

# Using Linear Regression Models to Analyse the Effect of Software Process Improvement

Joost Schalken<sup>1</sup>, Sjaak Brinkkemper<sup>2</sup>, and Hans van Vliet<sup>1</sup>

<sup>1</sup> Vrije Universiteit, Amsterdam, Department of Computer Science  
{jpp.schalken, jc.van.vliet}@few.vu.nl

<sup>2</sup> Utrecht University, Institute of Information and Computing Sciences  
s.brinkkemper@cs.uu.nl

**Abstract.** In this paper we publish the results of a thorough empirical evaluation of a CMM-based software process improvement program that took place at the IT department of a large Dutch financial institution. Data of 410 projects collected over a period of four years are analysed and a productivity improvement of about 20% is found. In addition to these results we explain how the use of linear regression models and hierarchical linear models greatly enhances the sensitivity of analysis of empirical data on software improvement programs.

## 1 Introduction

To improve the management and work processes in software development, the software process improvement field has proposed improvement models (such as the Capability Maturity Model [1], ISO-SPICE [2], and the Capability Maturity Model Integrated [3]) that are based on best practices and guidelines for software developing organisations. As each of these models focuses on a wide range of interacting practices, the benefits of an improvement model are not always intuitive. Therefore empirical data about the benefits of SPI is needed.

There is a lack of empirical studies on the effects of SPI in industry. Even for the most widely used improvement model, the Capability Maturity Model [1], little empirical data is available. In a recent meta analysis on the effects of the CMM, Galin and Avrahami [4] were only able to identify three studies that give details on productivity gains when an organisation progresses to CMM level 2 and only twelve studies that provide details on productivity gains when an organisation progresses to CMM level 3.

In this study we investigate the success of a software process improvement program at a large, Dutch financial institution. In this program the Capability Maturity Model has been used as the reference model for software process improvement and the Dynamic Systems Development Method (DSDM) [5] as the new project management methodology. We analysed the productivity of 410 projects during a period of four years and found a productivity increase of 20%.

If is often claimed that extensive measurement programs are ineffective in an immature organisation. We however believe that in immature organisations the

effects of SPI are invisible because the data is too noisy to be analysed with simple statistical techniques. In this paper we explain how regression models [6] and hierarchical linear models [7] help interpreting the productivity data. Regression models offer an improved sensitivity to changes in productivity and hierarchical linear models allow researchers to study SPI programs that take place in heterogeneous organisations. *Heterogeneous organisations* consist of departments that use different technologies and work on different products.

Using these statistical techniques results in an explained variance of over 60% for our data, as opposed to a mere 2% when a straight-forward productivity index is used.

This paper provides an answer to the following two questions:

1. What is the impact of a project's CMM level on its productivity?
2. To what extent do the outcomes of a CMM study depend on the choice of proper statistical techniques?

## 2 Related Work

Related work for this study consists of two bodies of literature: studies of the empirical results of software process improvement and literature of statistical techniques used in empirical software engineering.

In [8, 9, 10, 11] studies of software process improvement are described. The studies report the (solely positive) changes in productivity of software developing organisations, expressed in ratios of lines of code delivered per unit of effort (usually man months).

In their paper “*Do SQA Programs Work*” [4] Galin and Avrahami provide an overview of the above mentioned case studies and others that contain empirical evidence on the effects of software process improvement. They identified 22 studies relating to the effects of Capability Maturity Model based software process improvement. Of these 22 studies, only 19 contained sufficiently detailed quantitative data to allow a meta analysis of the SPI effects. The meta analysis examines the effects of CMM on error density, productivity, rework schedule time, conformance to schedule and the effectiveness of error detection.

The authors were able to locate three studies that examine the change in productivity when a software development organisation increases its maturity from CMM level 1 to CMM level 2 and ten studies that examine the change in productivity when an organisation increases its maturity from CMM level 2 to CMM level 3. On average an organisation increases its productivity by 42.3% when it matures to CMM level 2. And an organisation that increases its maturity to CMM level 3 improves its productivity by an additional 44.4%.

Related work on the analysis of productivity data is hard to find in software process improvement papers, however research in cost-estimation provides instructions on how to apply regression models to relate effort to size [12, chap. 5] [13, chap. 12] and therefore how to analyse productivity. Unfortunately the statistical techniques used for cost-estimation models are not used to elucidate changes in productivity caused by software process improvement. Related