CRITICAL BARRIERS FOR SOFTWARE PROCESS IMPROVEMENT IMPLEMENTATION: AN EMPIRICAL STUDY

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Abstract

In this paper we present findings from our recent empirical study of software process improvement (SPI) implementation critical barriers (CBs) in twenty-six Australian software companies. The objective of this study is to summarise the issues that play a negative role in the implementation of SPI programmes and to identify the key barriers. Through our empirical study we identified 5 barriers (organizational politics, lack of support, lack of formal methodology, lack of awareness and lack of resources) that are generally considered critical in undermining the SPI implementation process. We also report on a literature survey that identified 6 barriers (lack of resources, inexperienced staff/lack of knowledge, time pressure, organizational politics, SPI gets in the way of real work and staff turnover). We compared our empirical study results with the literature and confirmed the barriers identified by literature and also identified two new CBs – lack of SPI awareness and lack of formal methodology – which were not identified in the literature. Finally, we analysed CBs identified by different groups of practitioners and found the level of agreement across all practitioners about CBs that undermine SPI implementation. Our results also provide advice to SPI managers and practitioner on what critical barriers to address when developing SPI implementation strategies.

Key Words: Software process improvement, Empirical study, Software Engineering, Critical Barriers

1. Introduction

Despite the importance of the software process improvement (SPI) implementation process, little empirical research has been carried out on developing ways in which to effectively implement SPI programmes [1]. SPI models such as the Capability Maturity Model (CMM) [2], most recently CMMI [3], and standards such as ISO's SPICE [4] focus on processes to produce quality software. Little attention has been paid to the effective implementation of these models and standards [1] which has resulted in limited success for many SPI efforts. This suggests that the current problem with SPI is not a lack of a standard or model, but rather a lack of an effective strategy to successfully implement these standards or models

In this paper we present empirical findings of what undermines the implementation of SPI initiatives. Our study uses data from interviews of 31 Australian practitioners in 26 Australian companies. This paper provides insight to SPI managers by identifying issues that can undermine the SPI implementation initiatives.

The objective of this paper is to provide practitioners with advice about the CBs that they should address when developing SPI implementation strategies. Our ultimate aim of conducting this empirical study of CBs is to develop a SPI implementation framework in order to guide practitioners in designing effective SPI implementation strategies.

We have analysed the experiences, opinions and views of practitioners through the literature (i.e. case studies, technical reports and journal's articles) [5]. We have also conducted an empirical study of factors that have a negative impact on the implementation of a SPI program. Our results provide practical and timely advice to SPI managers in designing appropriate SPI implementation strategies.

This paper is organised as follows. Section 2 describes the background. Section 3 describes the research design. In Section 4 findings are presented and analysed with some discussion. Section 5 provides the conclusion and future work.

2. Background

McDermid and Bennet [6] have argued that the human factors to SPI have been ignored and this has impacted on effectiveness of SPI programmes. Hall and Wilson [7; 8] have also suggested that the experiences, opinions and perceptions of software practitioners impact indirectly on the quality of software produced. This also implies that such attributes influence the attitudes of software practitioners towards SPI implementation approaches. These views, experiences and perceptions collectively will provide practitioners with sufficient knowledge about the nature of issues that play a positive or negative role in the implementation of SPI programmes and will assist them in effectively planning SPI implementation strategies.

A number of empirical studies have investigated factors that positively or negatively impact SPI, e.g. [1; 9-12]. To highlight few of these: in the survey of 138 individuals in 56 software organizations, Goldenson and Herbsleb [1],

identified the factors necessary for implementing a successful SPI programme. Stelzer and Werner [9] determined ten factors that affect organizational change in SPI. Rainer and Hall [11] have conducted a questionnaire survey of UK companies and identified the key success factors that can impact on SPI implementation.

The work we report in this paper complements work previously done in above studies. So far we have not identified any empirical study that has been conducted with Australian practitioners in order to investigate what factors play a negative role in the implementation of SPI programmes. Much of the existing literature provides anecdotal evidence of CBs and little empirical work appears to have been conducted in this area. In order to provide more certainty it is important to conduct empirical research that explores these CBs - because empirical research is based on observation and experiences, it reflects the world more fully than other research approaches [13].

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. So this motivated the use of interviews in this study.

In our previous study [5], in order to explore the CBs for SPI implementation, we have analysed the SPI literature. We have identified 6 key barriers (lack of resources, time pressure, inexperienced staff/lack of knowledge, organizational politics, staff turnover and SPI gets in the way of real work) that can undermine the implementing of SPI. In this paper, we have conducted an empirical study to confirm these barriers and to explore other possible barriers that are critical among Australian practitioners.

There are three research questions that have motivated the work reported in this paper:

RQ1. What factors, as identified in the empirical study, have a negative impact on implementing SPI?

RQ2. Are there differences between the barriers identified through literature and an empirical study?

RQ3. Do different groups of practitioners believe that the same CBs impact the implementation of SPI?

3. Study Design

3.1 Sample Profile

From November 2002 to August 2003 we visited 26 software companies and conducted 31 interviews. The sample profile is shown in Appendix A. All of the 26 companies responded to a request for participants which was posted via the email. The target population in this research was those software-producing companies that have initiated SPI programmes. Although we do not claim this is a statistically representative sample, Table 1 does show that companies in the study range from a very small software house to very large multinational companies and cover a wide range of application areas. It is further important to acknowledge that the data was collected from companies who were tackling real issues on a daily basis; therefore we have high confidence in the accuracy and validity of data [14; 15].

Thirty-one practitioners voluntarily participated in this study. By volunteering to participate they have become a self-selecting sample. Self-sampling as opposed to random sampling though more practical is often prone to bias [16]. 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 [17]. 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 [14; 15].

Sample size is another source of bias. Generally, the larger the sample the less likely the sampling bias [17]. There are 26 participating companies in our 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 size of the Australian software companies. This is because many smaller companies have closed down their business due to recession. The other reason is that some companies are dedicated to software development only, whereas other companies have dedicated software development departments. Again this research suggests that the variety in company type, size, nature of business, age, type of applications etc can limit sample bias [14; 15].

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 [17]. In this research, in order to make the sample fairly representative of SPI practitioners in particular organization, one to three practitioners from each organisation self-selected to participate. The sample of practitioners researched includes developers, business analysts, methodology analyst, technical directors, project managers and senior management.

3.2 Data collection method

Interviews were conducted with three groups of practitioners:

- The first group was made up of designers/ testers/ programmer/ analyst. Referred to as "developers".

- The second group was made up of team leaders/ project managers. 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 negotiated interview duration was half an hour, however, the researcher and interviewee would determine the pace of the interview. Before the interview the researcher arranged the time and place with which the interviewees were comfortable. Most of the interviews took place in the interviewee's offices.

The researcher planned the interviews as to meet the University of Technology Sydney 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 consent to record their interviews.

3.3 Data analysis method

This research seeks to identify perceptions and experiences of practitioners about factors that play a negative role in the implementation of SPI programmes. In order to identify categories or common themes of barriers, the following process has been adopted in this research [15; 18]:

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

- Generate categories: All the interview transcripts were read again to generate categories for responses. Different themes were grouped together under one category. For example, poor response, user unwilling to be involved etc were grouped together under CB's category "lack of support". Each category represents a CB for the implementation of SPI programme.

According to Seaman [19] coding in empirical research is one method of extracting quantitative data from qualitative data in order to perform some statistical analysis. In our investigation data from the interviews was categorised and coded in order to perform frequency analysis and also to perform some comparative analysis of SPI implementation CBs within and between staff groups. We measured the occurrence of key barriers in each interview transcript. By comparing the occurrences of a key barrier in a number of interview transcripts we calculated the relative importance of each barrier. For example, if a barrier is mentioned in 10 out of 20 interviews transcripts, it has an importance of 50% for comparison purposes. In this way we compared and ranked each barrier. Finally, conclusions are drawn regarding the barriers that are critical in the empirical study.

4. Findings

In this section we discuss the results relating to RQ1, RQ2 and RQ3. This section shows the CBs 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 CB.

4.1 Critical Barriers identified through literature and an empirical study

Table 1 shows the list of CBs cited in the literature [5]. It shows that most of the practitioners consider lack of resources a major critical barrier for the implementation of SPI. The results also suggest that in practitioners' opinion time pressure and inexperienced staff can undermine the success of SPI implementation programs. It shows that practitioners do not want organizational politics and staff turnover during the implementation of SPI programs.

In order to answer RQ1, Table 1 shows the list of CBs cited in the interviews. Organizational politics is ranked highest in the interviews, i.e. 45%. Two new critical barriers – lack of formal methodology and lack of awareness – have been identified in our empirical study which have not been identified in the literature. The second most cited critical barrier in the interviews is lack of support. The critical barrier 'lack of resources' is cited 36% in the interviews.

4.2 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 1 and Figure 1). Our results show that two data sets have cited 8 barriers, i.e. inexperienced staff, lack of resources, lack of support, negative or bad experiences, organizational politics, paperwork required, SPI gets in the way of real work and time pressure. These findings suggest that organizations should focus on these barriers in order to successfully implement SPI programmes because we have more confidence that a barrier does indeed have an impact on SPI implementation if it is cited in both data sets.

There are also a number of significant differences between the findings (i.e. p value in Table 1 is highlighted for significant differences). For example, 'changing the mindset of management and technical staff' and 'staff turnover' have not been cited in our empirical study but these barriers are present in the literature. Similarly, lack of awareness of SPI and lack of formal methodology are critical in our empirical study but have not been identified through the literature. This shows that Australian practitioners are more concerned about SPI awareness activities and implementation methodology. This is because:

Table 1. Critical Barriers identified through literature and an empirical study

Barriers	Occurrence in literature (n=14)			Occurrence in interviews (n=31)			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**	4.635	1	**0.031**
Inertia	1	7	6	0	0	0	2.256	1	0.132
Inexperienced staff/lack of knowledge	5	36	2	7	23	4	0.851	1	0.356
Lack of awareness	**0**	**0**	**0**	**11**	**36**	**3**	6.575	1	**0.010**
Lack of communication	0	0	0	2	7	7	0.945	1	0.331
Lack of formal methodology	**0**	**0**	**0**	**12**	**39**	**2**	7.390	1	**0.007**
Lack of project management	0	0	0	3	10	6	1.452	1	0.228
Lack of resources	7	50	1	11	36	3	0.847	1	0.357
Lack of sponsorship	0	0	0	6	19	5	3.127	1	0.077
Lack of support	3	21	4	14	45	1	2.311	1	0.128
Lack of tools	0	0	0	1	3	8	0.462	1	0.497
Lack of training	0	0	0	3	10	6	1.452	1	0.228
Negative/Bad experience	1	7	6	2	7	7	0.007	1	0.931
Organizational politics	4	29	3	14	45	1	1.106	1	0.293
Paperwork required/formal procedures	1	7	6	7	23	4	1.572	1	0.210
SPI gets in the way of real work	**4**	**29**	3	**2**	**7**	7	4.084	1	**0.043**
Staff turnover	**4**	**29**	3	**0**	**0**	0	9.721	1	**0.002**
Time pressure	5	36	2	6	19	5	1.398	1	0.237

- SPI is an expensive and long-term approach and it takes a long time to realise the real benefits of this approach. Hence, in order to get the support of management and practitioners and to successfully continue SPI initiatives it is very important to provide sufficient awareness of SPI in organizations.

- Formal methodology has also emerged because little attention has been paid to the effective implementation of SPI initiatives [1] and studies show that 67% of SPI managers want guidance on how to implement SPI activities, rather than what SPI activities to actually implement [20]. This new barrier suggests that in practitioners' opinion the lack of a formal SPI implementation methodology can undermine the implementation of SPI programmes.

In order to answer RQ2, this is very clear from Figure 1 that 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.

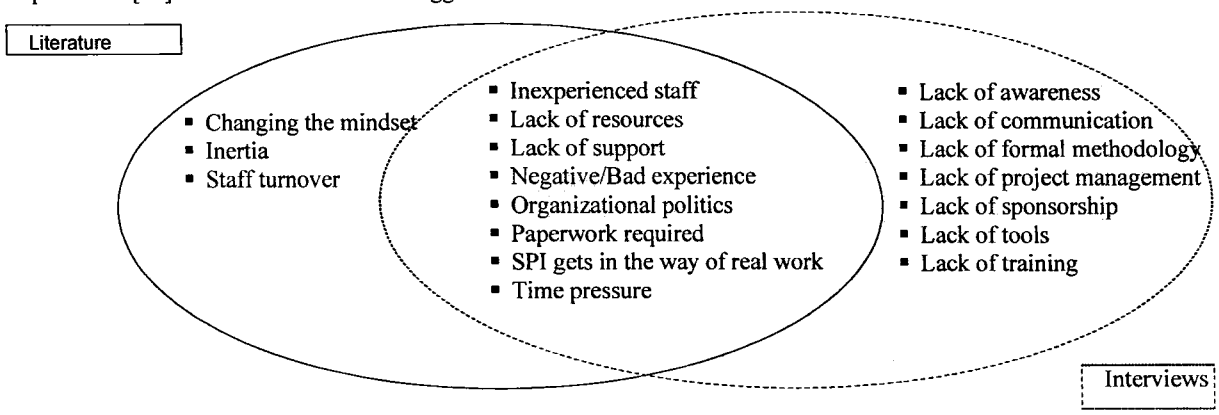

Figure. 1. A summary of CBs stated by literature and interviews. The barriers are listed as a bullet point. The area in which both categories overlap represents common barriers.

4.3. Critical Barriers identified by different groups of practitioners

We suggest that understanding the similarities in CBs across different group of practitioners can help 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 very seriously. This is because we have a barrier that is replicated across three groups of practitioners.

Table 2 and appendix B shows the spread of CBs cited by all three-practitioner groups.

Our 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 formal 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 very seriously. Our 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 experiences which realised them the importance of these three barriers. Developers and senior managers consider lack of support as a critical barrier.

Table 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.

In order to answer RQ3, this is very clear from Table 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 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.

5. Conclusion and future work

We report on our empirical study and literature survey of CBs that impact SPI implementation. We identified barriers that can undermine the SPI implementation effort. We suggest that organizations should address these CBs when developing SPI implementation strategies. Our findings show that there are both similarities and differences between the CBs identified through the literature and an empirical study. Our results also show that different group of practitioners are aware of what undermines the implementation of SPI programmes.

Through our empirical study we have identified 5 barriers that are generally considered critical for successfully implementing SPI. We have also identified 6 barriers from SPI literature. We compared our empirical study results with the literature and confirmed the barriers identified by literature and also identified two new CBs – "Lack of SPI awareness" and "Lack of formal methodology" – which were not identified in the literature. Our results suggest that organizations should address these common CBs in order to successfully implement SPI programmes because we have more confidence that a barrier does indeed have an impact on SPI implementation if it is critical in both data sets.

Table 2 Critical Barriers across practitioner groups

Barriers	**Developers n=10**	**Managers n=17**	**Senior Managers n=4**	**Chi-square Test $\alpha = 0.05$**		
	%	%	%	X^2	*df*	*p*
Inexperienced staff/lack of knowledge	30	12	50	3.173	2	0.205
Lack of awareness	40	35	25	0.281	2	0.869
Lack of communication	10	6	0	0.494	2	0.781
Lack of formal methodology	30	41	50	0.578	2	0.749
Lack of project management	10	12	0	0.514	2	0.773
Lack of resources	50	35	0	3.121	2	0.210
Lack of sponsorship	20	24	0	1.152	2	0.562
Lack of support	**80**	**18**	**75**	11.535	**2**	**0.003**
Lack of tools	10	0	0	2.170	2	0.338
Lack of training	10	6	25	1.356	2	0.508
Negative/Bad experience	0	12	0	1.761	2	0.415
Organizational politics	30	47	75	2.391	2	0.303
Paperwork required/formal procedures	20	18	50	1.995	2	0.369
SPI gets in the way of real work	10	6	0	0.494	2	0.781
Time pressure	20	24	0	1.152	2	0.562

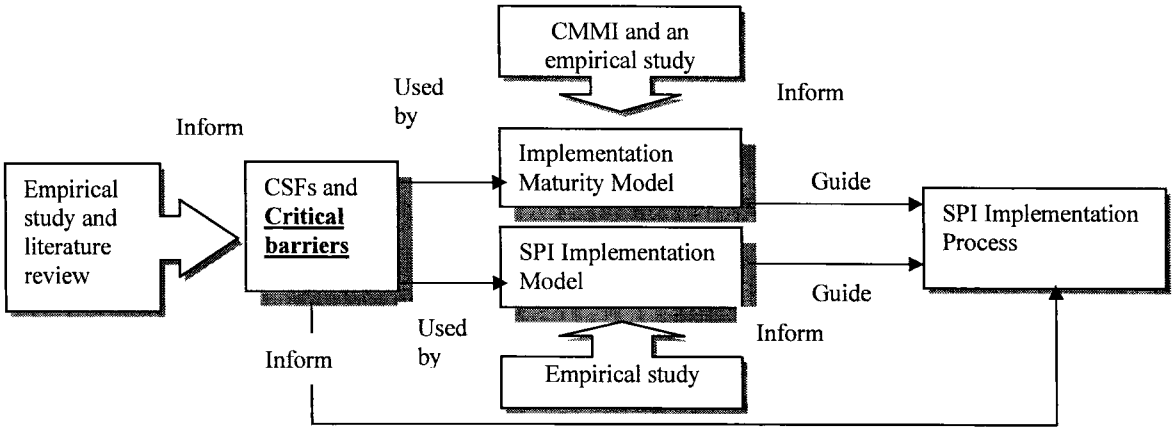

Figure 2. SPI implementation framework

Our results also suggest that organizations should focus on two new CBs in order to effectively implement SPI programmes because different practitioners who were tackling real issues on a daily basis frequently cited these barriers.

Our aim of identifying CBs is to understand the nature of issues that play a negative role in the implementation of SPI programmes. These findings will drive the development of a SPI implementation framework (see Figure 2) [21]. This paper only contributes to the one component of the framework, i.e. the identification of CBs. The eventual research outcome will be a framework for guiding the design of effective implementation strategies for SPI. As shown in Figure 2, the framework comprises an Implementation Maturity Model [22; 23] and an SPI Implementation Model [24]. The CBs reported here provide the input to the framework shown in Figure 2. The framework is in an initial stage and will be further developed on the basis of interviews with industry practitioners to confirm and extend the findings of the literature survey. The framework will then be evaluated using multiple case studies.

6. References

[1] Goldenson, D. R. and Herbsleb, J. D. 1995. *After the appraisal: A systematic survey of Process Improvement, Its benefits, And Factors That Influence Success.* SEI, CMU/SEI-95-TR-009

[2] Paulk, M., Curtis, B., Chrissis, M. and Weber, C. 1993. *Capability Maturity Model for software, Version 1.1.* CMU/SEI-93-TR-24, Software Engineering Institute USA

[3] SEI. 2002. *Capability Maturity Model® Integration (CMMISM), Version 1.1.* SEI, CMU/SEI-2002-TR-029

[4] ISO/IEC-15504. 1998. *Information technology - Software process assessment.* Technical report - Type 2

[5] Niazi, M., Wilson, D. and Zowghi, D. 2003. Critical success factors and critical barriers for software process improvement: An analysis of literature, To appear in the proceedings of. *Australasian Conference on Information Systems (ACIS03).*

[6] McDermid, J. and Bennet, K. 1999. Software Engineering research: A critical appraisal, *IEE Proceedings on software engineering* 146 (4). 179-186.

[7] Hall, T. and Wilson, D. 1997. Views of software quality: a field report, *IEEE Proceedings on Software Engineering* 144 (2).

[8] Hall, T. and Wilson, D. 1998. Perceptions of software quality: a pilot study, *Software quality journal* (7). 67-75.

[9] Stelzer, D. and Werner, M. 1999. Success factors of organizational change in software process improvement, *Software process improvement and practice* 4 (4).

[10] El-Emam, K., Fusaro, P. and Smith, B. 1999. Success factors and barriers for software process improvement. Better software practice for business benefit: Principles and experience, *IEEE Computer Society*

[11] Rainer, A. and Hall, T. 2002. Key success factors for implementing software process improvement: a maturity-based analysis, *Journal of Systems & Software* (62). 71-84.

[12] Rainer, A. and Hall, T. 2002. A quantitative and qualitative analysis of factors affecting software processes, *Journal of Systems & Software, Accepted awaiting publication*

[13] Harrison, R., Baddoo, N., Barry, E., Biffl, S., Parra, A., Winter, B. and Wuest, J. 1999. Directions and Methodologies for Empirical Software Engineering, *Empirical Software Engineering* 4 (4). 405-410.

[14] Baddoo, N. and Hall, T. 2002. Motivators of software process improvement: An analysis of practitioner's views, *Journal of Systems and Software* (62). 85-96.

[15] Baddoo, N. 2001. Motivators and De-Motivators in software process improvement: an empirical study, PhD, *University of Hertfordshire UK.*

[16] Krippendorf, K. 1980. *Content Analysis: An introduction to its Methodologies.* sage London.

[17] Coolican, H. 1999. *Research Methods and Statistics in Psychology.* Hodder and Stoughton, London.

[18] Burnard, P. 1991. A method of analysing interview transcripts in qualitative research, *Nurse education today* (11). 461-466.

[19] Seaman, C. 1999. Qualitative methods in empirical studies of software engineering, *IEEE Transactions on Software Engineering* 25 (4). 557-572.

[20] Herbsleb, J. D. and Goldenson, D. R. 1996. A systematic survey of CMM experience and results. *18th international conference on software engineering (ICSE-18).* Germany.

[21] Niazi, M., Wilson, D. and Zowghi, D. 2003. A framework for guiding the design of effective implementation strategies for software process improvement. *International Conference on Knowledge Engineering and Software Engineering (SEKE 03).* 366-371.

[22] Niazi, M. and Wilson, D. 2003. A Maturity Model for the Implementation of Software Process Improvement. *International*

Conference on Software Engineering Research and Practice (SERP03). 650-655.
[23] Niazi, M., Wilson, D. and Zowghi, D. 2003. A Maturity Model for the Implementation of Software Process Improvement: An empirical study: To Appear in, *Journal of Systems and Software*
[24] Niazi, M., Wilson, D. and Zowghi, D. 2003. A model for the implementation of software process improvement: A pilot study, To appear in the proceedings of. *International Conference on Software Quality (QSIC03).*

Appendix A: Participant Company Information

Company	Scope	Age (yrs)	Size	Software 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

Appendix B: CBs cited by group of practitioners