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Donald Harter
Carnegie Mellon University

Sandra Slaughter
Carnegie Mellon University

Mayuram Krishnan
University of Michigan

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Donald E. Harter
Sandra A. Slaughter
Graduate School of Industrial Administration
Carnegie Mellon University

Mayuram S. Krishnan
School of Business
University of Michigan

Abstract

Software process improvement historically focused on cost savings accrued in software engineering. However, the effect of process improvement on support activities is not well understood. This study examines the relationship between process maturity measured by the Software Engineering Institute's Capability Maturity Model and savings in non-engineering support activities such as configuration management, data processing operations, senior management, and quality assurance.

Introduction

This research examines the effect of software process improvements on software development support costs. By "support" we mean those infrastructure activities that are separate from software engineering but necessary for successful software efforts, such as configuration management (CM), automated data processing (ADP) operations, senior management, and quality assurance (QA). In the last decade, the Software Engineering Institute has focused on measuring software process maturity in order to understand better how to achieve higher levels of productivity and quality. The software process is recognized as one of the "controllable factors in improving software quality and organizational performance" (Paulish and Carleton, 1994). The Software Engineering Institute's (SEI) Capability Maturity Model (CMM) (Paulk et al., 1993) establishes a foundation for measuring the sophistication of processes and guiding process improvement. Several case studies (e.g., Herbsleb, 1994) have shown that organizations can improve productivity of software engineers by advancing process maturity. However, the effect of process maturity on support activities is not well understood.

This focus on development costs exclusive of support costs is also evident in the planning and estimation literature. Several estimation models use project size to estimate only development effort and not support costs (Albrecht and Gaffney, 1983), while others incorporate support as part of an aggregate estimate (COCOMO; Boehm, 1981). Some researchers have recognized the need to account for support activities such as "integration, testing, quality assurance, documentation, and management" in the models (Putman, 1992). The Software Engineering Institute, in summarizing comments from its community, recognized the need for one model that covers all aspects of the software development process including support activity costs (Park et al., 1994).

It is important to study support costs because in large-scale software development efforts these costs can represent a large portion of the total life cycle expenditures associated with the development process. Substantial benefits can accrue by leveraging process improvements that reduce not only software engineering costs but also associated support activity costs.

Our study examines the effect of software process maturity on software support costs. More precisely, we define support costs to include costs for configuration management, automated data processing operations, senior management, and quality assurance activities (Table 1).

Table 1. Definitions of Support Activities

Configuration Management (CM)	Management of baseline documents and software; formal reviews
Automated Data Processing (ADP) Operations	Computer operations, systems support, telecommunications, test and production support
Senior Management	Senior executive management of development, operations, and support activities
Quality Assurance (QA)	Auditing of processes and products (documents and software)

We expect that improvements in process maturity will reduce costs for some support activities. Configuration management and ADP operations should have reduced workload due to higher software quality and less rework requiring CM or ADP support.

On the other hand, we expect that support elements actively involved in process improvement will experience increased costs. Senior management and quality assurance are two key organizational elements in process improvement. Both activities are expected to have increased investment as the processes mature as a result of heightened levels of process monitoring and control. Whether the savings from reduced rework are sufficient to offset these investments is unclear.

Thus, we explore the following questions:

- Which support activities benefit with reduced costs due to improved process maturity?
- Which activities must expand roles in order to support more mature processes?

Methodology

We examine data collected at the systems integration division of a $1 billion per year IT firm. The software development effort comprised approximately 3.3 million lines of COBOL code. The software was developed as part of a $240 million effort to build a material requirements planning (MRP) information system to manage spare parts acquisition. Support costs at the organizational level were tracked from 1988 to 1993.

To assess the effect of process improvements on support costs, we examined the 24 quarters of longitudinal data for the software development site. During this period the organization actively worked on process improvement using the Software Engineering Institute's Capability Maturity Model (SEI/CMM) as a guide. Approximately 60% of all effort was expended on software development activities, while the remaining 40% of effort was employed in support activities. These activities included configuration management, automated data processing (ADP) operations, senior management, and quality assurance.

Data on the effort expended by activity, project size, and SEI/CMM process maturity, were obtained from the IS organization's archives. A lines of code measurement is used as a control for project size.

A multi-variate regression model was constructed to determine the effects of process improvement on support costs. The model assesses the effect of process maturity on support costs while controlling for the magnitude of the development effort. The dependent variables that were examined in the multi-variate model included costs for configuration management, ADP operations, senior management, and quality assurance.

We estimated the multi-variate models individually using OLS regression and checked that the OLS assumptions were satisfied. These checks included the Durbin-Watson and Breusch-Godfrey test for serial correlation, Kolmogorov's test for normality of the residuals (Greene, 1993), White's test for homoscedasticity (White, 1980), and tests for multicollinearity and outliers (Belsley, Kuh, and Welsch, 1980). All tests were satisfied except serial correlation for the ADP equation. Correction for serial correlation was applied to the ADP equation with results of the corrected model reported here.

Results

Table 3 presents the results of the OLS analysis. The results suggest that process maturity significantly influences configuration management costs. Increasing the SEI/CMM maturity by one level reduces CM costs by 526 person hours per quarter. This cost savings potentially reflects reduced iterations on documents and software migrations due to higher quality in the software development process.

Similarly, ADP operations exhibits a savings of 1109 person hours per quarter for a one level increase in CMM maturity. ADP operations are driven by the quantity of software testing and production activity. Higher levels of software process maturity should result in higher quality, less testing, and fewer production problems.

The effect of CMM maturity level on senior management time was not statistically significant. Although we expect additional investment is necessary in senior management to ensure process compliance, this investment appears to be offset by the benefit of reduced management of rework activities.

The effect of CMM level on quality assurance was also not significant. There are two forces at work here. First, quality assurance costs should increase since QA is the key activity responsible for monitoring and enforcing process standards. As processes mature, it becomes more important to ensure that the development team stringently follows these enhanced procedures, increasing the workload on the QA group. The second force is the potential decrease in workload due to less rework, specifically fewer audits and re-audits. Although it is not possible to separate these two effects in our study, it appears that the investment in increased monitoring balances the benefit due to decreased rework.

In summary, the total benefits from increasing process maturity appear to exceed the personnel costs. Converted to personnel equivalents, the savings for an increase in one level of software process maturity (from level 2 to level 3) is approximately three full-time staff in the CM and ADP operations over the period during the higher maturity level (Table 2).

Based only on the activities with statistically significant savings, the organization saved over three person equivalents in the last three years of the effort, or more than 10% of the support costs studied.

Implications and Contributions

Recent research has shown the benefit of process improvements for enhancing the productivity of software developers. This research demonstrates that these benefits extend to external activities that provide support to the development process. This study has presented insight into the potential savings accrued and investment necessary for software process improvement. Future research should explore the effects of software process improvement on other support activities and other parts of the system life cycle.

Table 2. Cost Savings by Support Activity

Activity	Average # of Staff	Staff Savings	% Savings
Configuration Management (CM)	9.5	-0.76	8.0%
Automated Data Processing (ADP) Operations	12.5	-2.36	18.9%
Senior Management	5.5	* ns	* ns
Quality Assurance (QA)	2.4	* ns	* ns
Net Effect	29.9	-3.12	10.4%

* ns – not statistically significant

Table 3. Model Results with One-sided t-tests

Dependent Variable: (Support Cost)	**Model F-statistic (p-value)**	**Adjusted R^2**	**Process Maturity Coefficient**	**t-value (p-value)**
Configuration Management (CM)	28.29 (.000)	.704	-526.39	-4.85 (.000)
Automated Data Processing (ADP) Operations	7.28 (.004)	.364	-1109.25	-3.78 (.001)
Senior Management	11.89 (.000)	.486	-295.53	-1.26 (.111)
Quality Assurance (QA)	9.00 (.002)	.410	-81.31	-0.73 (.238)

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