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This is the fourth in a series of articles aimed primarily at those who are beginning or thinking about beginning a process improvement journey. These articles address five questions, which have proven useful in thinking about and structuring process improvement programs. They are based on the premise that any process improvement program should be driven by and related to some set of business or overarching organizational needs. Process improvement for its own sake will soon die. It must address strategic organizational imperatives if it is to be successful.

The five questions are:
I. Motive - What are the critical business issues driving process improvement?
II. Model – Which reference model best maps to the organization practices?
III. Method – How can you quickly and effectively identify improvement opportunities?
IV. Managing Change - What factors impact the effectiveness of introduced changes?
V. Measures – What are critical factors in setting up a measurement program?

This article addresses question V – Measures.

Measurement Principles

The final step in process improvement (and the first step in the next improvement cycle) is to determine the impact on the organization of the changes that have been implemented. This implies some set of measures, which can be compared against a baseline in order to determine quantitatively how successful the process improvement program has been. To be effective, software measurement should be integrated with an overall strategy for software process improvement.

The Practical Software Measurement (PSM) project was developed to transition measurement into day-to-day practice. Measurement professionals from a wide variety of organizations participated in the PSM project, including U.S. and international representatives from government and industry. PSM is based on actual measurement experience on Department of Defense (DoD), government and industry programs, and treats measurement as a flexible process, not a pre-defined list of graphs or reports. The guidebook, Practical Software and Systems Measurement, is available from the Practical Software and Systems Measurement Support Center Web site at www.psmse.com.

PSM is built around nine measurement principles:

- **Objectives and issues** are used to drive the measurement requirements. Project objectives are goals and requirements: cost, schedule, quality, functionality, and technical performance. Issues are areas of concern that present obstacles: problems, risks and lack of information.
- **Define and collect measures** based on the technical and management processes. Measures should be collected as a natural byproduct of the work performed. Consider the processes of other team members and subcontractors as well as your own project processes.
- **Collect and analyze data** at a level of detail sufficient to identify and isolate problems. Periodically collect, process and analyze measurement data. Specific data depends on project objectives and issues and the kinds of questions you need to answer.
- **Implement an independent analysis capability.** An independent group should assess measurement data. This ensures objectivity and accurate, unbiased assessment of project status.
- **Use a systematic analysis process** to trace the measures to the decisions. The meaning of the numbers must be understood. There should be a clear flow from the data through the analysis to the conclusions. The analysis process should provide repeatable results.
- **Interpret** the measurement results in the context of other project information. No measurement result is good or bad by itself. A variance between planned and actual only indicates a possible problem, not the cause.
- **Integrate measurement** into the project management process. Measurement provides insight into the
current phase. It also can project consequences of current actions on later phases.

- Use the measurement process as a basis for objective communications. Involve the entire project in developing the measurement process. All parties should use same data and have a common understanding of the data definitions and commitment to the value of the measurement program.
- Focus initially on project-level analysis. Project success means meeting specific project objectives. Implement a consistent measurement process on all projects. Organization-level data can be derived from well-defined project measures.

**Measurement Program**

Setting up a metrics program (metrics are defined as a combination of two or more measurements) can be difficult and time-consuming. Perkins\(^2\) suggests a nine-step process in the, "Nine-Step Metrics Program."

**Planning:**

- Define information needs based on project issues and objectives.
- Define metrics and analysis methods.
- Define selected measures.
- Define the collection process of measurement data.

**Measurement implementation:**

- Collect the measurement data.
- Analyze the measurement data to derive metrics.
- Manage the measurement data and metrics.
- Report the metrics.

**Measurement program evaluation:**

- Review the usability of the selected metrics.

**What Information Should I Collect?**

Capers Jones\(^3\) suggests that the best way to decide what to measure is to find out what industry leaders measure, and then measure the same things. He recommends a large number of metrics in three categories: Quality Measures, Productivity and Schedule Measures, and Business and Corporate Measures.

On the other hand, lower maturity organizations should not try to do too much. A few metrics should be selected which will be useful for project management and applied across the board. As experience and confidence are gained, more metrics can be added. Those that don’t add significant value should be removed. For example, if the business goals are based on functionality, cost, time to market and quality, project and process issues that relate to achieving those goals should be identified. Process performance can then be quantified by measuring attributes of products produced by the processes as well as by measuring process attributes directly.\(^4\)

![Figure 1. The Goal-Question-Metric Approach](http://www.chips.navy.mil/archives/02_spring/index2_files/five_critical_questions_in_proc... 6/2/2006)
**The Goal-Question-Measures (GQM) Approach**

In goal-driven measurement the primary question is not "What metrics should I use?" but "What do I want to know or learn?" Because the answers depend on your goals, no fixed set of measures is universally appropriate. The goal-driven measurement process is based on three precepts, illustrated in Figure 1, and consists of ten steps. The three precepts are:

- Measurement goals are derived from business goals. The goal-driven process begins with identifying business goals and breaking them down into manageable sub-goals.
- Evolving mental models provide context and focus. The primary mechanisms for translating goals into issues, questions, and measures are the mental models that you have for the processes you use. These mental models gain substance and evolve as you begin to make them explicit. They are the engines that generate the insights that guide you to useful measures and actions.
- GQM translates informal goals into executable measurement structures. The process ends with a plan for implementing well-defined measures and indicators that support the goals. Along the way, it maintains tractability back to the goals, so that those who collect and process measurement data do not lose sight of the objectives.

The ten GQM steps are:

1. Identify your business goals.
2. Identify what you want to know or learn.
3. Identify your sub-goals.
4. Identify the entities and attributes.
5. Formalize your measurement goals.
6. Identify your measurement questions & indicators.
7. Identify the data elements.
8. Define and document measures and indicators.
9. Identify the actions needed to implement your measures.
10. Prepare a plan for implementing the measures.

In using the GQM approach to develop a set of metrics, use the following guidelines:

- State a goal. Use brainstorming technique or start from established goals.
- Do we understand the goal? If not, break it down to a lower level. Ask questions that will translate the goal into measurable attributes. We understand it when the focus or subject of the goal can be described in a single unit of measure (number)
- Once we understand the goal (or its attributes), identify the measures (or metrics) that characterize it. Use brainstorming to identify candidate metrics/measures. Select the primary metrics from the list of measures generated. Is it at the right level of detail? Is it a sub-element of another metric? Is it another (redundant) point of view? Is it derivable from directly measurable quantities? If so, have we identified those measures? Is it cost effective to collect?
- Decide what question(s) management should ask to determine if we are meeting the goal. This is Q in GQM that is our end product. Use brainstorming. Derive it from our metrics/measures.

More detail can be found in "Goal-Driven Software Measurement - A Guidebook.""^5

**Presenting the Data**

While numbers are the essence of measurement data, visual presentation can often be the most effective technique in helping understanding of the numbers. Rate charts, for example, quickly show the trend and direction of a time series such as cost or defects. Pie charts and column or bar charts can show the relative sizes of various groups such as defect categories or sources. Structure diagrams such as flow charts or organization charts portray relationships among critical elements of a system. The
key to creating effective data graphics is the combination of good graphic design and appreciation of statistics that Edward Tufte defined as graphical integrity.6, 7

Presentation of the data to process users and decision makers is another critical issue in measurement. At lower levels of organizational process maturity, measurement still needs to be "sold." Even if a metrics plan were perfectly implemented, it still would be incomplete unless the correct level of management makes decisions based on the metrics. It has been well documented that management buy-in and commitment are necessary before a metrics process can work.8

At higher levels of organizational maturity, data can be used to characterize and improve the processes as well as providing management control of projects. At Level 3 metrics are collected, analyzed, and used to status development and to make corrections to development efforts as necessary. At Level 4 measurements are quantitatively analyzed to control process performance of the project and to develop a quantitative understanding of the quality of products to achieve specific quality goals.9 At Level 5 data are used to identify and select new technologies and process innovations based on the organization’s process improvement goals and objective criteria, to understand the impact of proposed changes, to plan and manage deployment of changes, and to establish measurably better processes and products.10

Considerations

There are three questions to consider in setting up a measurement program:

Are the measures relevant? How will you know if your critical parameters have improved? How do those measures relate to the Key Process Areas? Will moving up maturity levels achieve improved effectiveness?

Are the measures significant? Is the Capability Maturity Model maturity level consistent with measured improvements in business and quality? Does the organization prepare with rigor for an assessment but afterwards give less than that effort to sustain and improve? The appearance of process maturity is not a substitute for having process maturity - there’s more to the CMM than an assessment!

Are the measures objective? "Think of the organizational measurement system as the dials and indicators in an airplane cockpit. For the complex task of navigating and flying an airplane, pilots need detailed information about many aspects of the flight: fuel, air speed, altitude, bearing, destination and other indicators that summarize the current and predicted environment."11

"Now consider what this analogy would be like if it included a multitude of tiny gremlins controlling wing flaps, fuel flow, and so on of a plane being buffeted by winds and generally struggling against nature, but with the gremlins always controlling information flow back into the cockpit instruments, for fear that the pilot might find gremlin replacements."12

Measurement Dangers

In "Measuring and Managing Performance in Organizations," Austin said, there are two main uses of measurements. Each has a set of problems associated with it. Further, mixing the two uses can have negative effects. In particular, informational measures can be intentionally or inadvertently subverted into motivational measures.

Informational measures are used to provide process/product insight and a basis for decision-making. They should not affect behavior. Informational measures have two kinds of problems:13

Unclear meaning. Numbers may not be clearly understood, due to not realizing the implicit model (10) between the numbers and the reality, e.g., what is the meaning in the real world of the Technical Complexity Factor in the Function Point Method? How does this impact project effort?

Inappropriate operations. Not all numbers can be meaningfully averaged or otherwise combined or manipulated. e.g., a 2000 LOC program probably will take something other than twice as long as a 1000 LOC program to complete.
Motivational measures are used to promote greater effort in pursuit of organizational goals. They should affect behavior. The main problem with motivational measures is that they can become dysfunctional; i.e., they can motivate undesired behaviors. Robert Austin said, "Dysfunction occurs when the validity of information … is compromised by the unintended reactions of those being measured. The major problem for most incentive systems is … bias intentionally introduced by those being measured." The dynamic of dysfunctional measures is shown in Figure 2.

Examples of dysfunctional measures include standardized tests (coaching and preparation skews results), production targets ("storming" ignores quality and equipment maintenance), sales commissions (overselling, not providing value to the customer), stock value (quick cuts, short-term changes), "kills" (Vietnam deaths encouraged/inflated), piecemeal pay (can lead to quality problems), planned vs. actual (re-baselined cost, schedule), and defects (over/understated, misdiagnosed). Dekkers suggests some ways to prevent dysfunction:

- Don't have the measures take the place of the underlying goals.
- Workers should be internally motivated; measurement should provide them with self-assessment information.
- Reinforce, don't enforce, human behavior.
- Watch out for opportunistic behaviors.
- Set solid objectives and plans.
- Make measurement part of the process.
- Understand benefits and limitations.
- Focus on cultural issues.
- Create a safe environment for collecting and reporting data.
- Be ready to change.
- Have a complementary suite of measures.

**Summary and Conclusion**

Measurement is both the end and the beginning of successful process improvement. The collection of accurate metrics is a pointless exercise until the data are analyzed and used to predict and influence future events. Any process improvement program should be driven by and related to some set of business or over-arching organizational needs. A model should be selected which maps well to the organization’s critical processes. After selecting a model it’s necessary to decide how the organization will assess its conformance to the model parameters. Based on the assessment findings an action plan is developed and implemented which addresses both specific process changes and organization cultural issues. The effects of these changes are then evaluated using the measurement program. These measures may indicate additional changes, which would be beneficial. The PDPISM framework illustrated in Figure 3 helps organizations deal with these five key issues of organization improvement and maturation.
Figure 3. Purpose Driven Process ImprovementSM Framework

References


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