

Holistic Software Process Performance Measurement From the Stakeholders' Perspective *

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Abstract

Organisations need to measure the performance of their software development process, in order to control, manage and improve it continuously. Current measurement approaches lack adequate metrics. This work improves software performance measurement with a stakeholder approach that fosters balanced and goal-oriented metrics. This approach has been implemented in a multi-national organisation. The metrics gathered have been actively utilised throughout the organisation for more than one year. The measurement approach has been verified through interviews with key project members.

1. Introduction

Organisations require a solid software process performance measurement program in order to improve their software development process continuously and to reach Level 3 of the Software Engineering Institute's Capability Maturity Model [7].

Software process measurement has been a research discipline for over 20 years, but there is a big gap between research and industry. Briand, Morasca and Basili analysed in [2] a large number of software metrics and point out that few metrics have successfully survived the initial definition phase, and are used in industry.

Software process performance measurement has a lot in common with other disciplines, but does not inevitably take their research results into account.

Business process performance measurement and software process performance measurement tackle similar research questions: the development of methodologies and metrics in order to measure, control, manage and improve a process. Business process performance measurement defines requirements for Key Performance Indicators (KPIs) that are fully ignored by the software metrics community. Well-established software measurement approaches, such as Goal Question Metric [1], do not link an organisation's strategy with the metrics of the software development process and do not focus on balanced measures.

In this work, we have integrated research results of business process performance measurement into software process performance measurement with the aim to foster goal-oriented and balanced metrics. In order to emphasise the importance of balanced metrics we have selected a stakeholder-driven performance measurement approach, described in Section 2. It has been applied to the software development process of a multi-national organisation. The metrics gathered are disseminated by a performance dashboard that has been in operation for more than one year. The dashboard is out of the scope of this work. In this paper, general requirements of software process performance measurement (Section 3), and the methodology and some metrics of the project are presented. We describe the process of deriving the metrics as well as the activities and roles of the project group in detail, and illustrate the set-up and design of the project in Section 4. The measurement approach has been verified through interviews with key project members (Section 5). Related work is discussed in Section 6. Finally, in Section 7 we conclude the paper and outline lessons learned.

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2. Stakeholders and Metrics

In the early 1990s a number of authors criticised traditional performance measurement. For instance, Kaplan and Norton argue that quality-oriented performance measures such as innovation or customer satisfaction are not an integral part of regular management reports, and that the very popular financial figures are hindering organisations' abilities to create future economic value [4]. An overemphasis on achieving and maintaining short-term financial results can cause organisations to overinvest into short-term fixes and to underinvest into long-term value creation. In order to provide a mechanism to help companies to translate and implement strategy, the Balanced Scorecard (BSC) [4] has been developed. The name reflects the balance provided between short- and long-term objectives, financial and non-financial. The BSC supplements traditional financial measures with three additional perspectives: customer, business process, innovation and learning.

Although the BSC has also been criticised, its achievement is the common acceptance of balanced indicators for modern performance measurement. The BSC is focused on corporations or organisational units, not on processes. It looks at business processes only as far as they have a great impact on customer satisfaction and achieve an organisation's financial objectives. As this work is focused on processes, we have chosen a measurement approach that is primarily focused on processes: Kueng's stakeholder driven process performance measurement approach [5]. The concept is focused on the stakeholders who have an interest in the process. For each KPI to be measured, one should be able to designate a group of people or organisations with a legal interest in getting information on the performance of the process, or who are able to improve process performance through their work. The term process performance is used as 'the degree of stakeholder satisfaction'.

There are four principal process stakeholders that represent an aspect or a dimension of process performance [5]: financial, employee, customer, and societal. In order to satisfy the four stakeholders in the long term, business processes need continuous improvement. Therefore, a fifth aspect has to be added, that is innovation. In general, stakeholders are not limited to these five; there can be more or less, if required.

The financial aspect measures the degree of satisfaction of the investor. The employee aspect evaluates the process from the employees' point of view. Employee aspects may cover a broad range of

subjects, e.g. communication, job conditions, physical discomfort, psychological well-being, workload, supervision, opportunities for growth, socialisation, or job satisfaction. The customer aspect evaluates the process performance from a customers' point of view, e.g. customer satisfaction through surveys. The societal aspect measures the impact of the process on the environment, for instance, what impact the process has on the local economy or how process-related pollution is perceived. The innovation aspect measures the improvement effort that is invested into the process. In summary, this approach is addressing to satisfy the four key stakeholders – investors, employees, customers and society – and improves the process continuously to guarantee long-term success.

After having discovered all stakeholders of the process, the appropriate process performance indicators must be derived from business process goals and target values must be determined for each indicator. The process goals can be derived from three sources: enterprise-wide objectives, business competitors, and stakeholders. Indicators must be balanced throughout all dimensions. This balanced set of indicators within a performance measurement system must cover *financial and non-financial indicators, quantitative and qualitative indicators, subjective and objective indicators as well as short-term and long-term indicators*.

3. Requirements of Software Process Performance Measurement

After studying the literature, we identified two types of requirements for software process performance measurement success: (1) the project team, and (2) metrics and methodology.

3.1. Project Team

According to Pfleger, Jeffery, Curtis and Kitchenham it is no coincidence that the most successful examples of software measurement are the ones where researchers, practitioners, and customers work hand in hand to meet goals and solve problems [8]. The following people are involved in software engineering and should be part of the measurement project, as they have a stake in the process [8]:

Developers, especially those involved in large projects with long schedules, use measurements to help them understand their progress toward completion.

Managers look for measurable milestones to give them a sense of project health and progress toward effort and schedule commitments.

Customers, who often have little control over software production, look to measurement to help determine the quality and functionality of products.

Maintainers use measurement to inform their decisions about reusability, reengineering, and legacy code replacement.

3.2. Metrics and Methodology

Beside the strong focus on balanced metrics (called KPIs in other disciplines), the following requirements for successful metrics are identified [3]:

Usefulness: The usefulness of metrics data should be obvious to all practitioners. If usefulness is not transparent, practitioners will collect data without enthusiasm and the data will probably lack validity.

Developer participation: Developers should participate in designing the metrics program. With high levels of developer participation, buy-in is more likely, as is the implementation of a more incisive metrics program.

Dedicated metrics team: Responsibility for the metrics program should be assigned to specific individuals.

A **Goal-oriented approach** is very important, as companies should collect data for a specific purpose.

Transparency: The metrics program must be obvious to practitioners. They must understand what data is being collected, why it is being collected, and how it is being used.

Metrics integrity: Practitioners should have confidence in the collected data.

Incremental implementation: Implementing a metrics program over time holds significantly less risk than a “big bang” approach.

4. Design

4.1. Project Background

Today’s typical requirement in a multinational organisation is to optimise the efforts on information technology (IT) related activities. Therefore, these organisations need to establish strong software development, maintenance and quality assurance skills.

The project described in this paper was set up as a feasibility study with a strong focus on the production environment. The project was a cooperation between the Vienna University of Technology and a multinational organisation, where all departments have access to the resources of the internal IT department. Several processes are established to coordinate and manage requests for internal IT projects.

It is not sufficient to measure the software process performance from outside considering the IT department a “black box”, but also the internal processes and collaboration between groups. The main goals of the project were to translate strategy into metrics and provide a holistic and integrated analytical measurement environment for the entire software development and maintenance process. Some IT groups already had some metrics in place but they were not comprehensive and well balanced.

4.2. Project Overview

Researchers from the university as well as employees of the organisation were members of the core project team. More precisely, the core project team consisted of the following people: 2 researchers, an IT project controller, a process designer, the software process owner, a quality management specialist, an architect, a developer, a BSC and metrics specialist, the developer of the organisation’s Software Process Performance Measurement System (SPPMS), and a person responsible for SLAs (service level agreements).

The enormous top management support raised the acceptance of the project and the willingness to cooperate with the project team. The Chief Information Officer was highly interested in the success of the prototype and therefore, he was the official project owner. The main goals of the SPPMS were:

- Translating IT strategy into metrics
- Timely information on projects at risk or failing projects
- Demonstration of the successful customer orientation of the IT department to the entire organisation
- Continuous software process improvement

The SPPMS has been designed and implemented to enable as well as support the measurement, control, management and improvement of the software development process. The process tackles software development, major or minor changes or bug fixes. The goals of the software development process are:

- Fast response time to initial project requests providing estimates for time, budget / resources and a delivery schedule
- High-quality of process outputs (accuracy of initial estimates, low cycle times, high product quality, delivery on time)
- Full (internal) transparency of the software development process at all stages

The software development process is the most important process of the IT department. But there are

also several other processes that support the strategic goals of the IT department. These goals are:

- Realise projects in time, in budget and in highest quality
- Provide defined operations in time and in budget
- Provide and guarantee adequate infrastructure equipment
- Improve customer satisfaction

The project was scheduled for 11 months (5 months design phase and 6 months implementation).

4.3. Metrics Elicitation

We identified the following stakeholders of the software development process:

Customers: Customers of the IT department are other departments that order IT projects.

Employees: People who are responsible for project development, major or minor changes or bug fixes and are part of the software development process.

Suppliers: Third party companies that deliver software or services for IT projects.

Internal or IT-Management: Similar to the finance dimension, the stakeholder represents the owner of the IT department.

Innovation: Represents the goal to continuously improve the software development process

Next, we defined goals for each stakeholder. These goals have been derived from software development process goals and strategic goals of the IT department. For each goal a number of metrics were derived. The data sources that supply the metrics with data were attached to each metric. Then, the metrics were prioritised by importance and ease of implementation. The metrics selected were specified in detail, according to the Metric Meta Data Specification (Table 1), which supports the requirements for transparency, integrity, usefulness and goal-orientation.

In the following we show goals of each stakeholder and some metrics that support these goals.

4.3.1. Stakeholder: Customer

The goals of the customers are: receive proposals immediately, high quality of product, adequate price, software according to specification, reliability in terms of time, stability of proposal, low administration effort and cost, transparency and flexibility.

The metrics for the stakeholder customer have a very balanced focus. There are metrics, e.g. “In time” and “In budget” that represent very traditional metrics: a financial, quantitative and objective metric. But there are also a lot of non-traditional metrics.

Customer satisfaction is important, as the customer could also select the products needed from external suppliers, not only from the internal IT department. In order to elicit the customers’ subjective opinion on the project, a customer survey was designed. For each project the customers receive a questionnaire and they have the opportunity to give feedback. There are several hundred completed projects per year. The metrics in the survey represent a comprehensive picture of the project. The metrics and questions of the customer survey can be found in Table 2. Each question can be marked between 1 and 5, where 1 is the best and 5 the worst mark is. The metrics of the survey are summarised in the “Survey Feedback Rating” and represent a non-traditional metric: a non-financial, qualitative and subjective metric.

Figure 1 shows as an example, how the metrics are visualised by the Dashboard. The screen of the metric ‘Customer Satisfaction Index’ is shown. This metric is comprised of several metrics including the metrics of the customer survey (Table 2). A so-called dashboard is a user interface, somewhat resembling an

Metric Meta Data Specification	
1.	Metric Name
2.	IT Department Goal
3.	Software Development Process Goal
4.	Stakeholder
5.	Description of Metric / Benefit of Metric
6.	Metric Type (Description of how the metric is calculated? Sum, average, formulas, etc.)
7.	Metric –Time - Aggregation: Yes / No?
8.	Measurement Category (e.g. Length)
9.	Unit (e.g. Meter)
10.	Metric Formula
11.	Target Value
12.	Data Source, Method of Data Collection
13.	Metric Owner (Responsible person for availability and correctness of metric)
14.	Metric User
15.	Metric Initiator (Core project team member who initiated the definition of the metric)
16.	Frequency of Availability
17.	Frequency of Reporting
18.	Dependencies, Strength of Impact: Which other metrics are affected by this metric and to what extend?
19.	Hints for Analysing poor Performance
20.	Presentation Metaphor (e.g. Traffic light, definition of colour regions)
21.	Short-term or Long-term metric
22.	Economic Importance
23.	Initial Expense (to establish metrics measurement and data integration)
24.	Operating Cost
25.	Priority for Implementation Within the Project

Table 1: Metric Meta Data Specification

automobile's dashboard. The goal is to provide all the important information at a glance. Typically, graphical metaphors (like traffic light colours) are used to allow the quick identification of which goals are on target and which areas need more attention.

Metric	Question in the Survey
Scope Fulfilled	Have all functions of the requirement specification been implemented?
Product Error-Free	Is the product error-free?
Progress reports	Have you received information on the progress of the project?
Quality of IT Contact Persons	Were you satisfied with your contact person?
Training	Have the users received adequate and sufficient training?
Price Adequacy	Is the cost / performance ratio adequate?
Documentation Fulfilled	Is the documentation helpful?
Time Adequacy	Have the requirements been realised in time?
Flexibility	Have changes of requirements been handled in a flexible way?
Cost Transparency	Are the proposed cost and actual cost transparent?
General Impression	Are you satisfied with the overall management of IT projects?

Table 2: Customer Survey

4.3.2. Stakeholder: Employee

The goals of the stakeholder employee are: modern work environment, good working conditions, and low administration effort. These goals are represented by traditional and non-traditional metrics. The goal good 'working conditions' is supported by an employee survey that is conducted twice a year, and a lot of traditional metrics: e.g. number of expired vacation days, number of vacation days not taken, working hours per week, sickness days, unscheduled work at weekends, labour turnover, bonuses, and number of projects the employee works on in parallel.

4.3.3. Stakeholder: Suppliers

The stakeholder supplier is focused on third party companies that deliver software or services for IT projects. The goals are: stability and reliability of outsourcing specifications, efficient completion of projects, and good documentation. The goal 'efficient completion of projects' is measured with the metrics: quality management costs for proof of product, time between contract and product, and product acceptance and payment. The goal 'stability and reliability of outsourcing specifications' is measured with the

metrics: number of changes of the specification and number of errors in the delivered product.

4.3.4. Stakeholder: Internal or IT Management

The goals of this stakeholder that represent the owner of the IT department are: profitability, transparency of resources, stability of proposal, low product life-cycle-cost, and that software development should be done according to the standard process without a lot of deviations. For example the goal 'stability of proposal' is measured with two metrics: number of proposal changes and number of accepted and rejected proposals.

Beside these traditional metrics, every project leader receives a questionnaire for every project (Table 3) where he / she can state a subjective opinion on key issues from a management's point of view. These results can be also used as an explanation for failed objective results. For example, very poor skills of the team members can justify the very long project duration or low quality of the software.

Metric	Question in the Survey
Requirement Specification	Has the requirement specification been described adequately?
Collaboration with DWH Team	Are you satisfied with the DWH Team?
Test and Acceptance Reports	Have you received adequate information on the test and acceptance reports?
Test Specification	Was the test specification adequate?
Collaboration with Quality Management	Are you satisfied with the quality management group?
Collaboration with the Customer	Was the collaboration with the customer satisfying?
Collaboration with Vendors	Was the collaboration with vendors satisfying?
Team Skills	Were the team members sufficient qualified to do a good job?
Internal Skills	Are there any internal employees who could have done the job of an external team member?

Table 3: Project Leader Survey

4.3.5. Stakeholder: Innovation

The stakeholder innovation is focused on improving the process itself and the skills of the organisation's employees. New software processes, development environments, programming languages, frameworks, etc. are targeted. Therefore, metrics like training days of employees, progress of innovation projects or the process owner's time spent on improvement issues are gathered. This stakeholder emphasises the process, as it has a direct impact on the quality of the software product.

5. Evaluation

The stakeholder driven approach has been evaluated with interviews of key project members one year after introduction. Meanwhile, all employees from the IT department have access to the Dashboard.

The enormous top management support raised the acceptance of the project. But the interviewees stated that this unusual approach would have not been possible without the participation of researchers from the university. The reasons for that are manifold: Firstly, because the researchers were accepted as specialists in their field. Secondly, the project did not require a big financial budget. Compared to a project with a consulting company, the financial expenditure was almost not to be taken into account. Thirdly, the researchers introduced a novel approach, which was highly appreciated by the technology minded employees of the IT department.

The interviewees further stated that the large project team supported the great acceptance, as the project members were from different departments and groups of the company and promoted the project there. In order to institutionalise the Dashboard as a means of reporting company-wide, the metrics have become part of the personal business commitments of the organisation's employees. Accomplishing or missing these goals impacts, like in any other organisation that applies management by objectives, on the height of promotions, and finally on salaries.

The interviewees stated that through the stakeholder approach atypical, interesting, and new metrics have flourished and they also admitted that these metrics were very useful for a broader analysis perspective. Beside balanced metrics, the stakeholder approach created an interesting side effect: a personal view for analysts, as the stakeholders focus on the dimension dedicated for them and analyse it as a personal view.

In general, the stakeholder approach is focused on balanced metrics. The focus of this project has been in particular on customer oriented metrics, captured by the customer survey. The survey has become well established and integrated in managerial structures. Management uses the available survey intensively and negative metrics lead to actions. They are very much interested in the opinions of their customers on the projects. For example, a poor communication between customers and the IT department has been highlighted by the customer survey and has lead to a new goal within the IT department, namely the improvement of the communication with customers. Actions supporting this goal, like giving regular information on the project state to the customer and integrating the feedback of

the customer have been integrated into the software development process. The customers very much appreciated the focus on their needs, especially because their feedback has led to improvements. The relationship between the IT department and its customers has improved, due to the customer focus of the metrics.

Before the project, the goals and metrics of the IT department as well as of the software development process were not explicitly available. This has been the greatest achievement of the project, to translate strategy into metrics and to make them visible to all employees. The extensive metric metadata specification, and the transparent link between metrics and goals have made sure that the usefulness and the transparency of metrics is obvious to practitioners.

The metrics are utilised as the basis for sensitive decisions, and all employees of the IT department focus on these metrics. The Dashboard has become an important source of information on the state of projects, and an integral part of every day work for management.

6. Related Work

There are a lot of measurement approaches available. The most important for researchers and practitioners is the Goal Question Metric (GQM) [1]. It is based upon the assumption that for an organisation to measure, it must first specify the goals for itself and its projects (GOALS), then it must trace those goals to the data defining them operationally (QUESTION), and finally provide a framework for interpreting the data with respect to the stated goals (METRIC). Goals are defined for objects, which are processes, products or resources. A set of questions is used to characterise the way the achievement of a specific goal is going to be performed. Metrics are seen as a set of data associated with every question in order to answer it in a quantitative way. The data can be objective or subjective. An objective measure depends only on the object being measured; the subjective measure depends also on the viewpoint from which it is taken. The focus of GQM approach is on quantitative metrics, it does not address balanced indicators, and stakeholders are of minor importance. Although the metrics are based on process goals, the goals are not linked to department or organisational goals, and the metrics are very traditional.

The stakeholder driven approach was successfully applied to business process performance measurement in [6]. The approach has led to balanced metrics, which are by far not as complex as the metrics of a software development processes.

7. Conclusion

In this work, a stakeholder-driven performance measurement approach has been applied to the software development process of a multi-national organisation. The metrics gathered are disseminated via a performance dashboard.

Researchers from the university, employees and customer representatives of the organisation were part of the project team. The strong management support raised the acceptance of the project. The integration of the measurement system into the organisational culture e.g. part of employees' personal business commitments has led to user acceptance. A comprehensive meta data specification of the metrics fostered transparency, and has also contributed to user acceptance. Non-traditional metrics, particularly subjective metrics have flourished e.g. the metrics of the customer survey. In general, an important achievement of the project was to make the goals and metrics of the IT department as well as of the software development process explicitly available, which was not the case before.

The project has shown that the stakeholder approach stresses the elicitation of balanced metrics. Overall, the stakeholder approach has proven successful in this organisation. Therefore, the project is going to be extended for all processes in the IT department.

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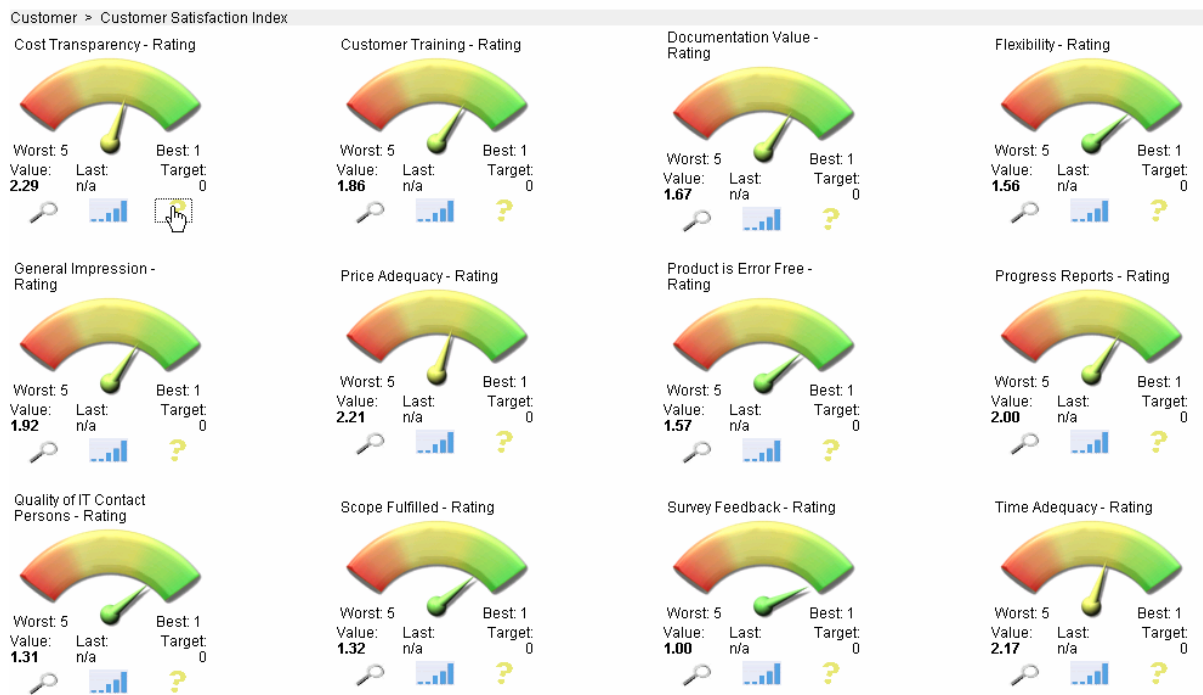


Figure 1: Customer Satisfaction Index