

# Key success factors for implementing software process improvement: a maturity-based analysis

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We report on a questionnaire survey of key success factors that impact software process improvement (SPI). We analysed responses to identify factors that have a major impact, or no impact, on implementing SPI. We found four factors (reviews, standards and procedures, training and mentoring, and experienced staff) that practitioners generally considered had a major impact on successfully implementing SPI, and a further four factors (internal leadership, inspections, executive support and internal process ownership) that the more mature companies considered had a major impact on successfully implementing SPI. We also identified two factors (estimating tools and reward schemes) that may not have an impact on SPI. We briefly discuss how these factors may be broadly understood in terms of process, people, skills and leadership. We discuss some of the implications of our findings for research and practice.

## 1 Introduction

A number of studies have investigated factors that positively and negatively impact software process improvement (SPI) e.g. (Brodman and Johnson, 1994; Johnson, 1994; Herbsleb and Goldenson, 1996; El Emam et al., 1998; Stelzer and Mellis, 1998; Wiegers, 1998; El Emam et al., 1999; Hammock, 1999; Dybå, 2000). Some of these studies recognise the requirement for further research on *implementing* SPI (e.g. (El Emam et al., 1999)), in particular the fact that practitioners want more guidance on *how*, not just what, to improve (Herbsleb and Goldenson, 1996; Pajerek, 2000). In this paper, we report the results of our questionnaire survey that examines practitioners' opinions on the factors that they believe impact SPI. We discuss some of the implications of our findings for research and practice.

The work we report in this paper complements work previously conducted by Goldenson and Herbsleb (Goldenson and Herbsleb, 1995), El Emam et al. (El Emam et al., 1999), and Stelzer and Mellis (Stelzer and Mellis, 1998). Little attention, in these three studies, is directed at the impact of factors at different levels of maturity. While Goldenson and Herbsleb investigate the relationship between maturity level and organisational performance, they do not investigate the relationships between particular factors, maturity levels and SPI success. (They focus on the relationship between a factor and SPI success, and ignore the maturity level.) Neither El Emam et al. or Stelzer and Mellis distinguish between maturity levels in their analyses. Given that we are investigating software process improvement, and given the fact that a dominant concept in SPI is the idea of maturity levels, our maturity-based analysis of success factors contributes insights in the following areas:

1. The identification of a greater diversity of success factors.
2. The identification of factors that relate to particular maturity levels.
3. The identification of an order in which factors could be used to help implement SPI.

In this paper we focus, in particular, on four research questions:

RQ1 What factors do respondents think have a major impact on implementing SPI?

RQ2 What factors do respondents think have no impact on implementing SPI?

RQ3 Do respondents from lower and higher maturity companies think that the same factors impact the implementation of SPI?

RQ4 Are there differences, in the factors recognised by respondents, between companies with successful and non-successful SPI programmes?

The work we report in this paper is part of our broader investigation of various aspects of practitioners' opinions on software process improvement (Rainer et al., 2001). For example, we have examined practitioners' attitudes to metrics and to inspections (Hall et al., 2000; Hall et al., 2001) and examined motivators and de-motivators (Baddoo and Hall, in press; Baddoo and Hall, in press). We are also developing a framework for the evaluation and prediction of software process improvement success (Wilson et al., in press).

The remainder of the paper is organised as follows. Section 2 reviews previous research and considers the importance of a maturity-based analysis. Section 3 describes the design of our study. Section 4 presents our investigation of the four research questions. Section 5 summarises the main factors identified, briefly compares the results with previous research, and summarises the main insights from the analysis. Section 6 offers conclusions. Finally, an appendix presents detailed data and results of statistical tests.

## 2 Background

As already noted, a number of studies have suggested factors necessary for implementing a successful software process improvement programme. We will focus on three such studies, each of which has investigated standards that are recognised internationally:

- Goldenson and Herbsleb's (Goldenson and Herbsleb, 1995) survey of CMM-appraised organisations in North America.
- El Emam et al.'s (El Emam et al., 1999) survey of companies involved in the first phase of the SPICE trials.
- Stelzer and Mellis' (Stelzer and Mellis, 1998) review of experience reports and case studies of software process improvement and quality systems initiatives.

Goldenson and Herbsleb (Goldenson and Herbsleb, 1995) (see also (Herbsleb and Goldenson, 1996; El Emam et al., 1998)) surveyed 138 respondents who were involved in 56 CMM appraisals. Each respondent was either a senior member of the technical staff, a project manager, or a member of a software engineering process group (SEPG). Having distinguished the more successful and less successful SPI efforts, Goldenson and Herbsleb then identified the factors that were associated with these two degrees of success. The factors associated with successful SPI programmes are presented in Table 1. Goldenson and Herbsleb also identified a number of factors associated with unsuccessful SPI programmes: organisational politics, turf guarding, discouragement and cynicism from previous unsuccessful improvement experience, belief that SPI gets in the way of real work, and the need for more guidance on how, not just what, to improve.

**Table 1 Factors affecting SPI, as identified by other researchers**

<b>Factor</b>	<b>Goldenson</b>	<b>El Emam</b>	<b>Stelzer</b>
Senior management commitment	Yes	Yes	Yes
Clear & relevant SPI goals	Yes	Yes	Yes
Clear, compensated assignment of responsibility for SPI	Yes	Yes	
Staff involvement	Yes	Yes	Yes
SPI people highly/well respected	Yes	Yes	
Staff time and resource.	Yes	Yes	
Creating process action teams		Yes	
Change agents and opinion leaders			Yes
Encouraging communication and collaboration			Yes
Managing the SPI project			Yes
Providing enhanced understanding			Yes
Stabilising changed processes			Yes
Tailoring improvement initiatives			Yes
Unfreezing the organisation			Yes

Notes:

An 'empty' cell indicates that the factor was not studied by the respective researchers

El Emam et al. (El Emam et al., 1999) surveyed responses from 14 companies involved in the SPICE trials. The questionnaire they used was derived, in part, from the questionnaire used by Goldenson and Herbsleb. El Emam et al. identified two 'measures' of success, and then investigated the relationships between a number of factors and these two 'measures'. Factors with statistically significant test results are summarised in Table 1. Given the similar designs of the two studies, the El Emam et al. study may be treated as a replication of Goldenson and Herbsleb.

Stelzer and Mellis (Stelzer and Mellis, 1998) conducted a review of experience reports and case studies of 56 software organisations that have either implemented an ISO 9000 quality system, or that have conducted a CMM-based process improvement initiative. From this review they identified 10 factors that affect organisational change in software process improvement efforts. These 10 factors are also summarised in Table 1.

There are some clear similarities between the findings of these three studies. In particular, all three sets of researchers recognise the contribution of senior management, the need for clear and relevant goals, and the involvement of staff in the improvement effort. Some of the factors identified by Stelzer and Mellis suggest ways in which other factors may be implemented. For example, encouraging communication and collaboration, and recruiting and promoting change agents and opinion leaders from the technical staff, may be ways to involve staff in SPI.

There are also a number of differences between the findings, mainly due to the fact that different studies have investigated different factors. These differences indicate that SPI researchers are still seeking to identify the key factors that affect SPI programmes. (Dybå (2000), for example, identified nearly 200 prescriptions for success, from an extensive review of quality management, organisational learning and software process improvement literature.) Our study is a contribution to this search.

As noted in the introduction, none of the three studies direct attention at the impact of factors at different levels of maturity.

### 3 Study design

#### 3.1 Factors

We identified 16 factors for further investigation. These factors were identified, in part, from a review of previous research (Humphrey, 1989; Humphrey et al., 1991; Paulk et al., 1994; Haley, 1996; Diaz and Sligo, 1997). See Table 5 for a full list of the factors. A small number of factors require further elaboration. The factor *risk assessment* refers to assessment of the risks to the SPI initiative, rather than assessments of the risks to software development projects. The factor *automation* refers to the automation of the software development process (e.g. (Humphrey, 1989)). We distinguished between

*reviews* and *inspections* because rigorous, Fagan-like inspections do not seem to be frequently implemented by companies. Instead companies appear to adopt reviews, possibly as ‘lightweight’ versions of inspections.

### 3.2 Data sets used in the analysis

We sent out approximately 1000 self-administered questionnaires. Approximately 200 were returned and, of those, 84 contained data appropriate for our analysis. The questionnaires were completed by the SPI manager, or equivalent, at each company. (See the appendix for detailed information on the responses. See (CeSPR, 2001) for further information on the companies involved in the study.)

**Table 2 Summary of data sets**

Data-set	n	CMM Maturity Level				
		1 f %	2 f %	3 f %	4 f %	5 f %
Appraised CMM maturity	11	4 36	2 18	4 36	1 9	0 0
Non-CMM appraisal	3					
Self-rated CMM maturity (excluding formally appraised)	36	8 22	21 58	5 14	2 6	0 0
No self-rate or appraisal	34					
<b>Total</b>	<b>84</b>					

We decided to partition our sample of companies according to their appraisal status (see the following sub-section for more information). Table 2 briefly describes the various data sets that can be organised from the 84 responses. Our sample consists of a mixture of UK and multi-national companies.

The large percentage (58%) of companies in our self-rated sample that self-rate themselves at CMM Level 2 may be due to optimism on the part of the respondents. Against that, most of the companies in our sample were ISO certified, so there is a basis for the companies to self-rate at CMM Level 2. (Assuming an ISO certification is equivalent to CMM Level 2.). The appendix to this paper provides information on company demographics.

### 3.3 Sample partitioning

As already noted, we decided to partition the 84 responses according to the appraisal status of the respective company. Each company was either formally appraised (using the CMM), provided a self-estimate of their maturity, or did not provide an estimate or formal appraisal.

#### 3.3.1 Formally appraised companies

Generally, respondents from companies with formal SPI programmes ought to have a more accurate understanding of SPI, compared to companies without a formal SPI programme. This is for at least two reasons. First, such companies have systematically focused on understanding and improving their processes, possibly through the conduct of formal appraisals. As a result, these companies ought to have a clearer understanding of the factors that affect their software development and their software process improvement. Second, companies with formal SPI programmes ought to have more effectively communicated the results of these assessments and programmes through, for example, process standards and the software process improvement programme itself.

We emphasise that we are not suggesting that companies with formal SPI programmes have a complete understanding or even a well-developed understanding of SPI. We only state that their understanding is likely to be more developed than companies without formal programmes. We also emphasise that we are not assuming that process models are complete. In this study, we have used the conduct of formal appraisals as our indicator of companies that have conducted a formal SPI programme.

### 3.3.2 Companies providing self-estimates

While the reliability of a self-rating is questionable, companies that self-rate themselves at a high level of maturity (such as CMM Levels 3 and 4) are likely to be more mature than companies that rate themselves at a low level of maturity (such as CMM Levels 1 and 2). While it would not be sensible to ‘collapse’ a sample of self-ratings with a sample of appraisals, it may be beneficial to compare the responses from two such samples. Such a comparison may act as a form of replication. In section 3.5.2, we direct more attention at the threats to validity caused by relying on self-ratings of maturity, and we explain how we have ‘protected’ our analysis against such threats.

### 3.3.3 Companies that do not provide an estimate

In principle, there should be no difference between a company that provides an estimate and a company that does not (except, of course, for the estimate). There is the problem, however, that without an estimate we do not have any indication of the maturity of the company. Therefore, we can analyse a third set of companies, and use such an analysis as another form of replication.

### 3.3.4 Analysing companies with different appraisal status

The comparison of companies that are formally appraised, companies that provide a self-estimate, and companies that do not provide an estimate, offers certain interesting opportunities for analysis. In particular:

- Where respondents from all three samples consider that a factor has, for example, a major impact on SPI then we may be more confident that this factor does, in general, have an impact on SPI. This is because we have, effectively, a finding that is replicated across three different kinds of sample.
- Where there are differences of opinion, between the three samples, then we may treat these differences as areas to target further research. This is because the responses suggest that practitioners require further information on these particular factors. For example, a particular factor may only have an affect within a particular environment.
- Different samples allow a more sensitive analysis of the factors, and this may reveal both a broader range of factors, and a possible sequence to the presence of these factors. For example, practitioners may think that inspections are useful once they have experienced the conduct and benefits of reviews.
- Factors that are identified by the more mature companies are not necessarily only applicable to mature companies. It may be that mature companies recognise these factors whereas less mature companies do not.

### 3.3.5 Analysing successful and non-successful companies

We may have more confidence that a factor does indeed have an impact on SPI if that factor is present for the successful companies and absent for the non-successful companies. Consequently, we also partitioned our data sets according to whether the companies had successful or non-successful SPI programmes. (We asked respondents to indicate the degree of success of their SPI programmes, and we collapsed their responses into ‘successful’ and ‘non-successful’ categories, removing responses of ‘don’t know’ and missing values.)

**Table 3 Successful and non-successful SPI programmes**

Data set	Successful SPI		Non-successful SPI		Unknown		Total	
	Count	%	Count	%	Count	%	Count	%
Appraised	6	55	3	27	2	18	11	14
Self-rated	20	56	9	25	7	19	36	44
Not-rated	23	68	4	12	7	21	34	42
<b>Total</b>	<b>49</b>	<b>60</b>	<b>16</b>	<b>20</b>	<b>16</b>	<b>20</b>	<b>81</b>	<b>100</b>

Table 3 indicates that 60% of the companies in our study had successful SPI programmes. Approximately 20% of the companies had unsuccessful or marginally successful programmes. For the remaining 20%, respondents either did not respond or responded that they were not able to assess the success of the programme (perhaps because the programme had started only recently). The companies with unknown success were not included in the success-based analysis that we conducted.

Due to the relatively small sample size, we were unable to analyse the impact of factors whilst controlling for both success and maturity-level.

### 3.4 Identifying important factors from the responses

For each of the 16 factors we investigated, we offered respondents the following options about the impact of that factor on SPI:

- Major impact
- Minor impact
- No impact
- Don't know

Because we are interested in identifying the key success factors, we sharpened our results by focusing on responses of major impact and no impact. We collapsed the responses of minor impact and don't know into an 'other' category. (Missing values were removed from the analysis.) El Emam et al. also collapsed their data to sharpen their analysis. We used the following criteria to identify important factors:

- 1 If the majority of respondents ( $\geq 50\%$ ) thought that the factor had a major impact then we treat that factor as having a major impact.
- 2 If the majority of respondents ( $\geq 50\%$ ) from a sample thought that the factor had no impact then we treat that factor as having no impact.

In reporting our results, however, we do indicate where *large minorities* of respondents thought that a factor had a major impact, or no impact. This is because these factors may be significant but our analysis is not sufficiently 'powerful' to identify these factors, or because our criteria may be too stringent.

### 3.5 Threats to the validity of the analysis

#### 3.5.1 The sample size

We have tried to address the problem of our relatively small sample size in three ways. First, through using the self-rated data (which we recognise presents its own potential threats, and which we discuss below). Second, through collapsing maturity levels (an approach also used by others, such as Goldenson and Herbsleb). Third, through the use of statistical methods that can 'tolerate' small sample sizes. El Emam et al. experienced the same problem in their investigation (they had a sample size of 14) and they used an approximate randomisation procedure. We have conducted chi-square tests using exact methods (SPSS, 1999).

#### 3.5.2 The reliability of self-ratings of maturity

We recognise that self-ratings may not be reliable indicators of maturity. But we also wanted to include the largest possible sample in our analyses. We have taken the following steps to 'protect' our analysis from threats to validity:

- We asked respondents to self-rate their respective companies against a well-known and established maturity model. Thus, the respondents have an independent framework against which to conduct their assessment. Also, we asked the respondents to self-rate against an explicit model, rather than simply asking respondents to indicate whether their organisation has low or high maturity.

- The fact that many respondents (n=34) did not provide an estimate suggests that respondents were not simply providing a self-estimate, but were evaluating their own ability to provide a self-estimate.
- We use the self-rated data set as one of three data sets, within a broader strategy of replication. Thus, our analysis is not solely, or even primarily, dependent on the self-rated data.
- In reporting our results, we explicitly and separately present the three data sets. Consequently, we provide the reader with the opportunity to judge the self-rated data independently of our other data sets.

### 3.5.3 The reliability of responses

In order to evaluate the reliability of the responses, we asked practitioners about the extent to which each of the factors was used in their organisation. Our assumption is that practitioners' opinions about the impact of a given factor will be more reliable where that factor has actually been used within the practitioners' company. For each factor, and for each of the three main data sets, we used chi-squares (with exact methods) to test the association between extent of use and degree of impact. (See the appendix for detailed information on the tests.)

The results of the tests indicate that, for most of the factors, the extent of use is associated with the degree of impact. For example, where a factor has a major extent of use (where the factor is used in a major way) it is also believed to have a major impact on SPI. These results indicate that practitioners are judging the impact of the factor based on the degree to which they have used the factor. Indeed, these results suggest that practitioners are using factors because they believe they work.

### 3.5.4 Factors with a negative impact

We have investigated those factors that respondents think have a positive impact, or no impact, on SPI success. We have not investigated those factors that respondents think have a negative impact on SPI success. Clearly, this is one direction in which this research can be extended.

### 3.5.5 Comparison of studies' findings

Our factors do not easily map to the factors identified by Goldensen and Herbsleb, El Emam et al., or Stelzer and Mellis. This introduces some problems in comparing the studies. At the same time it is clear, from the responses of the practitioners in our study, that many of the factors that we have investigated are recognised by practitioners as having a major impact (or no impact) on SPI. Thus, while our findings may not easily compare with the findings of others, our findings do suggest important issues that ought to be considered when implementing, or investigating, SPI.

## 4 Analysis

### 4.1 Factors impacting SPI

In this section, we discuss the results relating to the following two research questions

- RQ1 What factors do respondents think have a major impact on SPI?
- RQ2 What factors do respondents think have no impact on SPI?

**Table 4 Factors that either have a major impact, or no impact, on SPI success**

Factor	Appraised n=14	Samples Self-rated n=36	Not rated n=34
Reviews	Major	Major	Major
Standards and procedures	Major	Major	Major
Training and mentoring	Major	Major	Major
Experienced staff	Major	Major	Major
Internal process ownership	Major	<sup>a</sup>	Major
Internal leadership	<sup>a</sup>	Major	Major
Inspections <sup>c</sup>	Major		<sup>a</sup>
Metrics <sup>c</sup>	Major		
Automation	Major	<sup>b</sup>	
Stringent control <sup>d</sup>			Major
Executive support	<sup>a</sup>	<sup>a</sup>	<sup>a</sup>
Project post mortems <sup>d</sup>			<sup>a</sup>
External consultants		<sup>b</sup>	<sup>b</sup>
Estimating tools <sup>c</sup>		No	<sup>b</sup>
Reward schemes		No	No

Notes:

‘Major’ indicates that the factor is believed, by the majority of respondents, to have a major impact on SPI success.

‘No’ indicates that the factor is believed, by the majority of respondents, to have a no impact on SPI success.

An empty cell indicates that there is no majority who believe that the factor has a major impact, or no impact, on SPI success.

<sup>a</sup> There are large minorities (i.e.  $50\% > r \geq 40\%$ ) who think that this factor has a major impact on SPI success.

<sup>b</sup> There are large minorities (i.e.  $50\% > r \geq 40\%$ ) who think that this factor has *no impact* on SPI success.

<sup>c</sup> There is a statistically significant difference ( $p < 0.1$ ) between the appraised and self-rated companies for this factor (see the appendix for more information).

<sup>d</sup> There is a statistically significant difference ( $p < 0.1$ ) between the self-rated and no rated companies for this factor (see the appendix for more information).

#### 4.1.1 Factors with a major impact, or no impact

Table 4 summarises the results of our analysis of the first two research questions. Four of the 16 factors investigated are considered to have a major impact on SPI success. These factors are: reviews, standards and procedures, training and mentoring, and experienced staff.

Across all three samples, there are only large *minorities* who think that executive support has a major impact on SPI success. This is surprising when one considers the widely held opinion of researchers that executive support has a major impact on SPI success. It may be that our criteria for identifying factors are too stringent.

For two factors (estimating tools and rewards schemes), there are majorities of opinion that these factors do *not* have an impact on SPI success.

#### 4.1.2 Differences between the samples

For three factors (inspections, metrics and estimating tools), there are statistically significant differences between the responses from appraised and self-rated companies. For inspections and metrics, this may be explained by the increased rigour required of practitioners in the appraised companies. Indeed, companies that are appraised ought to be more *aware* of the issues of inspections and metrics. The third factor, estimating tools, is more difficult to explain. It may be that the appraised companies treat their SPI efforts more formally, and *as projects* (cf. (Rothman, 2000); Bach (Bach, 1998) offers a contrasting position, arguing that process improvement should *not* be treated as a project distinct from the software development projects they are intended to improve). Consequently, they employ project-management tools and techniques, such as estimation, to help manage those projects.



For two factors (project post mortems and stringent control), there are statistically significant differences between the responses from self-rated and no-rated companies. For project post mortems, more respondents (43%) from the no rated companies think that this has a major impact. For stringent control, again more respondents (52%) from the no-rated companies think that this has a major impact. We are unsure how to interpret the responses for project post mortems. The responses for stringent control may reflect a misconception of the real purpose of process standards.

## 4.2 Factors relating to maturity

In this section, we discuss the results relating to our third research question:

RQ3 Do respondents from lower and higher maturity companies think that the same factors impact SPI?

This section provides a finer-grained analysis of responses from two samples: the appraised companies and the self-rated companies. Due to the small sample sizes, we have collapsed companies with CMM Levels 1 and 2 into a ‘low maturity’ sample, and collapsed companies with CMM Levels 3 or 4 into a ‘high maturity’ sample. (We have no data for any Level 5 company.)

**Table 5 Factors that either have a major impact, or no impact, on SPI success**

Factor	Appraised		Self rated	
	Low maturity n=6	High maturity n=5	Low maturity n=29	High maturity n=7
Reviews	Major	Major	Major	Major
Training and mentoring	Major	Major	Major	Major
Standards and procedures		Major	Major	Major
Internal leadership		Major	Major	Major
Experienced staff <sup>c</sup>		Major	Major	Major
Inspections <sup>d</sup>		Major		Major
Executive support <sup>d</sup>		Major		Major
Internal process ownership <sup>c d</sup>		Major		Major
Metrics		Major		<sup>a</sup>
Risk assessment		Major		<sup>a</sup>
Automation	<sup>a</sup>	Major	<sup>b</sup>	<sup>a</sup>
Project post mortems		Major		
Estimating tools		Major	No	<sup>b</sup>
Reward schemes	<sup>b</sup>		No	No
External consultants <sup>d</sup>			<sup>b</sup>	
Stringent control				<sup>b</sup>

Notes:

‘Major’ indicates that the factor is believed, by the majority of respondents, to have a major impact on SPI success.

‘No’ indicates that the factor is believed, by the majority of respondents, to have a no impact on SPI success.

An empty cell indicates that that there is no majority who believe that the factor has a major impact, or no impact, on SPI success.

<sup>a</sup> There are a large minority (i.e.  $50\% > r \geq 40\%$ ) who think that this factor has a major impact on SPI success

<sup>b</sup> There are a large minority (i.e.  $50\% > r \geq 40\%$ ) of respondents who think that this factor has *no impact* on SPI success.

<sup>c</sup> There is a statistically significant difference ( $p \leq 0.1$ ) between the appraised low maturity and appraised high maturity companies for this factor.

<sup>d</sup> There is a statistically significant difference ( $p \leq 0.1$ ) between the self-rated low maturity and self-rated high maturity companies for this factor.

Of the 16 specific factors that we investigated, there are majorities of opinion, across all the four sub-samples, for 14 of these factors. The remaining two factors have large minorities of opinion. All 16 factors are presented in Table 5.

### 4.2.1 Factors with a major impact, or no impact

Two factors are recognised by all four samples as having a major impact on SPI success: reviews, and training and mentoring. Three of the four samples recognise the importance of standards and procedures, internal leadership and experienced staff. The more mature companies (both appraised and self-rated) also recognise the importance of inspections, executive support, and internal process ownership. The high-maturity, *appraised* companies recognise the importance of a number of additional factors: metrics, risk assessment, automation, and project post mortems. (There appears to be some disagreement over the importance of estimating tools.)

There are no majorities of respondents from the appraised companies that think that any factor has no impact. But the self-rated companies think that reward schemes have no impact. This finding is simply a reflection of the analysis of the main three samples.

### 4.2.2 Differences between the sub-samples

For two factors (experienced staff and internal process ownership) there are statistically significant differences between the responses from the appraised low-maturity and appraised high-maturity companies. This may reflect the greater experience of the high-maturity companies.

For four factors (inspections, executive support, internal process ownership and external consultants) there are statistically significant differences between the responses of the self-rated low-maturity and self-rated high-maturity companies. Again, these differences may be attributed to the greater experience of the more mature companies.

## 4.3 Factors relating to SPI success

In this section, we discuss the results relating to our fourth research question:

RQ4 Are there differences, in the factors recognised by respondents, between companies with successful and non-successful SPI programmes?

**Table 6 Factors having a major impact on successful SPI programmes**

<b>Data set</b>	<b>Factor</b>
Appraised	Metrics
	Training and mentoring
Self-rated	Inspections
	Training and mentoring
Not-rated	Internal process ownership

For each of the 16 factors, we conducted a chi-square test comparing the successful and unsuccessful sub-samples of each data set. (See the appendix for detailed information on the tests.) There were few significant results, with only one factor (training and mentoring) being significant across more than one data set.

Table 6 summarises those factors that were significant. For each of the four factors, the respondents from the companies with successful SPI programmes thought that the factor had a major impact on SPI. (This was determined by examining the distribution of frequencies in the cross-tabulation.)

## 5 Discussion

### 5.1 Summary and discussion of factors

**Table 7 Factors identified as having a major impact, by different samples**

Factor	All	Maturity <sup>a</sup>		Successful companies		
		High	Low	Appraised	Self-rated	Not-rated
Training & mentoring	Yes	Yes	Yes	Yes	Yes	
Reviews	Yes	Yes	Yes			
Standards & procedures	Yes	Yes				
Experienced staff	Yes	Yes				
Inspections		Yes			Yes	
Internal process ownership		Yes				Yes
Internal leadership		Yes				
Executive support		Yes				
Metrics				Yes		
<b>Total</b>	4	8	2	2	2	1

Notes:

<sup>a</sup> The high-maturity and low-maturity samples include appraised and self-rated data.

Table 7 summarises the factors that the respondents, from the different data sets, think have a major impact on SPI. The most prominent factor is training and mentoring, 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. The importance of training and mentoring has been recognised in the research literature. Bach (Bach, 1997) argues that sustained training and mentoring effect real performance improvement. A series of papers (Billings et al., 1994; Krasner et al., 1994; Paulk et al., 1994) discuss the mentoring and training programmes of the Space Shuttle Onboard Software Project. Paulk et al. (Paulk et al., 1994) and Krasner et al. (Krasner et al., 1994) both describe how the Space Shuttle Project transfers the principles for developing mature process to other projects, by transferring managers and technical staff:

“... the most effective transfer occurred with the reassignment of people possessing the dynamic knowledge about how to apply mature processes and improvement methods.”  
((Paulk et al., 1994), p. 121)

Humphrey et al (Humphrey et al., 1991), reporting on the process improvements at Hughes, indicated that process-improvement teams must become experts.

A surprising finding from our analysis is that executive support is only recognised as having a major impact by the high maturity companies (appraised and self-rated). The major impact of metrics is only recognised by those appraised companies that have a successful SPI programme.

Four broader themes emerge from the eight factors presented in Table 7: people, process, skills and leadership. Reviews, standards and procedures, inspections and process ownership relate to the broader theme of process. Training and mentoring, experienced staff, executive support, and internal leadership relate to the broader theme of people. These two themes suggest that, unsurprisingly, SPI needs to consider both process and people. Training and mentoring, and experienced staff can also be related to the broader theme of skill. This suggests that SPI needs to be more specifically directed at both improving the process and improving practitioners' skills. Executive support and internal leadership both relate to a broader theme of leadership. This suggests that SPI programmes need to be lead at both a corporate and a local level.

#### Key success factors recognised by all companies

In general, respondents think that reviews, standards and procedures, training and mentoring, and experienced staff have a major impact on SPI success. Because these four factors are recognised by all

three of the main data sets (see Table 4), findings relating to these four factors ought to be of interest to a wide range of practitioners. Findings concerning *how* to implement SPI programmes, in terms of these four factors, may be of even more interest to practitioners, given Goldenson and Herbsleb, and El Emam et al.'s findings on implementing SPI. Research that investigates the causal relationships between these four factors and SPI success could be beneficial to practitioners. Research that clarifies the nature of these four factors (i.e. defines them more precisely) could also be beneficial to practitioners.

These four factors relate to process (reviews, and standards and procedures) and to skills (i.e. training and mentoring, and experienced staff). This suggests that a fundamental element of software process improvement is process improvement *in conjunction with* skill development. This assertion is supported by the prominence of the training and mentoring factor, in Table 7 (particularly the fact that training and mentoring was recognised as a major factor by the successful companies).

### Key success factors recognised by the low maturity companies

The low-maturity companies appear to have a less developed understanding of software process improvement, as indicated by their identification of only two factors having a major impact on SPI. Nevertheless, these two factors are recognised by the mature companies, so it is likely that the low-maturity companies recognise factors that have a genuine impact on SPI. These two factors also suggest a starting point for each company's SPI i.e. seek improvements first through training and mentoring and through reviews; then look to develop standards and procedures. The prominence of the training and mentoring factor supports this assertion. Also, both training and mentoring, and standards and procedures are considered to be mechanisms for 'capturing' and disseminating the experience of the more experienced staff. Also, while the main purpose of reviews may be to improve quality, one possible by-product is the sharing of knowledge and experience between the more experienced and less experienced members of staff.

### Key success factors recognised by the high maturity companies

The more mature companies (whether they are appraised or self-rated) appear to have a more detailed understanding of software process improvement, in that these companies recognise more factors as having a major impact on SPI success. The additional factors are: internal leadership, inspections, executive support, and internal process ownership. It may be that these factors are only relevant when a company is seeking a higher maturity, because these companies already have some pre-requisite processes in place. For example, inspection processes may be implemented more effectively and efficiently if review processes are already implemented. An alternative interpretation is that these four factors are useful for all levels of maturity, but are only recognised by the more mature companies (perhaps because of their experiences with progressing from a lower maturity).

Research relating to these four factors may also be of interest to a wide range of practitioners, particularly if such research can demonstrate the presence and effects of these factors at lower levels of maturity.

## 5.2 Comparison with previous research

We were also interested in comparing our findings with those of the three studies that we reviewed in section 2. Our study has a different design, and purpose, to that of the three studies. Consequently, we would not expect to find a high degree of similarity in the factors investigated. We are also being conservative in our comparisons, in that we choose not to collapse factors prior to the comparison. There are only two factors that are similar between our findings and *some* of the previous studies: executive support and reward schemes. For executive support, all three of the previous studies found that executive support has a major impact on SPI success. We do not have such strong results, but our results are in the same direction. That is, majorities or large minorities of our respondents think that executive support has a major impact. There were no samples where majorities or large minorities thought that executive support had no impact. For reward schemes, Goldenson and Herbsleb found that reward schemes did not seem to have an impact on SPI success. We have made a similar finding.

## 6 Conclusions

We have conducted a survey questionnaire of factors that impact the implementation of SPI. We have conducted this survey in order to offer recommendations to practitioners and researchers on software process improvement. Our study is intended to complement previous research, such as the studies of

Goldenson and Herblseb, El Emam et al. and Stelzer and Mellis. We conducted three sets of analysis (general, maturity-based, and success-based) against three main data sets (companies with appraised maturity, self-rated maturity, and no rating of maturity) to identify those factors that have a major impact, or no impact, on implementing SPI.

We found four factors (reviews, standards and procedures, training and mentoring, and experienced staff) that all companies generally considered had a major impact on SPI; only two factors (reviews, standards, and training and mentoring) that companies with low-maturity considered had a major impact on SPI; a further four factors (internal leadership, inspections, executive support, and internal process ownership) that the more mature companies considered had a major impact on SPI; and two factors (estimating tools and reward schemes) that may not have an impact on SPI. From these factors, four broader themes emerged: process, people, skills and leadership. These themes suggest that process improvement may be more effective if it occurs in conjunction with skill development. This suggestion is supported by the prominence of the training and mentoring factor across our three sets of analyses.

These 10 factors provide a simple basis for recommendations to practitioners and researchers. For researchers, the factors suggest particular issues for which practitioners may want advice and clarification. For practitioners, the factors suggest particular issues that need to be considered when implementing a software process improvement programme.

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## 7 Appendix: Raw data and results of statistical tests

**Table 8 Company demographics**

<b>Characteristic</b>	<b>Categories</b>	<b>Frequency</b>
Primary business	Software	60
	Hardware	23
	Services	38
	Outsourcing	3
Company scope	Multi-national	45
	UK company	38
	Missing	1
Age of company	Less than 5 years	2
	6-10 years	12
	11-20 years	34
	21-50 years	20
	More than 50 years	16
Company size (UK)	Less than 10	2
	11-100	32
	101-500	27
	501-2000	7
	More than 2000	14
	Missing	2
Company size (Worldwide)	Less than 10	8
	11-100	9
	101-500	6
	501-2000	9
	More than 2000	23
	Don't know	2
	Missing	27

Table 8 provides information on company demographics. Where the total frequency of categories for a characteristic exceeds 84, this is because respondents could respond with more than category.

The following tables present the counts and percentages of responses of major impact, no impact and other for the factors investigated in our study, together with the results of the chi-square tests of association. (The other category includes ‘don’t know’ and ‘minor impact’, but excludes missing values.) We included two ‘other’ factors in our questionnaire, but response rates on these factors were very low. Also, it is difficult to know how to interpret such a vague factor. We were using these two factors to simply *identify* additional factors, rather than to rate those factors. Because of the design of our investigation, we are not using the chi-square ( $\chi^2$ ) to test whether each factor has a statistically significant impact on SPI success, but whether there are statistically significant differences between the opinions of respondents between the various samples. We use the frequency of responses of major impact to determine whether a factor has an impact on SPI success, and the frequency of responses of no impact to determine whether a factor has no impact on SPI success.

In the table, statistically significant differences are emboldened. Factors that the *majority* of respondents think have a major impact on SPI success, or no impact, are also emboldened.

**Table 9 General analysis of appraised and self-rated companies**

Factor	Data sets						statistics	
	Appraised (n=14)			Self-rated (n=36)			$\chi^2$	p
	Major	None	Other	Major	None	Other		
<b>Inspections</b>	9	1	3	10	1	21	6.730	<b>0.040</b>
%	69	8	23	31	3	66		
<b>Reviews</b>	10	0	2	23	1	12	1.685	0.476
%	83	0	17	64	3	33		
<b>Standards &amp; Procedures</b>	7	0	6	26	1	9	2.236	0.480
%	54	0	46	72	3	25		
Project Post Mortems	3	2	8	6	5	23	0.201	0.892
%	23	15	62	18	15	68		
<b>Metrics</b>	7	2	4	6	7	20	5.951	<b>0.055</b>
%	54	15	31	18	21	61		
Risk Assessment	2	1	9	8	6	20	1.066	0.702
%	17	8	75	24	18	59		
Estimating Tools	3	1	5	4	18	8	6.673	<b>0.026</b>
%	33	11	56	13	60	27		
<b>Automation</b>	6	1	4	10	14	8	4.392	0.144
%	55	9	36	31	44	25		
<b>Training &amp; Mentoring</b>	9	0	4	22	2	10	0.800	0.888
%	69	0	31	65	6	29		
Reward Schemes	1	3	7	2	18	10	3.530	0.153
%	9	27	64	7	60	33		
<b>Internal Leadership</b>	6	1	6	19	5	10	1.304	0.586
%	46	8	46	56	15	29		
<b>Internal Process Ownership</b>	7	0	6	14	4	17	1.913	0.406
%	54	0	46	40	11	49		
Executive Support	5	0	7	15	2	15	1.031	0.656
%	42	0	58	47	6	47		
<b>Experienced Staff</b>	7	0	5	27	1	8	1.943	0.452
%	58	0	42	75	3	22		
External Consultants	3	2	7	7	13	11	2.684	0.294
%	25	17	58	23	42	35		
Stringent Control	3	4	5	5	11	13	0.330	0.819
%	25	33	42	17	38	45		



**Table 10 General analysis of self-rated and non-rated companies**

Factor	Data set						Chi-square ( $\chi^2$ ) statistics		
	Self-rated (n=36)			Non rated (n=34)			$\chi^2$	df	p
	Major	None	Other	Major	None	Other			
Inspections	10	1	21	10	2	11	2.040	2	0.483
%	31	3	66	43	9	48			
<b>Reviews</b>	23	1	12	21	0	5	2.423	2	0.309
%	64	3	33	81	0	19			
<b>Standards and procedures</b>	26	1	9	24	0	3	2.853	2	0.256
%	72	3	25	89	0	11			
Project Post Mortems	6	5	23	10	4	9	5.311	2	<b>0.067</b>
%	18	15	68	43	17	39			
Metrics	6	7	20	2	2	17	2.477	2	0.333
%	18	21	61	10	10	81			
Risk Assessment	8	6	20	6	2	11	0.710	2	0.725
%	24	18	59	32	11	58			
Estimating Tools	4	18	8	3	8	9	2.133	2	0.410
%	13	60	27	15	40	45			
Automation	10	14	8	3	6	10	4.147	2	0.145
%	31	44	25	16	32	53			
<b>Training and mentoring</b>	22	2	10	18	0	7	1.594	2	0.628
%	65	6	29	72	0	28			
Reward Schemes	2	18	10	2	14	5	0.597	2	0.750
%	7	60	33	10	67	24			
<b>Internal Leadership</b>	19	5	10	12	1	9	1.812	2	0.450
%	56	15	29	55	5	41			
<b>Internal process ownership</b>	14	4	17	14	3	7	2.340	2	0.368
%	40	11	49	58	13	29			
Executive Support	15	2	15	9	2	10	0.227	2	1.000
%	47	6	47	43	10	48			
<b>Experienced Staff</b>	27	1	8	17	0	6	0.729	2	1.0
%	75	3	22	74	0	26			
External Consultants	7	13	11	6	10	5	0.826	2	0.719
%	23	42	35	29	48	24			
<b>Stringent Control</b>	5	11	13	11	3	7	7.534	2	<b>0.020</b>
%	17	38	45	52	14	33			

**Table 11 Maturity-based analysis of appraised companies**

Factor	CMM Level 1+2 (n=6)			CMM Level 3+4 (n=5)			$\chi^2$	statistics df	p
	Major	None	Other	Major	None	Other			
<b>Inspections</b>	2	1	3	4	0	0	4.444	2	0.105
	33	17	50	100	0	0			
<b>Reviews</b>	4	0	2	3	0	0	1.286	1	0.5
	67	0	33	100	0	0			
<b>Standards and procedures</b>	2	0	4	2	0	2	0.278	1	1.0
	33	0	67	50	0	50			
<b>Project post mortems</b>	0	1	5	2	0	2	4.048	2	0.133
	0	17	83	50	0	50			
<b>Metrics</b>	2	1	3	3	0	1	1.875	2	0.714
	33	17	50	75	0	25			
<b>Risk assessment</b>	0	1	4	2	0	2	3.6	2	0.286
	0	20	80	50	0	50			
<b>Estimating tools</b>	1	0	3	2	0	1	1.215	1	0.486
	25	0	75	67	0	33			
<b>Automation</b>	2	1	2	3	0	1	1.440	2	1.0
	40	20	40	75	0	25			
<b>Training &amp; mentoring</b>	3	0	3	3	0	1	0.625	1	0.571
	50	0	50	75	0	25			
Reward schemes	0	2	3	1	1	2	1.440	2	1.0
	0	40	60	25	25	50			
<b>Internal leadership</b>	2	1	3	2	0	2	0.833	2	1.0
	33	17	50	50	0	50			
<b>Internal process ownership</b>	2	0	4	4	0	0	4.444	1	0.076
	33	0	67	100	0	0			
<b>Executive support</b>	1	0	4	2	0	2	0.9	1	0.524
	20	0	80	50	0	50			
<b>Experienced staff</b>	1	0	5	3	0	0	5.625	1	<b>0.048</b>
	17	0	83	100	0	0			
External consultants	1	0	5	1	1	1	3.0	2	0.405
	17	0	83	33	33	33			
Stringent control	1	2	3	0	1	2	0.6	2	1.0

**Table 12 Maturity-based analysis of self-rated companies**

Factor	CMM Level 1+2 (n=29)			CMM Level 3+4 (n=7)			$\chi^2$	statistics df	p
	Major	None	Other	Major	None	Other			
<b>Inspections</b>	5	1	19	5	0	2	6.783	2	<b>0.048</b>
	20	4	76	71	0	29			
<b>Reviews</b>	19	1	9	4	0	3	0.54	2	0.734
	66	3	31	57	0	43			
<b>Standards &amp; procedures</b>	20	1	8	6	0	1	0.859	2	0.716
	69	3	28	86	0	14			
Project post mortems	5	4	18	1	1	5	0.076	2	1.0
	19	15	67	14	14	71			
Metrics	3	6	17	3	1	3	3.638	2	0.157
	12	23	65	43	14	43			
Risk assessment	5	6	16	3	0	4	2.959	2	0.318
	19	22	59	43	0	57			
Estimating tools	2	15	6	2	3	2	2.050	2	0.489
	9	65	26	29	43	29			
Automation	7	12	6	3	2	2	0.904	2	0.653
	28	48	24	43	29	29			
<b>Training &amp; mentoring</b>	18	2	7	4	0	3	1.138	2	0.780
	67	7	26	57	0	43			
Reward schemes	2	14	7	0	4	3	0.870	2	1.0
	9	61	30	0	57	43			
<b>Internal leadership</b>	14	4	9	5	1	1	1.068	2	0.730
	52	15	33	71	14	14			
<b>Internal process ownership</b>	8	4	16	6	0	1	7.689	2	<b>0.034</b>
	29	14	57	86	0	14			
<b>Executive support</b>	9	2	14	6	0	1	5.474	2	0.097
	36	8	56	86	0	14			
<b>Experienced staff</b>	21	1	7	6	0	1	0.621	2	0.729
	72	3	24	86	0	14			
External consultants	7	12	6	0	1	5	7.613	2	<b>0.029</b>
	28	48	24	0	17	83			
Stringent control	3	8	11	2	3	2	1.290	2	0.622
	14	36	50	29	43	29			

**Table 13 Results of chi-square tests of extent of use and degree of impact**

Factor	Appraised				Self-rated				Not-rated			
	n	df	$\chi^2$	p	n	df	$\chi^2$	p	n	df	$\chi^2$	p
Inspections	10	3	7.6	0.03	32	6	36.4	0.005	23	4	32.2	<0.001
Reviews	9	1	9.0	0.28	36	6	39.4	0.004	26	1	9.1	0.031
Standards and procedures	10	1	2.9	0.17	36	6	47.0	0.001	27	1	3.3	0.214
Project post mortem	10	3	6.0	0.13	34	6	20.4	0.003	23	6	14.2	0.044
Metrics	10	3	6.7	0.07	33	6	14.9	0.023	21	6	12.4	0.171
Risk assessment	9	6	10.8	0.10	34	6	38.8	<0.001	19	6	15.4	0.009
Estimating tools	7	2	4.3	0.23	30	6	33.4	<0.001	20	9	37.6	<0.001
Automation	9	6	14.4	0.03	32	6	29.5	<0.001	19	9	34.1	<0.001
Training and mentoring	10	1	6.4	0.03	34	6	5.1	<0.001	25	1	5.9	0.032
Reward schemes	9	3	7.0	0.05	30	6	25.0	0.003	21	9	20.3	0.071
Internal leadership	10	3	7.0	0.08	34	6	19.6	0.004	22	4	31.2	<0.001
Internal process ownership	10	1	6.4	0.03	35	6	34.5	<0.001	24	6	19.8	0.004
Executive support	9	2	5.1	0.17	32	6	35.1	<0.001	21	9	39.6	<0.001
Experienced staff	9	1	2.1	0.28	36	6	38.4	0.008	23	1	8.4	0.009
External consultants	9	4	14.0	0.01	31	6	27.6	0.002	21	4	27.0	<0.001
Stringent control	9	6	9.9	0.24	29	6	40.3	<0.001	21	9	38.5	<0.001

**Table 14 Results of chi-square tests of successful and unsuccessful companies**

Factor	Appraised				Self-rated				Not-rated			
	n	df	$\chi^2$	p	n	df	$\chi^2$	p	n	df	$\chi^2$	p
Inspections	9	2	0.8	1.0	26	2	4.9	<b>0.08</b>	22	2	4.1	0.29
Reviews	8	1	1.9	0.38	29	2	2.4	0.46	25	1	0.4	1.0
Standards and procedures	9	1	3.6	0.17	29	2	4.6	0.11	26	1	0.8	0.41
Project post mortem	9	2	2.3	0.64	28	2	2.4	0.38	22	2	0.5	1.0
Metrics	9	2	9.0	<b>0.01</b>	26	2	1.5	0.49	20	2	0.6	1.0
Risk assessment	8	2	2.9	0.46	27	2	2.7	0.30	18	2	4.5	0.18
Estimating tools	6	1	3.0	0.40	24	2	0.23	1.0	19	2	0.5	1.0
Automation	8	2	2.9	0.46	26	2	4.6	0.10	18	2	1.8	0.67
Training and mentoring	9	1	9.0	<b>0.01</b>	28	2	6.5	<b>0.03</b>	24	1	3.2	0.14
Reward schemes	8	2	0.9	1.0	24	2	4.5	0.16	20	2	0.5	1.0
Internal leadership	9	2	1.1	1.0	28	2	2.2	0.46	21	2	2.9	0.40
Internal process ownership	9	1	2.3	0.46	29	2	2.8	0.26	23	2	9.8	<b>0.02</b>
Executive support	8	1	0.03	1.0	26	2	0.6	1.0	20	2	4.6	0.20
Experienced staff	8	1	0.5	1.0	29	2	3.3	0.23	22	1	0.06	1.0
External consultants	8	2	2.9	0.46	25	2	1.8	0.46	20	2	2.2	0.47
Stringent control	8	2	4.6	0.11	24	2	0.2	1.0	20	2	3.3	0.19