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Measurement: Key Concepts and Practices

All successful software organizations implement measurement as part of their day-to-day management and technical activities. Measurement provides the objective information they need to make informed decisions that positively impact their business and engineering performance. In successful software organizations, measurement-derived information is treated as an important resource and is made available to decision makers throughout all levels of management.

Software measurement has evolved into a key software engineering discipline. In the past, many software organizations treated measurement as an additional, non-value-added task, or just “another thing to do.” Measurement is now considered to be a basic software engineering practice, as evidenced by its inclusion in the Level 2 maturity requirements of the Software Engineering Institute’s Capability Maturity Model Integration (CMMI) products and related commercial software process standards.

The way measurement is actually implemented and used in a software organization determines how much value is realized in terms of business and engineering performance. Measurement is most effective when implemented in support of an organization’s business and technical objectives and when integrated with the existing technical and management activities that define a software project. Measurement works best when it provides

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objective information related to the risks and problems that may impact a project's defined objectives. In other words, measurement works best when it is considered a significant, integral part of project management.

Top-performing organizations design their technical and management processes to make use of objective measurement data. Measurement data and associated analysis results support both short and long-term decision making. A mature software development organization typically uses measurement to help plan and evaluate a proposed software project, to objectively track actual performance against planned objectives, to guide software process improvement decisions and investments, and to help assess overall business and technical performance against market-driven requirements. A top-performing organization uses measurement across the entire life cycle of a software project, from inception to retirement. Measurement is implemented as a proactive discipline, and measurement-derived information is considered to be a strategic resource.

1.1 Motivation for Measurement

Why measure software? To begin, software has become a major factor in corporate investment and business strategies, even for "non-software-intensive" organizations. It is a key component in an organization's ability to maintain pace with rapidly changing information technology in an increasingly competitive environment. Given the large corporate investment in developing and maintaining critical information assets, there is a growing demand for more objective assessment and management of software-intensive projects.

Measurement is most important at the project level. Software measurement helps the project manager do a better job. It helps to define and implement more realistic plans, to properly allocate scarce resources to put those plans into place, and to accurately monitor progress and performance against those plans. Software measurement provides the information required to make key project decisions and to take appropriate action. Measurement helps to relate and integrate the information derived from other project and technical management disciplines. In effect, it allows the software project manager to make decisions using objective information.

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Specifically, software measurement provides objective information to help the project manager do the following:

- *Communicate Effectively:* Measurement provides objective information throughout the software organization. This reduces the ambiguity that often surrounds complex and constrained software projects. Measurement helps managers to identify, prioritize, track, and communicate objectives and associated issues at all levels within the organization. It also is important to communicating between supplier and acquirer organizations.
- *Track Specific Project Objectives:* Measurement can accurately describe the status of software project processes and products. It is key to objectively representing the progress of project activities and the quality of associated software products across the project life cycle. Measurement helps to answer crucial questions such as: “Is the project on schedule?” and “Is the software ready to be delivered to the user?”
- *Identify and Correct Problems Early:* Measurement facilitates a proactive management strategy. Potential problems are objectively identified as risks to be assessed and managed. Existing problems can be better evaluated and prioritized. Measurement fosters the early discovery and correction of technical and management problems that can be more difficult and costly to resolve later. Managers use measurement as a resource to anticipate problems and to avoid being forced into a reactive, fix-on-fail approach.
- *Make Key Trade-off Decisions:* Every software project is subject to constraints. Cost, schedule, capability, technical quality, and performance must be traded off against each other as well as managed together to meet established project objectives. Decisions in one area almost always impact other areas, even if they seem unrelated. Measurement helps the decision maker to assess these impacts objectively and make informed trade-offs to best meet project objectives and to optimize software project and product performance.
- *Justify Decisions:* The current software and information technology business environments demand successful project performance. Business, technical, and project managers must be able to *defend* the basis of their estimates and plans with historical performance data. Then, they must be able to justify changes to plans with current

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performance data. Measurement provides an effective rationale for selecting the best alternatives.

Like any management or technical tool, measurement cannot guarantee that a project will be successful. However, it does help the decision maker take a proactive approach in dealing with the critical issues inherent in software- intensive projects. Measurement helps the project, and consequently the organization, to succeed.

1.2 Measurement as an Organizational Discriminator

The current software business environment is characterized by rapidly changing technology within an extremely competitive market. In both the shrink-wrapped and unique-application software marketplace, customers demand more functionality at a lower price and rapid implementation of any new capability to satisfy their changing business demands. In today's environment, it is becoming increasingly difficult to establish a software organization as an information technology market leader and even more difficult to maintain it as a top-performing organization—an organization that performs better than its competitors from both technical and business perspectives.

Experience has shown that almost every top-performing organization can be described as follows:

- Accurate, objective information is available to all decision makers, and its use is an integral part of the corporate culture.
- Past, present, and future business and technical perspectives are taken into account to help define project objectives and performance expectations.
- Organizational processes and procedures are designed to identify, characterize, and manage change. Dealing with change is part of how the organization does business.
- Both good and bad news are freely communicated within the organization. Issues are openly identified and addressed.
- There is a cultural bias for informed decision making and taking action.

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These characteristics are all information-related and, therefore, measurement-related. To be a top performer in its sector, an organization needs the right kind of information, on a regular basis, to make the right decisions. It uses information to become more efficient and to produce better-quality products. Measurement facilitates and accelerates organizational learning and supports corporate adaptation within the marketplace. Measurement provides a structure for learning from each project, whether or not it was a good experience. Measurement also helps an organization understand the gaps between how it is performing and the performance levels demanded by the marketplace. It allows an organization to optimize within its business and technical constraints. In effect, measurement information becomes a competitive resource, and an effective measurement process becomes an organizational discriminator.

1.3 The Foundation—Project Measurement

Given measurement's strong relationship to software organizational performance, the key challenge is to implement it in a manner that has the most positive impact on each of the projects within the organization. The foundation of any organizational software measurement program is established at the project level. An organization's performance is essentially based on the success of its projects. To be successful, project and technical managers must make critical decisions related to project resources, schedule, and functional capability on a continual basis. These decisions must result in optimization of the business and technical performance of the software product within organizational and market-driven constraints. There is little room for project rework and restarts.

The software project manager must integrate all of the diverse aspects of software to be successful. Decisions are made daily, if not hourly, on how the technical product will be developed and managed, how resources will be allocated, and which issues will be addressed in what priority. The more effective these decisions are, the more successful the project. The more objective the available data and information, the better the decisions. The project manager usually must guide the project toward planned project objectives, while operating within established constraints.

The project environment is generally one of multiple and diverse cost, schedule, and technical considerations. Experience shows that even in rel-

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atively small information technology organizations, each project is unique in terms of domain application, implemented technical processes, operational interdependencies with other systems, and various constraints. Add in the usual and sometimes constant technical and management changes, and each project emerges with distinct process and product characteristics.

The organizational measurement approach must be adaptable to effectively address the unique information needs and characteristics of each project. *Practical Software Measurement* focuses on project-level measurement and shows how measurement can be tailored to satisfy the needs of each project.

Although the project level is the primary level for implementing measurement within an organization, there are valid information needs at higher organizational management levels. In almost all cases, objective organizational-level information is derived from the projects. You need good project data to analyze overall organization. Organizational software measurement can be viewed as measurement across many projects, validly combining the measurement data generated by each project and using different analysis techniques to satisfy different information needs. For example, managers at many different organizational levels may be concerned with how long it takes to develop and field a given software product. The project manager is concerned with the time it takes to implement product capability and reliability and with developing the software product within cost objectives. The marketing or business manager may be concerned with the time it takes to market a new capability and the potential impact of a possible delay on market share. The process manager may be concerned with an overall increase or decrease of the average software-development time line for all of the organization's products and the related impacts from organizational process changes. In all cases, the key variable is the availability of quality data at the project level, and, in fact, most corporate measurement activities take place at the project level.

1.4 What Makes Measurement Work

Many different approaches have been used to implement software measurement on a software-intensive project. Not all of them have been effec-

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tive, and many have not even outlived the project itself. Some of these approaches have been based on the detailed definition of the “best” set of measures equally applicable to every project in the organization. Others have relied on automated measurement and analysis tools purchased from a vendor with little regard for the organization’s processes or business practices already in place. In both of these cases, measurement became just “something else to do” and did not materially help the project achieve its objectives. What makes measurement work in an already challenging project environment? Experience across a wide range of software development and maintenance projects suggests two key characteristics of a successful measurement program:

- The collection, analysis, and reporting of measurement data that relates directly to the **information needs** of the project decision makers. This can be characterized as an information-driven measurement approach, where measures are defined and implemented to address the specific information needs of the project on a prioritized basis, as defined by established project objectives and associated issues. As the project progresses and the information needs change, so do the applied measures. Inherent to the information-driven measurement approach is a clear understanding of the relationships between what information is needed, what is actually measured, and how the measures are defined and combined into usable results.
- A structured and repeatable **measurement process** that defines project measurement activities and related information interfaces. This process must be flexible and adaptable to support existing software technical and management processes and environments already in place, as well as to support the characteristics of the specific application domain. The measurement process must be iterative, continually focusing measurement efforts on the most critical issues. The measurement process is in place throughout the existence of the project. It supports the measurement of evolving process and product attributes as project information needs, and related objectives and issues, change.

The information-driven measurement approach and the measurement process work together on a continual basis during the project life cycle, providing different information to the project managers as their needs change. Both are tailored to meet the specific characteristics of each proj-

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ect. Together they provide a basis for measurement tasks and procedures that support successful project completion and improved business and engineering performance.

To be effective, measurement must be implemented within a project or organization as a supporting software engineering process. As such, measurement must include all of the activities associated with planning, performing, and evaluating measurement-related tasks within an overall project or organizational structure. Measurement does not stand alone. It is implemented within the project environment to define what information the decision makers need and how this information is collected, analyzed, presented, and used. The measurement process combines diverse subjective and objective data into integrated information products that directly address defined project information needs.

Practical Software Measurement provides experience-based guidance on how to define and implement a viable information-driven measurement process for a software-intensive project. PSM addresses the development of a project measurement information structure using the **Measurement Information Model**, and it describes measurement activities and tasks using the **Measurement Process Model**.

1.5 Measurement Information Model

The Measurement Information Model described here is one of the fundamental concepts inherent to a successful, information-driven measurement program. The Measurement Information Model is a mechanism for linking defined information needs to the project software processes and products, the entities that can actually be measured. It establishes a defined structure for relating measurement concepts and, as such, provides a basis for accurately communicating measurement results within the organization.

The Measurement Information Model is a primary resource within the measurement process. It provides a structure that defines specific project measures and relates them to the needs of project decision makers. It provides a well-defined analysis path that supports recommendations derived

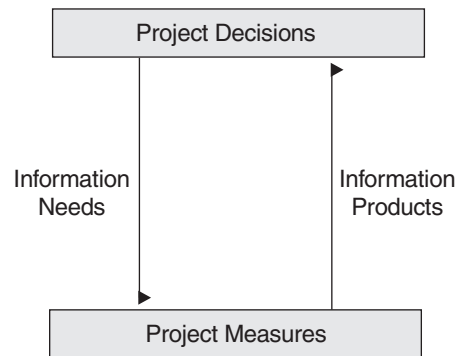


Figure 1-1 Measurement Information Model Relationships

from the analysis of the collected data. The Measurement Information Model directly supports both measurement planning and analysis activities.

In their most basic form, the relationships defined by the Measurement Information Model are depicted in Figure 1-1. During the planning and execution phases of a software project, technical and management decisions addressing many different areas must be made on a continuing basis. Decision makers must make trade-off decisions involving cost, schedule, capability, and quality. As a result, there is a definitive need for information to support the decision-making process. The Measurement Information Model helps to define the information needs of the project decision makers and focuses measurement planning activities on the selection and specification of the most appropriate software measures to address those needs. As the measures are implemented and data is collected, the Measurement Information Model structures the measurement data and associated analysis into structured **information products**. These information products integrate the measurement results with established decision criteria and present recommendations to project decision makers on alternative courses of action.

In a typical software project, there are many information needs defined at any point in time. These information needs tend to change significantly during the course of the project, based on changing project objectives, assumptions, and constraints.

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Chapter 2 fully describes the Measurement Information Model and all of its components.

1.6 Measurement Process Model

The Measurement Information Model provides a structure for relating information needs, measures, and information products. The Measurement Process Model works in conjunction with the Measurement Information Model to provide an application framework for implementing measurement on a project. Both models work together to define a measurement program appropriate for each particular, and unique, project.

Figure 1-2 depicts the Measurement Process Model. The model is built around a typical “Plan-Do-Check-Act” management sequence, adapted to support measurement-specific activities and tasks. The Measurement Process Model includes four primary activities, each of which is essential to successful measurement implementation. These activities include

- Plan Measurement
- Perform Measurement
- Evaluate Measurement
- Establish and Sustain Commitment

The Plan Measurement activity encompasses the identification of project information needs and the selection of appropriate measures to address these needs using the Measurement Information Model. Plan Measurement also includes tasks related to the definition of data collection, analysis, and reporting procedures; tasks related to planning for evaluating the measurement results in the form of various information products; and tasks for assessing the measurement process itself. Most significantly, the Plan Measurement activity provides for the integration of the measures into existing project technical and management processes. Rather than force a project to implement a predefined measure, PSM, through this integration task, ensures that the selected measures will be effective within the context of the project. The Plan Measurement activity also addresses the resources and technologies required to implement a project measure-

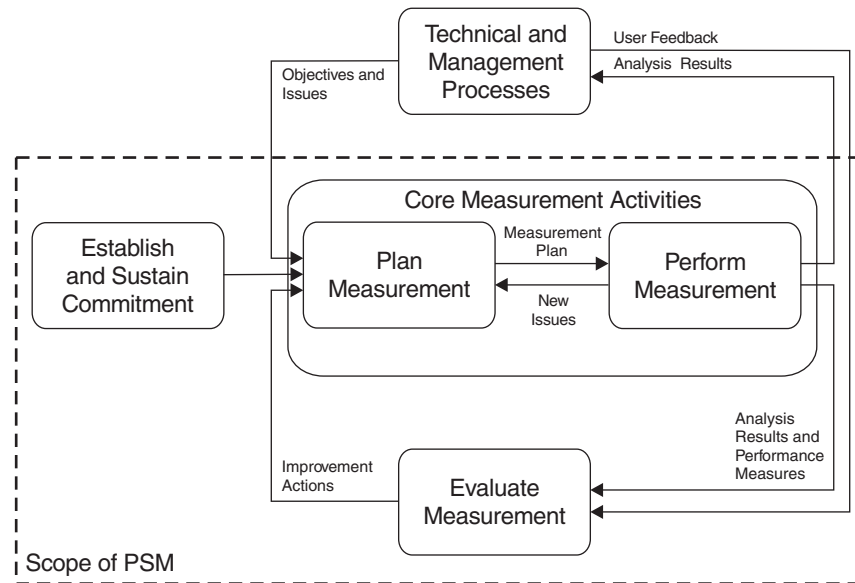


Figure 1-2 Measurement Process Model

ment program. The output of the Plan Measurement activity is a well-defined measurement approach that directly supports the project's information needs.

The Perform Measurement activity, along with Plan Measurement, is one of the core activities that directly address the requirements of the measurement user. Perform Measurement encompasses the collecting and processing of measurement data; the use of the data to analyze both individual information needs and how the information needs and associated issues inter-relate; and the generation of information products to present the analysis results, alternative courses of action, and recommendations to the project decision makers. Perform Measurement implements the measurement plan and produces the information products necessary for effective measurement-based decision making.

The Evaluate Measurement activity applies measurement and analysis techniques to the measurement process itself. It assesses both the applied measures and the capability of the measurement process, and it helps iden-

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tify associated improvement actions. The Evaluate Measurement activity ensures that the project measurement approach is continually updated to address current information needs and promotes an increasing maturity of the project and organizational measurement process.

The Establish and Sustain Commitment activity ensures that measurement is supported both at the project and organizational levels. It provides the resources and organizational infrastructure required to implement a viable measurement program.

A fifth activity, Technical and Management Processes, is also depicted in the Measurement Process Model. Although technically not a measurement-specific activity the technical and management processes interface directly with the measurement process. The project decision makers operate within these processes, defining information needs and using the measurement information products to make decisions.

The Measurement Process Model is iterative by design. It is defined to be tailored to the characteristics and context of a particular project and to be adaptable to changing project information and decision requirements. Both the Measurement Information Model and the Measurement Process Model establish a measurement approach that captures the experience of and principles learned from previous software measurement applications. Together they provide the basis for an effective software measurement program.