Y	
Reward schemes						Y										
Senior management commitment		Y	Y		Y	Y	Y	Y	Y	Y	Y	Y			Y	Y
SPI people highly/well respected						Y	Y									
Staff involvement		Y	Y		Y	Y	Y		Y			Y	Y		Y	Y
Staff time and resources		Y		Y	Y	Y	Y		Y		Y					
Standards and procedures													Y			
Training and mentoring	Y			Y								Y			Y	Y

CSFs identified during 1997-todate

Success Factors	2	4	7	8	9	12	13	14	15	16	17	19	25	26	27	28	30	31	35	36	37	38	39	40	41	42	43	44	46	48	50
Assignment of responsibility of SPI				Y			Y		Y							Y					Y									Y	
Clear and relevant SPI goals			Y	Y		Y	Y	Y				Y									Y	Y			Y		Y				
Creating process action teams/ Change agents and opinion leaders			Y	Y	Y								Y	Y		Y			Y		Y						Y			Y	
Encouraging communication and collaboration or sharing best practices	Y		Y		Y						Y						Y			Y							Y			Y	
Experienced staff	Y											Y	Y			Y				Y	Y	Y	Y	Y	Y						
Internal leadership					Y							Y									Y		Y				Y				
Managing the SPI project			Y						Y								Y			Y		Y					Y				
Process ownership	Y	Y							Y			Y								Y	Y		Y	Y							Y
Providing enhanced understanding			Y		Y	Y											Y										Y			Y	
Reviews			Y		Y				Y							Y				Y		Y	Y	Y					Y	Y	
Reward schemes	Y				Y											Y	Y			Y		Y									
Senior management commitment	Y	Y	Y		Y	Y	Y			Y		Y		Y		Y			Y		Y	Y	Y	Y			Y	Y	Y	Y	
SPI people highly/well respected							Y					Y					Y														
Staff involvement			Y		Y	Y	Y			Y		Y		Y		Y	Y				Y				Y		Y	Y			Y
Staff time and resources	Y				Y		Y			Y		Y	Y	Y	Y	Y						Y								Y	
Standards and procedures				Y																			Y	Y							
Training and mentoring		Y	Y						Y	Y	Y	Y	Y			Y	Y	Y	Y	Y	Y	Y	Y	Y					Y	Y	
Tailoring improvement initiatives									Y			Y	Y						Y							Y	Y			Y	

Summary of CSFs in different periods of time

Success Factors	1991-96 (n=16)			1997-to date (n=31)		
	Freq.	%	Rank	Freq	%	Rank
Senior management commitment	12	75	1	19	61	1
Staff involvement	10	63	2	14	45	3
Staff time and resources	7	44	3	11	35	4
Assignment of responsibility of SPI	6	38	4	6	19	9
Training and mentoring	5	31	5	18	58	2
Creating process action teams	5	31	5	10	32	5
Reviews	4	25	6	7	23	8
Experienced staff	3	19	6	10	32	5
Clear and relevant SPI goals	2	13	7	10	32	5
Process ownership	2	13	7	9	29	6
SPI people highly/well respected	2	13	7	3	10	
Encouraging communication and collaboration	2	13	7	8	26	7
Reward schemes	1	6	8	6	19	9
Managing the SPI project	1	6	8	6	19	9
Providing enhanced understanding	1	6	8	6	19	9
Standards and procedures	1	6	8	3	10	11
Internal leadership	1	6	8	5	16	10

Appendix G: CSFs and CBs identified by different group of practitioners

Critical Success Factors identified by different group of practitioners

It is suggested that understanding the similarities in CSFs across different group of practitioners can assist to develop effective SPI implementation strategies. This is because, where respondents from all three groups of practitioners consider that a factor has an impact on SPI implementation then that barrier needs to be taken seriously. This is because I have a factor that is replicated across three groups of practitioners.

Table C.1 shows the CSFs cited by all three-practitioner groups. The results show that there are more similarities than differences in CFS across practitioner groups. It shows that all practitioners have cited 7 factors, i.e. higher management support, training, awareness, allocation of resources, staff involvement, experienced staff and defined SPI implementation methodology. These common CSFs need to be taken seriously.

The findings indicate that developers and managers consider higher management support and training important for the implementation of SPI initiative. This is due to the SPI implementation experience which realised them the importance of these two factors. Managers and senior managers consider awareness as an integral part of SPI implementation. This is because through awareness management can motivate the developers to adopt SPI standards in their routine working. Table C.1 also shows the opinion of each individual practitioner group. For example, the results show that developers want more facilitation and more resources to be allocated for SPI implementation programmes. It also shows that senior managers want experienced staff and defined methodology because these factors can play a vital role in the implementation of SPI programmes.

Table C.1 CSFs across practitioner groups

Success Factors	**Developers (n=10)**	**Managers (n=20)**	**Senior Managers (n=4)**	**Chi-square Test $\alpha = 0.05$**		
	%	%	%	X^2	*df*	*p*
Higher Management support	70	75	25	3.843	2	0.146
Training	80	70	25	4.072	2	0.131
Awareness	30	75	50	5.719	2	0.057
Allocation of resources	70	35	50	3.294	2	0.193
Staff involvement	50	20	50	3.387	2	0.184
Experienced staff	30	35	75	2.665	2	0.264
Defined SPI implementation methodology	20	40	50	1.597	2	0.450
Communication	0	20	25	2.509	2	0.285
Facilitation	60	15	0	8.568	2	0.014
Project management	0	20	25	2.509	2	0.285
Formal Documentation	0	10	25	2.303	2	0.316
Review	10	10	0	0.439	2	0.803
Tailoring improvement initiatives	0	10	0	1.488	2	0.475
Company Culture	0	5	25	3.294	2	0.193
Quality assurance	**40**	**0**	**25**	**8.887**	**2**	**0.012**
Formalised relationship between development team	0	5	0	0.721	2	0.697
Creating process action teams/external agents	0	10	0	1.488	2	0.475
Logical sequence/order of SPI implementation	0	10	0	1.488	2	0.475
Measurement	10	5	0	0.584	2	0.747
Customer satisfaction	20	0	0	5.100	2	0.078
Automated tools/packages	0	10	0	1.488	2	0.475
Higher staff moral	0	5	0	0.721	2	0.697

This is clear from Table C.1 that there are more similarities than differences between the CSFs identified by different group of practitioners. For factor 'quality assurance' there is statistically significant difference between the responses of practitioners (i.e. p=0.05<=0.05). Table C.1 also shows that for all other factors there are no statistically significant differences between the responses of practitioners. This shows the level of agreement across all practitioners about CSFs of SPI implementation.

Critical Barriers identified by different groups of practitioners

It is suggested that understanding the similarities in CBs across different group of practitioners can assist to develop effective SPI implementation strategies. This is because, where respondents from all three groups of practitioners consider that a barrier has an impact on SPI implementation then that barrier needs to be taken seriously. This is because I have a barrier that is replicated across three groups of practitioners.

Table C.2 shows the spread of CBs cited by all three-practitioner groups.

The results show that there are both similarities and differences in CBs across practitioner groups. It shows that all practitioners have cited 7 barriers, i.e. inexperienced staff, lack of awareness, lack of defined SPI implementation methodology, lack of support, lack of training, organizational politics, and paperwork required. This shows the level of agreement that practitioners across all staff groups have about CBs that undermine SPI implementation. These common CBs need to be taken seriously. My findings indicate that developers and managers consider lack of resources, lack of sponsorship and time pressure as barriers that can undermine SPI implementation programmes. This is due to the SPI implementation experience which realised them the importance of these three barriers. Developers and senior managers consider lack of support as a critical barrier.

Table C.2 also shows the opinion of each individual practitioner group. For example, the results show that developers want more support and more resources to be allocated for SPI implementation programmes. It also shows that senior managers have problems with formal procedures and inexperienced staff.

Table C.2 Critical Barriers across practitioner groups

Barriers	**Developers n=10**	**Managers n=20**	**Senior Managers n=4**	**Chi-square Test $\alpha = 0.05$**		
	%	%	%	X^2	*df*	*p*
Inexperienced staff/lack of knowledge	30	20	50	1.632	2	0.442
Lack of awareness	40	40	25	0.336	2	0.845
Lack of communication	10	5	0	0.584	2	0.747
Lack of defined SPI implementation methodology	30	35	50	0.502	2	0.778
Lack of project management	10	10	0	0.439	2	0.803
Lack of resources	50	35	0	3.130	2	0.209
Lack of sponsorship	20	20	0	0.971	2	0.615
Lack of support	**80**	**25**	**75**	9.515	**2**	**0.009**
Lack of tools	10	10	0	0.439	2	0.803
Lack of training	10	5	25	1.682	2	0.431
Negative/Bad experience	0	10	0	1.488	2	0.475
Organizational politics	30	40	75	2.416	2	0.299
Paperwork required/formal procedures	20	15	50	2.501	2	0.286
SPI gets in the way of real work	10	5	0	0.584	2	0.747
Time pressure	20	25	0	1.277	2	0.528

This is clear from Table C.2 that for barrier 'lack of support' there is statistically significant difference between the responses of practitioners (i.e. $p=0.003<0.05$). Table C.2 also shows that for all other barriers there are no statistically significant differences between the responses of practitioners. This shows the level of agreement across all practitioners about CBs that undermine SPI implementation.

Appendix H: Assessment instrument (Source (Daskalantonakis, 1994))

Score	Key Activity evaluation dimensions		
	Approach	**Deployment**	**Results**
Poor (0)	▪ No management recognition of need ▪ No organizational ability ▪ No organizational commitment ▪ Practice not evident	▪ No part of the organization uses the practice ▪ No part of the organization shows interest	▪ Ineffective
Weak (2)	▪ Management begins to recognize need ▪ Support items for the practice start to be created ▪ A few parts of organization are able to implement the practice	▪ Fragmented use ▪ Inconsistent use ▪ Deployed in some parts of the organization ▪ Limited to monitoring/verification of use	▪ Spotty results ▪ Inconsistent results ▪ Some evidence of effectiveness for some parts of the organization
Fair (4)	▪ Wide but not complete commitment by management ▪ Road map for practice implementation defined ▪ Several supporting items for the practice in place	▪ Less fragmented use ▪ Some consistency in use ▪ Deployed in some major parts of the organization ▪ Monitoring/verification of use for several parts of the organization	▪ Consistent and positive results for several parts of the organization ▪ Inconsistent results for other parts of the organization
Marginally qualified (6)	▪ Some management commitment; some management becomes proactive ▪ Practice implementation well under way across parts of the organization ▪ Supporting items in place	▪ Deployed in some parts of the organization ▪ Mostly consistent use across many parts of the organization ▪ Monitoring/verification of use for many parts of the organization	▪ Positive measurable results in most parts of the organization ▪ Consistently positive results over time across many parts of the organization
Qualified (8)	▪ Total management commitment ▪ Majority of management is proactive ▪ Practice established as an integral part of the process ▪ Supporting items encourage and facilitate the use of practice	▪ Deployed in almost all parts of the organization ▪ Consistent use across almost all parts of the organization ▪ Monitoring/verification of use for almost all parts of the organization	▪ Positive measurable results in almost all parts of the organization ▪ Consistently positive results over time across almost all parts of the organization
Outstanding (10)	▪ Management provides zealous leadership and commitment ▪ Organizational excellence in the practice recognized even outside the company	▪ Pervasive and consistent deployed across all parts of the organization ▪ Consistent use over time across all parts of the organization ▪ Monitoring/verification for all parts of the organization	▪ Requirements exceeded ▪ Consistently world-class results ▪ Counsel sought by others

Appendix I: List of practices for CSFs and CBs

CSFs and CBs	List of Practices
Awareness	P1. The benefits of SPI have been promoted among the staff members of the organization before Software Process Improvement Implementation P2. Higher management is aware of investment required and long term benefits of Software Process Improvement before Software Process Improvement Implementation P3. Staff members are aware of their roles and responsibilities during the implementation of SPI within their unit of work P4. Planning has been done to organize and continue SPI awareness events within the organization P5. A mechanism has been established to make the SPI as part of the organization's culture
Creating process action teams	P1. SPI implementation action groups have been established with experienced people P2. Responsibilities have been assigned to provide technical support to the process action teams P3. A mechanism has been established to monitor the progress of each process action team P4. A mechanism has been established to collect and analyze the feedback data from each process action team and to extract the main lessons learned P5. A process has been established to distribute the lessons learned to the relevant staff members
Experienced staff	P1. People have been selected for SPI activities who have track record of different successful projects P2. Conflict resolution plan has been established P3. Responsibilities have been assigned to each staff member about SPI implementation activities P4. A mechanism has been established to monitor the progress of each staff member P5. A mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned
Defined SPI implementation methodology	P1. SPI implementation methodology has been developed using current trends P2. SPI implementation methodology has been tried and tested in pilot projects P3. Staff members have been satisfied with the performance of methodology in the pilot projects P4. Training has been provided for developing the skills and knowledge needed to successfully use a methodology P5. Work has been done to continuously improve a methodology with the aim of using it in whole organization
Lack of support	P1. Management provides strong leadership and support for SPI P 2. Management is committed to provide all the required resources P 3. Work has been done to facilitate staff members during SPI implementation P4. Staff members are aware of the benefits of SPI implementation P5. A mechanism has been established to monitor the progress of each staff member

CSFs and CBs	List of Practices
Management support/ commitment	P1. Management provides strong leadership and commitment for SPI P2. Management establishes SPI practices as an integral part of the software development process P3. Management at all levels of the organization supports the SPI initiative P4. Management is willing to participate in assessment meetings and improvement workshops. P5. Management is committed to provide training and resources for SPI implementation
Reviews	P1. Organization has developed a review process for SPI implementation requirements P2. Work has been done to continuously monitor existing SPI implementation methodology/process with emerging and new trends P3. Organization has developed a process in order to review each CSF and critical barrier of Software Process Improvement P4. Responsibilities have been assigned to conduct continuous SPI implementation reviews within organization P5. All the key stakeholders are involved in SPI implementation reviews
Staff involvement	P1. The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort P2. Work has been done to facilitate staff members during SPI implementation P3. Work has been done to allocate the time necessary to make staff participation successful P4. Local process teams and forums for the exchange of ideas have been established P5. Conflict resolution plan has been established
Staff time and resources dedicated to SPI	P1. Preparation has been done to provide all the required resources (funds, tools, people) for SPI implementation P2. Staff members have been allocated time for SPI efforts P3. Staff members are happy with allocated time P4. Work has been done to avoid staff from time pressure P5. Work has been done that SPI will not get in the way of day to day work
Time pressure	P1. Staff members have been allocated time for SPI efforts and staff members are happy with allocated time P2. Work has been done to avoid staff from time pressure P3. Work has been done that SPI will not get in the way of real work P4.The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort. P5 Work has been done to facilitate staff members during SPI implementation
Training and Mentoring	P1. Training is provided for developing the skills and knowledge needed to perform SPI implementation P2. Sufficient resources and additional time to participate in SPI training will be provided to staff members. P3. Training programme activities are reviewed on a periodic basis P4. Organization has developed a written training policy for SPI to meet its training needs P5. All future group or individual trainings of SPI are planned

Organizational politics	P1. Management and staff members provide strong support for SPI P2. A mechanism has been established to make SPI as part of the organization's culture P3. The benefits of SPI have been promoted among the management and staff members of the organization P4. All the key stakeholders are involved in SPI implementation initiatives P5. Conflict resolution plan has been established

Appendix J: Expert Panel Questionnaire

Section 1: Demographics

Interviewee name: _____

Interviewee job title: _____

E-mail address: _____

Company: _____

Address: _____

Date: _____

.

Q1 How long have you worked in computing/software engineering/IT? _____years

Q2. How do you rate your knowledge of SPI implementation?

Expert 4 ---------- 3 ---------- 2 ---------- 1 None No Opinion [ ]

Q3. How do you rate your practical experience of SPI implementation?

Expert 4 ---------- 3 ---------- 2 ---------- 1 None No Opinion [ ]

Section 2: Implementation Maturity Model

2.1 Ease of Learning

Q4. How clear is the representation of the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No Opinion [ ]

Q5. How consistent is the level of detail given within the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No Opinion [ ]

Q6. How much knowledge of SPI implementation is required to learn how to use this Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No Opinion [ ]

Q7. How easy is it to understand the distribution of CSFs and critical barriers among different categories, e.g. awareness, organizational and support?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q8. How easy is it to understand the distribution of three categories among four levels of the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q9. How easy is it to understand the five practices designed for each CSF and critical barrier?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q10. How easy is it to understand the assessment method?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q11. How confident are you in the ratings that you have made in this section?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

2.2 User Satisfaction

Q12. Implementation Maturity Model is general and can be applied to most companies

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q13. How self-contained is the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q14. Each individual practice is easy to understand and unambiguous

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q15. The categories listed in each of the 4 maturity levels reflect the activities associated within each maturity level

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q16. How useful would it be to the software industry to use this model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q17. How useful is the distribution of CSFs and critical barriers among different categories, e.g. awareness, organizational and support?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q18. How useful is the distribution of three categories among four levels of the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q19. How useful is the assessment method?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q20. Using the Implementation Maturity Model would improve our SPI implementation process

Strongly agree 4 ---------- 3 ---------- 2 ----------1 Strongly disagree No opinion [ ]

Q21. If the Implementation Maturity Model were available for my job, I predict that I would use it on regular basis in the future

Strongly agree 4 ---------- 3 ----------2 ---------- 1 Strongly disagree No opinion [ ]

Q22. How confident are you in the ratings that you have made in this section?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

2.3 Structure of Implementation Maturity Model

Q23. How much knowledge of SPI implementation is required to use the Implementation Maturity Model?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q24. How easy would it be to use the Implementation Maturity Model to assess and improve SPI implementation maturity?

Very 4 ---------- 3 ---------- 2 ---------- 1 Not at all No opinion [ ]

Q25. All the components of the Implementation Maturity Model are self explanatory and require no further explanation to be used effectively?

Strongly agree 4 ---------- 3 ---------- 2 ---------- 1 Strongly disagree No opinion [ ]

Q26. In the following table we are interested to validate the distribution of CSFs and critical barriers among three categories.

Please provide comments relating to the distribution of CSF and critical barriers among three categories (i.e. awareness, organizational and support)

Awareness	Critical success factor and critical barriers	Agree	Disagree	Move this factor to (name of category)	Don't know
	Senior management commitment				
	Training and mentoring				
	Staff involvement				
	Awareness of SPI				
	Lack of awareness				
	lack of support				
Organizational	Creating process action teams				
	Experienced staff				
	Staff time and resources,				
	Defined SPI implementation methodology				
	Lack of resources				
	Time pressure				
	Inexperienced staff				
	Org. politics				
	Lack of defined SPI implementation methodology				
Support	Reviews				

Q27. In the following table we are interested to validate the distribution of practices among different CSFs and critical barriers.

CSFs and critical barriers	**Practices**	Agree	**Disagree**	Move the practice to (name of factor)	Don't know
Management support/ commitment	P1. Management provides strong leadership and commitment for SPI				
	P2. Management establishes SPI practices as an integral part of the software development process				
	P 3. Management at all levels of the organization supports the SPI initiative.				
	P 4. Management is willing to participate in assessment meetings and improvement workshops.				
	P 5. Management is committed to provide training and resources for SPI implementation				
Staff involvement	P 1. The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.				
	P 2. Work has been done to facilitate staff members during SPI implementation				
	P 3. Work has been done to allocate the time necessary to make staff participation successful.				
	P 4. Local process teams and forums for the exchange of ideas have been established				
	P 5. Conflict resolution plan has been established				

Training and Mentoring	P 1. Training is provided for developing the skills and knowledge needed to perform SPI implementation				
	P 2. Sufficient resources and additional time to participate in SPI training will be provided to staff members.				
	P 3. Training program activities are reviewed on a periodic basis				
	P 4. Organization has developed a written training policy for SPI to meet its training needs				
	P 5. All future group or individual trainings of SPI are planned				
Staff time and resources dedicated to SPI	P1. Preparation has been done to provide all the required resources (funds, tools, people) for SPI implementation				
	P2. Staff members have been allocated time for SPI efforts				
	P3. Staff members are happy with allocated time				
	P4. Work has been done to avoid staff from time pressure				
	P5. Work has been done that SPI will not get in the way of day to day work				
Creating process action teams	P1. SPI implementation action groups have been established with experienced people				
	P2. Responsibilities have been assigned to provide technical support to the process action teams				
	P3. A mechanism has been established to monitor the progress of each process action team				
	P4. A mechanism has been established to collect and analyze the feedback data from each process action team and to extract the main lessons learned				
	P5. A process has been established to distribute the lessons learned to the relevant staff members				
Experienced staff	P1. People have been selected for SPI activities who have track record of different successful projects				
	P2. Conflict resolution plan has been established				
	P3. Responsibilities have been assigned to each staff member about SPI implementation activities				
	P4. A mechanism has been established to monitor the progress of each staff member				
	P5. A mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned				

Reviews	P1. Organization has developed a review process for SPI implementation requirements				
	P2. Work has been done to continuously monitor existing SPI implementation methodology/process with emerging and new trends				
	P3. Organization has developed a process in order to review each CSF and critical barrier of Software Process Improvement				
	P4. Responsibilities have been assigned to conduct continuous SPI implementation reviews within organization				
	P5. All the key stakeholders are involved in SPI implementation reviews				
Awareness	P1. The benefits of SPI have been promoted among the staff members of the organization before Software Process Improvement Implementation				
	P2. Higher management is aware of investment required and long term benefits of Software Process Improvement before Software Process Improvement Implementation				
	P3. Staff members are aware of their roles and responsibilities during the implementation of SPI within their unit of work				
	P4. Planning has been done to organize and continue SPI awareness events within the organization				
	P5. A mechanism has been established to make the SPI as part of the organization's culture				
Defined SPI implementation methodology	P1. SPI implementation methodology has been developed using current trends				
	P2. SPI implementation methodology has been tried and tested in pilot projects				
	P3. Staff members have been satisfied with the performance of methodology in the pilot projects				
	P4. Training has been provided for developing the skills and knowledge needed to successfully use a methodology				
	P5. Work has been done to continuously improve a methodology with the aim of using it in whole organization				

Lack of support	P1. Management provides strong leadership and support for SPI				
	P 2. Management is committed to provide all the required resources				
	P 3. Work has been done to facilitate staff members during SPI implementation				
	P4. Staff members are aware of the benefits of SPI implementation				
	P5. A mechanism has been established to monitor the progress of each staff member				
Organizational politics	P1. Management and staff members provide strong support for SPI				
	P2. A mechanism has been established to make SPI as part of the organization's culture				
	P3. The benefits of SPI have been promoted among the management and staff members of the organization				
	P4. All the key stakeholders are involved in SPI implementation initiatives				
	P5. Conflict resolution plan has been established				
Time pressure	P1. Staff members have been allocated time for SPI efforts and staff members are happy with allocated time				
	P2. Work has been done to avoid staff from time pressure				
	P3. Work has been done that SPI will not get in the way of real work				
	P4.The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.				
	P5 Work has been done to facilitate staff members during SPI implementation				

Q28. Please provide any comments relating to the 4 maturity levels

Q29. Please provide any comments relating to the distribution of categories among 4 maturity levels

Q30. Please provide any comments relating to the assessment method

Appendix K: Assessment done at Company A

Management support/commitment	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and commitment for SPI								√			
P2. Management establishes SPI practices as an integral part of the software development process						√					
P 3. Management at all levels of the organization supports the SPI initiative.									√		
P 4. Management is willing to participate in assessment meetings and improvement workshops.						√					
P 5. Management is committed to provide training and resources for SPI implementation								√			

Score= 32/5= 6.4

Staff involvement	0	1	2	3	4	5	6	7	8	9	10
P 1. The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.									√		
P 2. Work has been done to facilitate staff members during SPI implementation									√		
P 3. Work has been done to allocate the time necessary to make staff participation successful.							√				
P 4. Local process teams and forums for the exchange of ideas have been established							√				
P 5. Conflict resolution plan has been established				√							

Score= 31/5=6.2

Training and Mentoring	0	1	2	3	4	5	6	7	8	9	10
P 1. Training is provided for developing the skills and knowledge needed to perform SPI implementation									√		
P 2. Sufficient resources and additional time to participate in SPI training will be provided to staff members.								√			
P 3. Training programme activities are reviewed on a periodic basis									√		
P 4. Organization has developed a written training policy for SPI to meet its training needs										√	
P 5. All future group or individual trainings of SPI are planned							√				

Score= 38/5= 7.6

Staff time and resources dedicated to SPI	0	1	2	3	4	5	6	7	8	9	10
P1. Preparation has been done to provide all the required resources (funds, tools, people) for SPI implementation									√		
P2. Staff members have been allocated time for SPI efforts									√		
P3. Staff members are happy with allocated time							√				
P4. Work has been done to avoid staff from time pressure			√								
P5. Work has been done that SPI will not get in the way of day to day work		√									

Score= 25/5= 5

Creating process action teams	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation action groups have been established with experienced people									√		
P2. Responsibilities have been assigned to provide technical support to the process action teams										√	
P3. A mechanism has been established to monitor the progress of each process action team							√				
P4. A mechanism has been established to collect and analyze the feedback data from each process action team and to extract the main lessons learned					√						
P5. A process has been established to distribute the lessons learned to the relevant staff members					√						

Score= 31/5= 6.2

Experienced staff	0	1	2	3	4	5	6	7	8	9	10
P1. People have been selected for SPI activities who have track record of different successful projects											√
P2. Conflict resolution plan has been established				√							
P3. Responsibilities have been assigned to each staff member about SPI implementation activities									√		
P4. A mechanism has been established to monitor the progress of each staff member									√		
P5. A mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned									√		

Score= 38/5= 7.4

Reviews	0	1	2	3	4	5	6	7	8	9	10
P1. Organization has developed a review process for SPI implementation requirements							√				
P2. Work has been done to continuously monitor existing SPI implementation methodology/process with emerging and new trends									√		
P3. Organization has developed a process in order to review each CSF and critical barrier of Software Process Improvement							√				
P4. Responsibilities have been assigned to conduct continuous SPI implementation reviews within organization								√			
P5. All the key stakeholders are involved in SPI implementation reviews										√	

Score= 36/5 =7.2

Awareness	0	1	2	3	4	5	6	7	8	9	10
P1. The benefits of SPI have been promoted among the staff members of the organization before Software Process Improvement Implementation									√		
P2. Higher management is aware of investment required and long term benefits of Software Process Improvement before Software Process Improvement Implementation											√
P3. Staff members are aware of their roles and responsibilities during the implementation of SPI within their unit of work						√					
P4. Planning has been done to organize and continue SPI awareness events within the organization							√				
P5. A mechanism has been established to make the SPI as part of the organization's culture									√		

Score= 37/5= 7.4

Defined SPI implementation methodology	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation methodology has been developed using current trends									√		
P2. SPI implementation methodology has been tried and tested in pilot projects						√					
P3. Staff members have been satisfied with the performance of methodology in the pilot projects						√					
P4. Training has been provided for developing the skills and knowledge needed to successfully use a methodology									√		
P5. Work has been done to continuously improve a methodology with the aim of using it in whole organization										√	

Score= 35/5= 7

Lack of support	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and support for SPI										√	
P 2. Management is committed to provide all the required resources						√					
P 3. Work has been done to facilitate staff members during SPI implementation						√					
P4. Staff members are aware of the benefits of SPI implementation										√	
P5. A mechanism has been established to monitor the progress of each staff member								√			

Score= 35/5= 7

Organizational politics	0	1	2	3	4	5	6	7	8	9	10
P1. Management and staff members provide strong support for SPI										√	
P2. A mechanism has been established to make SPI as part of the organization's culture									√		
P3. The benefits of SPI have been promoted among the management and staff members of the organization								√			
P4. All the key stakeholders are involved in SPI implementation initiatives									√		
P5. Conflict resolution plan has been established				√							

Score= 35/5= 7

Time pressure	0	1	2	3	4	5	6	7	8	9	10
P1. Staff members have been allocated time for SPI efforts and staff members are happy with allocated time				√							
P2. Work has been done to avoid staff from time pressure			√								
P3. Work has been done that SPI will not get in the way of real work		√									
P4.The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.								√			
P5 Work has been done to facilitate staff members during SPI implementation						√					

Score= 18/5= 3.6

Appendix L: Assessment done at Company B

Management support/commitment	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and commitment for SPI								√			
P2. Management establishes SPI practices as an integral part of the software development process									√		
P 3. Management at all levels of the organization supports the SPI initiative.								√			
P 4. Management is willing to participate in assessment meetings and improvement workshops.								√			
P 5. Management is committed to provide training and resources for SPI implementation								√			

Score = 36/5=7.2

Staff involvement	0	1	2	3	4	5	6	7	8	9	10
P 1. The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.						√					
P 2. Work has been done to facilitate staff members during SPI implementation							√				
P 3. Work has been done to allocate the time necessary to make staff participation successful.								√			
P 4. Local process teams and forums for the exchange of ideas have been established							√				
P 5. Conflict resolution plan has been established						√					

Score = 29/5= 5.8

Training and Mentoring	0	1	2	3	4	5	6	7	8	9	10
P 1. Training is provided for developing the skills and knowledge needed to perform SPI implementation								√			
P 2. Sufficient resources and additional time to participate in SPI training will be provided to staff members.							√				
P 3. Training programme activities are reviewed on a periodic basis							√				
P 4. Organization has developed a written training policy for SPI to meet its training needs								√			
P 5. All future group or individual trainings of SPI are planned							√				

Score = 32/5= 6.4

Staff time and resources dedicated to SPI	0	1	2	3	4	5	6	7	8	9	10
P1. Preparation has been done to provide all the required resources (funds, tools, people) for SPI implementation						√					
P2. Staff members have been allocated time for SPI efforts						√					
P3. Staff members are happy with allocated time					√						
P4. Work has been done to avoid staff from time pressure					√						
P5. Work has been done that SPI will not get in the way of day to day work					√						

Score= 22/5 = 4.4

Creating process action teams	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation action groups have been established with experienced people								√			
P2. Responsibilities have been assigned to provide technical support to the process action teams							√				
P3. A mechanism has been established to monitor the progress of each process action team								√			
P4. A mechanism has been established to collect and analyze the feedback data from each process action team and to extract the main lessons learned								√			
P5. A process has been established to distribute the lessons learned to the relevant staff members								√			

Score= 34/5 = 6.8

Experienced staff	0	1	2	3	4	5	6	7	8	9	10
P1. People have been selected for SPI activities who have track record of different successful projects								√			
P2. Conflict resolution plan has been established							√				
P3. Responsibilities have been assigned to each staff member about SPI implementation activities								√			
P4. A mechanism has been established to monitor the progress of each staff member								√			
P5. A mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned						√					

Score = 32/5= 6.4

Reviews	0	1	2	3	4	5	6	7	8	9	10
P1. Organization has developed a review process for SPI implementation requirements									√		
P2. Work has been done to continuously monitor existing SPI implementation methodology/process with emerging and new trends								√			
P3. Organization has developed a process in order to review each CSF and critical barrier of Software Process Improvement							√				
P4. Responsibilities have been assigned to conduct continuous SPI implementation reviews within organization								√			
P5. All the key stakeholders are involved in SPI implementation reviews							√				

Score = 34/5= 6.8

Awareness	0	1	2	3	4	5	6	7	8	9	10
P1. The benefits of SPI have been promoted among the staff members of the organization before Software Process Improvement Implementation							√				
P2. Higher management is aware of investment required and long term benefits of Software Process Improvement before Software Process Improvement Implementation									√		
P3. Staff members are aware of their roles and responsibilities during the implementation of SPI within their unit of work						√					
P4. Planning has been done to organize and continue SPI awareness events within the organization								√			
P5. A mechanism has been established to make the SPI as part of the organization's culture									√		

Score = 34/5= 6.8

Defined SPI implementation methodology	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation methodology has been developed using current trends									√		
P2. SPI implementation methodology has been tried and tested in pilot projects									√		
P3. Staff members have been satisfied with the performance of methodology in the pilot projects							√				
P4. Training has been provided for developing the skills and knowledge needed to successfully use a methodology							√				
P5. Work has been done to continuously improve a methodology with the aim of using it in whole organization								√			

Score = 35/5= 7

Lack of support	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and support for SPI								√			
P 2. Management is committed to provide all the required resources							√				
P 3. Work has been done to facilitate staff members during SPI implementation							√				
P4. Staff members are aware of the benefits of SPI implementation							√				
P5. A mechanism has been established to monitor the progress of each staff member						√					

Score = 30/5= 6

Organizational politics	0	1	2	3	4	5	6	7	8	9	10
P1. Management and staff members provide strong support for SPI									√		
P2. A mechanism has been established to make SPI as part of the organization's culture							√				
P3. The benefits of SPI have been promoted among the management and staff members of the organization									√		
P4. All the key stakeholders are involved in SPI implementation initiatives									√		
P5. Conflict resolution plan has been established							√				

Score = 36/5= 7.2

Time pressure	0	1	2	3	4	5	6	7	8	9	10
P1. Staff members have been allocated time for SPI efforts and staff members are happy with allocated time					√						
P2. Work has been done to avoid staff from time pressure						√					
P3. Work has been done that SPI will not get in the way of real work						√					
P4.The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.							√				
P5 Work has been done to facilitate staff members during SPI implementation						√					

Score = 25/5= 5

Appendix M: Assessment done at Company C

Management support/commitment	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and commitment for SPI							√				
P2. Management establishes SPI practices as an integral part of the software development process								√			
P 3. Management at all levels of the organization supports the SPI initiative.							√				
P 4. Management is willing to participate in assessment meetings and improvement workshops.							√				
P 5. Management is committed to provide training and resources for SPI implementation						√					

Score = 30/5= 6

Staff involvement	0	1	2	3	4	5	6	7	8	9	10
P 1. The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.								√			
P 2. Work has been done to facilitate staff members during SPI implementation								√			
P 3. Work has been done to allocate the time necessary to make staff participation successful.							√				
P 4. Local process teams and forums for the exchange of ideas have been established							√				
P 5. Conflict resolution plan has been established							√				

Score 35/5=7

Training and Mentoring	0	1	2	3	4	5	6	7	8	9	10
P 1. Training is provided for developing the skills and knowledge needed to perform SPI implementation						√					
P 2. Sufficient resources and additional time to participate in SPI training will be provided to staff members.						√					
P 3. Training programme activities are reviewed on a periodic basis					√						
P 4. Organization has developed a written training policy for SPI to meet its training needs						√					
P 5. All future group or individual trainings of SPI are planned				√							

Score= 22/5 = 4.4

Staff time and resources dedicated to SPI	0	1	2	3	4	5	6	7	8	9	10
P1. Preparation has been done to provide all the required resources (funds, tools, people) for SPI implementation									√		
P2. Staff members have been allocated time for SPI efforts									√		
P3. Staff members are happy with allocated time							√				
P4. Work has been done to avoid staff from time pressure					√						
P5. Work has been done that SPI will not get in the way of day to day work					√						

Score 30/5= 6

Creating process action teams	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation action groups have been established with experienced people									√		
P2. Responsibilities have been assigned to provide technical support to the process action teams									√		
P3. A mechanism has been established to monitor the progress of each process action team									√		
P4. A mechanism has been established to collect and analyze the feedback data from each process action team and to extract the main lessons learned								√			
P5. A process has been established to distribute the lessons learned to the relevant staff members							√				

Score= 37/5= 7.4

Experienced staff	0	1	2	3	4	5	6	7	8	9	10
P1. People have been selected for SPI activities who have track record of different successful projects									√		
P2. Conflict resolution plan has been established						√					
P3. Responsibilities have been assigned to each staff member about SPI implementation activities								√			
P4. A mechanism has been established to monitor the progress of each staff member								√			
P5. A mechanism has been established to collect and analyze the feedback data from each staff member and to extract the main lessons learned						√					

Score= 32/5= 6.4

Reviews	0	1	2	3	4	5	6	7	8	9	10
P1. Organization has developed a review process for SPI implementation requirements									√		
P2. Work has been done to continuously monitor existing SPI implementation methodology/process with emerging and new trends								√			
P3. Organization has developed a process in order to review each CSF and critical barrier of Software Process Improvement							√				
P4. Responsibilities have been assigned to conduct continuous SPI implementation reviews within organization						√					
P5. All the key stakeholders are involved in SPI implementation reviews						√					

Score= 31/5=6.2

Awareness	0	1	2	3	4	5	6	7	8	9	10
P1. The benefits of SPI have been promoted among the staff members of the organization before Software Process Improvement Implementation							√				
P2. Higher management is aware of investment required and long term benefits of Software Process Improvement before Software Process Improvement Implementation								√			
P3. Staff members are aware of their roles and responsibilities during the implementation of SPI within their unit of work							√				
P4. Planning has been done to organize and continue SPI awareness events within the organization							√				
P5. A mechanism has been established to make the SPI as part of the organization's culture							√				

Score = 31/5= 6.2

Defined SPI implementation methodology	0	1	2	3	4	5	6	7	8	9	10
P1. SPI implementation methodology has been developed using current trends									√		
P2. SPI implementation methodology has been tried and tested in pilot projects									√		
P3. Staff members have been satisfied with the performance of methodology in the pilot projects							√				
P4. Training has been provided for developing the skills and knowledge needed to successfully use a methodology								√			
P5. Work has been done to continuously improve a methodology with the aim of using it in whole organization							√				

Score= 35/5= 7

Lack of support	0	1	2	3	4	5	6	7	8	9	10
P1. Management provides strong leadership and support for SPI								√			
P 2. Management is committed to provide all the required resources							√				
P 3. Work has been done to facilitate staff members during SPI implementation							√				
P4. Staff members are aware of the benefits of SPI implementation							√				
P5. A mechanism has been established to monitor the progress of each staff member						√					

Score= 30/5= 6

Organizational politics	0	1	2	3	4	5	6	7	8	9	10
P1. Management and staff members provide strong support for SPI							√				
P2. A mechanism has been established to make SPI as part of the organization's culture							√				
P3. The benefits of SPI have been promoted among the management and staff members of the organization								√			
P4. All the key stakeholders are involved in SPI implementation initiatives							√				
P5. Conflict resolution plan has been established						√					

Score= 30/5= 6

Time pressure	0	1	2	3	4	5	6	7	8	9	10
P1. Staff members have been allocated time for SPI efforts and staff members are happy with allocated time						√					
P2. Work has been done to avoid staff from time pressure					√						
P3. Work has been done that SPI will not get in the way of real work				√							
P4.The SPI implementation effort has been staffed by people who indicated interest and commitment in the effort.									√		
P5 Work has been done to facilitate staff members during SPI implementation						√					

Score= 25/5= 5

Appendix N: The list of publications

The following papers have been published from this research project

1. Mahmood Niazi, David Wilson and Didar Zowghi (2005), A Maturity Model for the Implementation of Software Process Improvement: An empirical study, Journal of Systems and Software (JSS), 74(2), pp. 155-172.

2. Mahmood Niazi, David Wilson and Didar Zowghi (2005), A Framework for Assisting the Design of Effective Software Process Improvement Implementation Strategies, Accepted for publication, Journal of Systems and Software (JSS).

3. Mahmood Niazi, What is Missing in Software Process Improvement, IMPROVE, Software Process Improvement Newsletter, SPIKE, Feb 2004.

4. Mahmood Niazi, David Wilson, Didar Zowghi and Bernard Wong (2004), A model for the implementation of software process improvement: An empirical study, 5th International Conference on Product Focused Software Process Improvement (Profes2004), Japan, April 5-8, 2004, pp1-16.

5. Mahmood Niazi, David Wilson and Didar Zowghi (2004), Critical Barriers for SPI Implementation: An empirical study, IASTED International Conference on Software Engineering (SE 2004), Austria, February 16-19, 2004, pp 389-395.

6. Mahmood Niazi, David Wilson and Didar Zowghi (2003), A framework for the guidance of designing effective implementation strategies for software process improvement, International Conference on Software Engineering and Knowledge Engineering (SEKE2003), pp 366-371.

7. Mahmood Niazi and David Wilson (2003), A Maturity Model for the Implementation of Software Process Improvement, International Conference on Software Engineering Research and Practice (SERP 2003), pp 650-655.

8. Mahmood Niazi, David Wilson and Didar Zowghi (2003), A model for the implementation of software process improvement: A pilot study, In the proceedings of third International Conference on Software Quality (QSIC2003), IEEE Computer Society, Dallas, Texas, USA, pp 196-203.

9. Mahmood Niazi, David Wilson and Didar Zowghi (2003), Critical success factors and critical barriers for Software Process Improvement: An Analysis of Literature, in the proceedings of Australasian Conference on Information Systems ACIS2003, Perth, Australia, November 26-28, 2003.