PROCESS CAPABILITY ASSESSMENTS IN SMALL DEVELOPMENT FIRMS

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ABSTRACT

Assessment-based Software Process Improvement (SPI) programs such as the Capability Maturity Model (CMM), Bootstrap, and SPICE (ISO/IEC 15504) are based on formal frameworks and promote the use of systematic processes and management practices for software development. These approaches identify best practices for the management of software development and when applied, enable organizations to understand, control and improve development processes. The purpose of a SPI assessment is to compare the current processes used in an organization with a list of recommended or 'best' practices.

This research investigates the adoption of SPI initiatives by four small software development firms. These four firms participated in a process improvement program which was sponsored by Software Engineering Australia (SEA) (Queensland). The assessment method was based on SPICE (ISO/IEC 15504) and included an initial assessment, recommendations, and a follow-up meeting. For each firm, before and after snapshots are provided of the capability as assessed on eight processes. The discussion which follows summarizes the improvements realized and considers the critical success factors relating to SPI adoption for small firms.

KEY WORDS

Software process evaluation and improvement.

1. INTRODUCTION

For many small software firms, full-scale software process improvement (SPI) initiatives are often out of reach due to prohibitive costs and lack of SPI knowledge. However, to compete in the global market, software developers must improve their productivity, time to market and customer satisfaction.

The basic principles of the software process assessment method developed by Humphrey [1] and others at the Software Engineering Institute are based on the Total Quality Management concepts of statistical process control. However, software development managers need to be convinced that investment in SPI will provide a worthwhile return on investment and commercial advantage. SPI issues recently researched include: evaluation of SPI Assessments [2, 3, 4, 5]; SPI success/failure [6, 7, 8]; SPI barriers [9]; and SPI for small firms [10, 11, 12, 13, 14, 15, 16].

In the late 60s, a significant source of large scale software was development contracts issued by the U.S. Department of Defense (DoD). Consequently, the DoD contract software development scenario has been the dominant influence for researchers to develop, enhance and promulgate SPI models [10]. Today, the software development contract effort for large government departments is dwarfed by mass-market software, much of which is produced by small firms, but issues such as firm size, development mode (contract versus commercial off-the-shelf), development size (program size, shipped volume) and development speed have not been adequately addressed by researchers. In particular, it is believed that start-up firms have special needs which cannot be met by traditional software engineering models.

The models underlying traditional SPI programs such as CMM were designed for large organizations undertaking extensive projects. However, while these models have been evolving over many years, the software industry has changed dramatically. In the software development industry, there has been a large increase in the proportion of small software development firms. Such firms are involved in producing commercial-off-the-shelf packages and also custom writing small software applications for clients. Although the customized software market is still substantial, its growth is being outstripped by that for packaged software, with many firms choosing to buy packaged software which they can customize internally, rather than buying a fully bespoke system [17].

Therefore this research looks at the impact of a SPI initiative on a select group of small firms involved in software development. By such means, it is hoped to better understand the factors that influence adoption of SPI. Linked to this is a need to assess the relevance of traditional SPI models to today's small software development firms.

2. PROCESS ASSESSMENT METHOD

SPICE (ISO/IEC 15504) is a major international initiative to develop a standard for software process assessment, bringing together suppliers and users of assessment methods. The SPICE (ISO/IEC 15504) standard [18] sketches out a roadmap for the implementation of best practice in software engineering by defining 40 processes, divided into five categories: customer-supplier; engineering; support; management; and organization. The process capability of each defined process 'measures how well each process is managed to achieve its purpose and the organization's objectives for it' [19 p.57]. Capability is measured in levels from incomplete (level 0); performed (level 1); managed (level 2); established (level 3); predictable (level 4) to optimising (level 5). SPICE (ISO/IEC 15504) was chosen as the basis for the SPI program as it is the emerging standard on software process assessment and qualified SPICE assessors were available to undertake the assessments.

As the assessments were restricted to one day each, rather than use the 40 processes defined in ISO/IEC 15504, eight key processes were selected: Requirements Gathering; Software Development; Project Management; Configuration Management (CM); Quality Assurance (QA); Problem Resolution; Risk Management; and Process Establishment.

Although ISO/IEC 15504 provides rating levels from 0 (incomplete) to 5 (optimizing), only questions relating to level 1 (performed), level 2 (managed) and level 3 (established) were included for the assessments.

Two trained SPICE assessors undertook each evaluation, one in the role of team leader and the other as support assessor. The assessors conducted on-site interviews with key people involved in managing the software development effort of the organization. For each of the eight processes examined, the assessors followed the script of the assessment instrument [20] to determine the extent to which the process attributes have been achieved using a four point scale: not achieved; partially achieved; largely achieved; and fully achieved. The capability level (0, 1, 2 or 3) for each process was then determined, based on the organization's achievement of the process attributes.

About six months after the assessment, a half-day follow-up meeting was conducted at each firm, and the final report prepared for the organization sponsor and SEA (Queensland).

3. ASSESSMENT OUTCOMES

In the following section, the findings from the assessments and follow-up meetings of four organizations are reported. To preserve confidentiality and to protect the identity of the firms, they are referred to as Firm A, B, C and D.

Firm A Initial Assessment. Firm A was the smallest of the four firms with only 6 staff. The assessment found that Firm A had a generally informal process for development of software that was supported by excellent tool selection, leading to high confidence in the integrity of the delivered software. The firm placed significance on the service and support of its customer base. Considerable effort had been invested in the development of user requirements for the core product.

The informality in the development processes was seen as constituting significant risks for the firm in an environment of system and market growth. There was a need to adopt a more formal and structured approach to both technical and management issues. It was recommended that more attention should be paid to aspects of software development, in particular testing, and also to the establishment of a coherent strategy for project management.

Firm A Follow-Up Meeting. Seven months after the initial assessment, a follow-up meeting was held. Since the assessment, the firm had relocated to new offices, and the staffing profile had changed slightly, with additional domain expertise and fewer part-time staff. The firm had been reorganized, with the aim of reducing the managerial load on the Senior Manager. There had been noticeable growth in business opportunities, with a major contract being negotiated.

The development process had been formalised. Project plans, containing a detailed statement of scope for the work to be performed, were now produced for all work except corrective maintenance, which was still monitored using the requests and defects system. A specification of requirements, based upon IEEE Std 830, had been introduced. The requests and defects system had been improved and was now used as a key driver for all work in the firm. Formal projects were linked to existing requests, and corrective maintenance was managed using the requests and defects system.

New procedures had been introduced in relation to the control of report generation routines, where a major problem with consistency and integrity had been found. The range of application of the CM system had been expanded, partly in response to this problem.

Individual projects were now defined and the scope of work was clearly documented. The project plan supported better decisions on feasibility, which was reinforced by more effective contract reviews.

The objectives for QA have been defined; the firm had a documented and well-disseminated Quality Policy. A variety of quality records were now identified and

retained. Responsibilities for QA and control were defined and seemed to be well understood.

Risks were now routinely identified for all projects, and mitigation strategies were defined. There had been significant activity in the development of new and revised procedures for software development and project management. However, the process for establishing these additional process assets remained largely ad-hoc and uncontrolled.

Awareness of the importance of measurement as a source of objective information on status was high. A number of relevant data items were collected on a routine basis, and some of the key systems in the firm, including the requests and defects system, have been modified to improve data collection. A timesheet system had been introduced for recording effort, with work breakdown codes in use. Although there was much more data being collected, there was very limited analysis of the data, and the impact of the added data on actual project performance was minimal.

Firm B Initial Assessment. Firm B employed about 10 staff and concentrated its development on a single product. The product had a high reputation, and the firm had developed good relationships with all of its client groups. The firm followed a reasonable planning process to establish the scope of major releases of the product, though activities to achieve the plans were tracked only informally. Sound CM practices to ensure the integrity of the product were in place. A stable environment helped to control the risks associated with processes that did not demonstrate adequate capability.

Product development was weakened by the lack of any structured approach to system testing. In addition, the process for tracking customer-reported problems was informal and not controlled effectively. Tracking of activities was limited, and no records of the effort, costs or duration of tasks were kept, so that estimating for new releases lacked credibility. No effective processes existed for QA or risk management, and while some assets to support process performance existed, there was no mechanism to identify or develop additional assets.

Firm B Follow-Up Meeting. Nine months after the initial assessment, a follow-up meeting was held. Since the assessment had been performed, the Australian Government had introduced a Goods and Services Tax (GST) which had a major impact on Firm B's clients. To cope with the huge increase in product sales and subsequent training and support, the total number of staff had increased by 70 percent. The chief programmer had resigned (and had not yet been replaced) and a full-time tester had been appointed.

As a result of the assessment, Firm B had commenced a SPI project to document and formalise the software development processes. To address recognised risks regarding testing, a tester had been appointed, test plans were formulated and test logs and incidents recorded. Furthermore, Firm B's Workflow Management system had been extended to integrate client registration, automated problem tracking, help desk and despatches. This system was being integrated with the development systems. This project and others were being tracked with Microsoft Outlook at the task level.

As Firm B had just commenced its SPI project, the capability of the target processes was not formally re-evaluated. Details relating to size of released product were being collected. Also, tasks associated with six projects were being tracked in Outlook. Firm B considered the assessment to be of great benefit. Prior to the assessment, the firm had recognized the need to undertake a SPI program, but did not know where to start. The proposals for action in the assessment report provided the impetus to develop a SPI program by enabling the firm to focus on a set of tasks. As well as providing a practical approach, the involvement of the 3rd party assessors provided a measure of accountability: staff were motivated to get the SPI program underway prior to the follow-up meeting.

Firm B's SPI program was not as advanced as it hoped, however, the improvements in the testing procedures have resulted in Firm B being more confident in releasing products. Also, there was more confidence to expand the development effort. The SPI program had already shown value by reducing the disruption resulting from staff turnover.

On the whole, Firm B found the assessment provided value in motivating improvement actions. Due to phenomenal sales and support activity (due to GST introduction) and the loss of key staff, Firm B was not very advanced with the improvement actions taken since the assessment. However, Firm B was convinced the actions taken have already resulted in improvements in its product and processes.

Firm C Initial Assessment. Firm C employed about 10 staff. The assessment revealed that Firm C had a remarkably mature process for a small business. The principal business of the organization focused around a well-defined process, based upon the firm's methodology and Quality Manual. There was excellent control of initial project requirements, and changes over the course of a project were well handled, though on an individual project basis. Firm C effectively addressed financial risks, through undertaking work on a "time and materials" basis. Project management was limited in scope but effective.

As a result of relatively rapid growth in recent years, Firm C faced problems in ensuring consistent application of its defined process across the life cycle. Many of its

approaches to project management, while appropriate to its current environment, were limited in their use in less well-controlled environments. There was a need for a thorough review of the quality management system, to ensure that it retained its usefulness in a changing business environment. Firm C also needed to take more advantage of its strengths by developing effective measures for monitoring performance in terms of both productivity and product quality.

Firm C Follow-Up Meeting. The follow-up meeting was held 9 months after the initial assessment. The firm's methodology had been through a major review process and subsequently updated. In particular, modeling had been extended to include Object Oriented and Unified Modeling Language concepts. All templates were updated to reflect changes. To ensure all staff became familiar with the changes, a workshop was developed and delivered.

Procedures for the use of a CM tool were updated and dispersed through mentoring. A staff member had been given the duties of code librarian. An Enterprise-wide change request system had been designed and was in the process of being developed. Also, a software package had been introduced to help track and manage bugs and issues.

A Risk Assessment and Management procedure was developed. This project had a major impact on the Quality Management System and necessitated changes to procedures including testing, contract review and planning, and requirements control. A process for developing new procedures had been defined and a template had been developed and included in the Quality Manual to be used for all new procedures.

The changes implemented by Firm C impacted on the capability of four of the target processes: Software Development; CM; Risk Management; and Process Establishment. Many of the changes were too new to have impacted at the time of the follow-up meeting. However, the CM tool and error-tracking software had made it easier to manage multiple developer projects, and testing had been enhanced in terms of efficiency and quality.

Firm C considered that the assessment provided valuable motivation to review and improve the software development process. The assessment provided the impetus to make available resources to address the action items from the assessment report. Staff at Firm C also considered the assessment results provide evidence of their software process capability and therefore provide competitive advantage in formal tenders. Finally, the strengths highlighted in the assessment report improved the morale of the team by providing positive feedback about the value of process improvement. Firm C was convinced the improvement actions resulting from the assessment would return great value in the future by ensuring it is better placed to bid for large projects.

Firm D Initial Assessment. Firm D, employing about 60 staff, was the largest of the four organizations. Software development in Firm D was generally performed so as to achieve the purpose of the processes employed. There was however considerable inconsistency across the organization in process implementation. This problem was accentuated by the distributed nature of Firm D's organization, with development activities spread across several locations in different regions. This problem had been addressed by emphasising the professionalism and competency of staff, and there had been significant investment in staff development.

Most of the challenges faced by Firm D derived from the distributed nature of the organization. With project tasks being performed in multiple locations, project management was more difficult, particularly for monitoring and recording progress. CM posed particular problems, while difficulties were found in QA and problem resolution. The development of a consistent approach to process performance across the organization would help to address many of these issues.

Firm D Follow-Up Meeting. Eleven months after the initial assessment, a follow-up meeting was held. An internet-based document control system had been set up but was not well supported within the firm. The level of Internet access varied considerably between the different firm locations, and this had been a major factor hindering implementation.

A more formal system for approval of projects had been established, involving approval by the relevant Business Unit, with overall coordination and monitoring through a new control unit. A workflow management system was being developed to support the control of tasks for individual project tasks. While the system has been designed and development had commenced, it had not yet been implemented at the time of the follow-up meeting.

Difficulties had been encountered in the development and deployment of an effective problem management system. The distribution of functions across the different sites of the firm was partly responsible for these difficulties; problems were often reported in terms that were not easily understood by the group responsible for addressing them.

The establishment of a control unit had resulted in clarification of responsibilities for risk management within Firm D. Risk management was still seen mainly as the responsibility of top-level management, and the process for managing risk remained informal. The additional control steps introduced through the establishment of the control unit and the revised project approval process have helped to address some of the

identified weaknesses in the Project Management process.

The development of a common approach to systems development across the widely-distributed sites of the firm remained the principal focus of attempts to improve overall effectiveness. Because each site was an independent cost-centre within the enterprise as a whole, there tended to be an inward focus by management, with each centre taking actions in their own interest, rather than in the interest of the firm. Until more progress is made towards the more effective integration of the whole enterprise, simple process improvement efforts will tend to have limited success. Nonetheless, useful progress had been made towards addressing some of the identified risk areas, and further actions were planned.

4. SUMMARY OF PROGRAM OUTCOMES

The capability ratings determined by the initial assessments for the four firms are shown in table 1. The processes of two of the small firms, A and B were largely ad-hoc and relied on the personal techniques of key staff. In contrast, Firm C already had a Quality Management System in place and had documented and institutionalized many key processes. Firm D, the largest of the four organizations in this study, was aware of the importance of managing process assets, but efforts were hampered by the distribution of development activities across regions.

Table 1. Capability Levels by Process at Initial Assessment

Process	Firm			
	A	B	C	D
Number of developers	6	10	10	30
Requirements Gathering	1	1	3	2
Software Development	1	1	2	2
Project Management	0	0	2	1
Configuration Management	1	1	1	2
Quality Assurance	0	0	2	1
Problem Resolution	1	0	1	1
Risk Management	0	0	0	0
Process Establishment	0	0	1	0
Levels: 0 incomplete, 1 performed, 2 managed, 3 established				

Across all firms, requirements gathering exhibited greatest maturity; on the other hand, all four firms initially had an incomplete process for risk management. Process establishment was also neglected in all firms except for Firm C where it was performed.

Table 2 highlights processes improved as reported from the follow-up meetings. In firms B and D, as the achievement of process attributes was not formally reassessed, there was no change to the capability levels. Where the capability levels were reassessed and improved, this is denoted by **. In some instances, denoted by *, process improvement was evident, but not of sufficient magnitude to affect the capability level.

Table 2. Process Improvements at Follow-up Meeting

Process	Firm			
	A	B	C	D
Requirements Gathering				
Software Development		*	**	
Project Management	**			
Configuration Management		*	**	
Quality Assurance	**			*
Problem Resolution		*	*	
Risk Management	*		**	
Process Establishment	*		**	*
Levels: 0 incomplete, 1 performed, 2 managed, 3 established * Process Improved ** Capability Level Increased				

As evident from the follow-up meetings, the main benefits included improved CM, project management, and testing. All firms improved the standard of their documentation, a move which has already returned dividends for one firm which lost a key developer. A further important benefit in one firm was the competitive advantage provided by the capability ratings.

A number of factors can be identified as contributing to the success of this SPI initiative. Firstly, the SPI sponsor in each organization committed the firm to the program, participated in the planning, assessment and follow-up stages of the program, and took on the responsibility of ensuring progress was monitored so that, as far as possible, agreed recommendations were implemented prior to the follow-up meeting.

Secondly, the people involved were respected as all the assessors had completed the SPICE certification training, were experienced assessors and associates of the Software Quality Institute (SQI). Also, their credibility was enhanced by the reputation of SQI which provides a focus in Queensland for expertise in software quality, and serves as a catalyst for innovations in software quality techniques. The SPICE assessors, as external change agents with authority from the sponsor, were seen as removed from the internal firm politics and outside the scope of 'turf wars'. Another positive influence was involvement of key technical staff in the assessments and follow-up meetings.

An important factor in the overall success of the process improvement program was the availability of appropriate training courses and seminars conducted by SEA (Queensland). This issue is particularly relevant to small firms which typically lack the range of expertise found in large organizations.

However, there were some inhibiting factors. It is clear from the follow-up meetings that commercial pressures limited the availability of staff and resources. Although the focus was on action items achievable within the 6-month time frame leading up to the follow-up meeting, many of the recommendations were not implemented due to time and budget constraints. Even in limiting the scope to 8 processes, it was not feasible to achieve radical change in a 6 month time-frame.

As stressed by Acuña et al. [21], small firms suffer proportionally higher costs compared to large organizations. As well as these prohibitive costs, the cultural issues are different in small firms and although small firms may find it easier to overcome inertia and gain management commitment, often they lack the technical SPI knowledge available in large organizations.

5. CONCLUSION

Even though dramatic improvements in capability levels were not attained, the assessments focussed and motivated the organizations to improve their software processes. The assessments described in this paper were sponsored by SEA, funded by the Australian Government to enhance the competitiveness of the local software industry. Many small firms find the cost of a formal process assessment beyond their means. These cases show that even with sponsored assessments, lack of resources limit the implementation of recommended improvements.

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