15939™

IEEE Standard Adoption of ISO/IEC 15939:2007— Systems and Software Engineering— Measurement Process

IEEE Computer Society

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IEEE Standard Adoption of ISO/IEC 15939:2007— Systems and Software Engineering— Measurement Process

Sponsor

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Abstract: A measurement process applicable to system and software engineering and management disciplines is defined by this International Standard. The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users. This International Standard identifies a process that supports defining a suitable set of measures that address specific information needs. It identifies the activities and tasks that are necessary to successfully identify, define, select, apply, and improve measurement within an overall project or organizational measurement structure. It also provides definitions for commonly used measurement terms. This International Standard provides an elaboration of the measurement process from ISO/IEC 15288:2008 and IEEE Std 15288-2008, as well as ISO/IEC 12207:2008 and IEEE Std 12207-2008.

Keywords: measurement, metric

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Introduction

This introduction is not part of IEEE Std 15939-2008, IEEE Standard—Adoption of ISO/IEC 15939:2007—Systems and Software Engineering— Measurement Process.

This standard is identical to ISO/IEC 15939:2007. The properties of the activities of the measurement process that are defined in this International Standard are the same properties defined in ISO/IEC 15288:2008, IEEE Std 15288-2008, ISO/IEC 12207:2008, and IEEE Std 12207-2008. These standards were jointly developed by ISO/IEC and IEEE.

This adoption is one result of an ongoing harmonization of the standards of the IEEE Computer Society's Software and Systems Engineering Standards Committee (S2ESC) and the corresponding international standards committee, ISO/IEC JTC1/SC7 (Software and Systems Engineering).

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IEEE Standard Adoption of ISO/IEC 15939:2007— Systems and Software Engineering— Measurement Process

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INTERNATIONAL STANDARD

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Ingénierie des systèmes et du logiciel — Processus de mesure

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Contents

Page

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 15939 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and systems engineering*.

This second edition cancels and replaces the first edition (ISO/IEC 15939:2002), which has been technically revised.

This corrected version of ISO/IEC 15939:2007 contains new cross-reference numbering in Figure 1, 3.3 and Figure B.1, which was incorrect in the original version. It also updates all references to ISO/IEC 15288 and ISO/IEC 12207 to the second editions, which have now been published.

Introduction

Measurement supports the management and improvement of processes and products. Measurement is a primary tool for managing system and software life cycle activities, assessing the feasibility of project plans, and monitoring the adherence of project activities to those plans. System and software measurement is also a key discipline in evaluating the quality of products and the capability of organizational processes. It is becoming increasingly important in two-party business agreements, where it provides a basis for specification, management, and acceptance criteria.

Continual improvement requires change within the organization. Evaluation of change requires measurement. Measurement itself does not initiate change. Measurement should lead to action and not be employed purely to accumulate data. Measurements should have a clearly defined purpose.

This International Standard defines a measurement process applicable to system and software engineering and management disciplines. The process is described through a model that defines the activities of the measurement process that are required to adequately specify what measurement information is required, how the measures and analysis results are to be applied, and how to determine if the analysis results are valid. The measurement process is flexible, tailorable, and adaptable to the needs of different users.

The measurement process defined in this International Standard, while written for system and software domains, can be applied in other domains.

Systems and software engineering — Measurement process

1 Scope

1.1 Purpose

This International Standard identifies the activities and tasks that are necessary to successfully identify, define, select, apply and improve measurement within an overall project or organizational measurement structure. It also provides definitions for measurement terms commonly used within the system and software industries.

This International Standard does not catalogue measures, nor does it provide a recommended set of measures to apply on projects. It does identify a process that supports defining a suitable set of measures that address specific information needs.

1.2 Field of application

This International Standard is intended to be used by suppliers and acquirers. Suppliers include personnel performing management, technical and quality management functions in system and software development, maintenance, integration and product support organizations. Acquirers include personnel performing management, technical and quality management functions in procurement and user organizations.

The following are examples of how this International Standard can be used:

- by a supplier to implement a measurement process to address specific project or organizational information requirements;
- by an acquirer (or third-party agents) for evaluating conformance of the supplier's measurement process to this International Standard;
- by an acquirer (or third-party agents) to implement a measurement process to address specific technical and project management information requirements related to the acquisition;
- in a contract between an acquirer and a supplier as a method for defining the process and product measurement information to be exchanged.

1.3 Tailoring this International Standard

This International Standard contains a set of activities and tasks that comprise a measurement process that meets the specific needs of organizations, enterprises and projects. The tailoring process consists of modifying the non-normative descriptions of the tasks to achieve the purpose and outcomes of the measurement process. All normative clauses need to be satisfied. New activities and tasks not defined in this International Standard may be added as part of tailoring.

1.4 Conformance

Conformance to this International Standard is defined as satisfying the purpose and outcomes of the measurement process and all of the normative clauses within the tasks in Clause 4. Any organization imposing this International Standard as a condition of trade is responsible for specifying and making public all task-specific criteria to be imposed in conjunction with this International Standard.

Throughout this International Standard, “shall” is used to express a provision that is binding on the party that is applying this International Standard, “should” to express a recommendation among other possibilities, and “may” to indicate a course of action permissible within the limits of the International Standard.

It is the responsibility of the organization to maintain appropriate evidence of satisfaction of the normative clauses for the purposes of demonstrating conformance.

1.5 Limitations

This International Standard does not assume or prescribe an organizational model for measurement. The user of this International Standard should decide, for example, whether a separate measurement function is necessary within the organization and whether the measurement function should be integrated within individual projects or across projects, based on the current organizational structure, culture and prevailing constraints.

This International Standard is not intended to prescribe the name, format or explicit content of the documentation to be produced. This International Standard does not imply that documents be packaged or combined in some fashion. These decisions are left to the user of this International Standard.

The measurement process should be appropriately integrated with the organizational quality system. Not all aspects of internal audits and non-compliance reporting are covered explicitly in this International Standard as they are assumed to be in the domain of the quality system.

This International Standard is not intended to conflict with any organizational policies, standards or procedures that are already in place. However, any conflict should be resolved and any overriding conditions and situations need to be cited in writing as exceptions to the application of this International Standard.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
acquirer
stakeholder that acquires or procures a product or service from a supplier

[ISO/IEC 15288:2008]

NOTE Other terms commonly used for an acquirer are buyer, customer, owner and purchaser.

2.2
attribute
property or characteristic of an entity that can be distinguished quantitatively or qualitatively by human or automated means

2.3
base measure
measure defined in terms of an attribute and the method for quantifying it

NOTE 1 A base measure is functionally independent of other measures.

NOTE 2 Based on the definition of “base quantity” in the International Vocabulary of Basic and General Terms in Metrology, 1993.

2.4
data
collection of values assigned to base measures, derived measures and/or indicators

2.5
data provider
individual or organization that is a source of data

2.6
data store
organized and persistent collection of data and information that allows for its retrieval

2.7
decision criteria
thresholds, targets, or patterns used to determine the need for action or further investigation, or to describe the level of confidence in a given result

2.8
derived measure
measure that is defined as a function of two or more values of base measures

NOTE Adapted from the definition of “derived quantity” in the International Vocabulary of Basic and General Terms in Metrology, 1993.

2.9
entity
object that is to be characterized by measuring its attributes

NOTE An entity can be a process, product, project or resource.

2.10
indicator
measure that provides an estimate or evaluation of specified attributes derived from a model with respect to defined information needs

2.11
indicator value
numerical or categorical result assigned to an indicator

2.12
information need
insight necessary to manage objectives, goals, risks and problems

2.13
information product
one or more indicators and their associated interpretations that address an information need

EXAMPLE A comparison of a measured defect rate to planned defect rate along with an assessment of whether or not the difference indicates a problem.

2.14
measurable concept
abstract relationship between attributes of entities and information needs

2.15
measure, noun
variable to which a value is assigned as the result of measurement

NOTE The plural form “measures” is used to refer collectively to base measures, derived measures and indicators.

2.16
measure, verb
make a measurement

[ISO/IEC 14598-1:1999]

2.17
measurement
set of operations having the object of determining a value of a measure

NOTE Adapted from the International Vocabulary of Basic and General Terms in Metrology, 1993.

2.18
measurement analyst
individual or organization that is responsible for the planning, performance, evaluation and improvement of measurement

2.19
measurement experience base
data store that contains the evaluation of the information products and the measurement process as well as any lessons learned during the measurement process

2.20
measurement function
algorithm or calculation performed to combine two or more base measures

2.21
measurement librarian
individual or organization that is responsible for managing the measurement data store(s)

2.22
measurement method
logical sequence of operations, described generically, used in quantifying an attribute with respect to a specified scale

NOTE 1 The type of measurement method depends on the nature of the operations used to quantify an attribute. Two types can be distinguished:

— subjective: quantification involving human judgment;

— objective: quantification based on numerical rules.

NOTE 2 Based on the definition of “method of measurement” in the International Vocabulary of Basic and General Terms in Metrology, 1993.

2.23
measurement procedure
set of operations, described specifically, used in the performance of a particular measurement according to a given method

[International Vocabulary of Basic and General Terms in Metrology, 1993]

2.24
measurement process
process for establishing, planning, performing and evaluating measurement within an overall project, enterprise or organizational measurement structure

2.25
measurement process owner
individual or organization responsible for the measurement process

2.26
measurement sponsor
individual or organization that authorizes and supports the establishment of the measurement process

2.27
measurement user
individual or organization that uses the information products

2.28
model
algorithm or calculation combining one or more base and/or derived measures with associated decision criteria

2.29
observation
instance of applying a measurement procedure to produce a value for a base measure

2.30
operator
entity that performs the operation of a system

2.31
organizational unit
part of an organization that is the subject of measurement

NOTE Adapted from ISO/IEC 15504-1:2004.

2.32
process
set of interrelated or interacting activities which transforms inputs into outputs

[ISO 9000:2005]

2.33
product
result of a process

[ISO 9000:2005]

NOTE There are four agreed generic product categories: hardware (e.g. engine mechanical part), software (e.g. computer program), services (e.g. transport), and processed materials (e.g. lubricant). Hardware and processed materials are generally tangible products, while software or services are generally intangible. Most products comprise elements belonging to different generic product categories. Whether the product is then called hardware, processed material, software or service depends on the dominant element.

2.34
project
endeavour with defined start and finish dates undertaken to create a product or service in accordance with specified resources and requirements

NOTE 1 Adapted from ISO 9000:2005.

NOTE 2 A project may be viewed as a unique process comprising coordinated and controlled activities and may be composed of activities from the Project Processes and Technical Processes defined in this International Standard.

2.35
scale
ordered set of values, continuous or discrete, or a set of categories to which the attribute is mapped

NOTE 1 The type of scale depends on the nature of the relationship between values on the scale. Four types of scale are commonly defined:

— nominal: the measurement values are categorical;

— ordinal: the measurement values are rankings;

— interval: the measurement values have equal distances corresponding to equal quantities of the attribute;

— ratio: the measurement values have equal distances corresponding to equal quantities of the attribute, where the value of zero corresponds to none of the attribute.

These are just examples of the types of scale. Roberts [15] defines more types of scale. Annex A contains examples of each type of scale.

NOTE 2 Based on the definition of “scale (of a measuring instrument)” in the International Vocabulary of Basic and General Terms in Metrology, 1993.

2.36
service
performance of activities, work or duties associated with a product

2.37
stakeholder
individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations

NOTE Within this International Standard, an individual or organization that sponsors measurement, provides data, is a user of the measurement results or otherwise participates in the measurement process.

2.38
supplier
organization or individual that enters into an agreement with the acquirer for the supply of a product or service

NOTE 1 Other terms commonly used for supplier are contractor, producer, seller and vendor.

NOTE 2 The acquirer and the supplier may be part of the same organization.

2.39
system
combination of interacting elements organized to achieve one or more stated purposes

NOTE A system may be considered as a product or as the services it provides.

2.40
unit of measurement
particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitude relative to that quantity

[International Vocabulary of Basic and General Terms in Metrology, 1993]

2.41
user
individual or group that benefits from a system during its utilization

2.42
value
numerical or categorical result assigned to a base measure, derived measure or indicator

3 Application of this International Standard

This clause presents an overview of the measurement process. The objective is to orient the users of this International Standard so that they can apply it properly within context.

3.1 Purpose and outcomes of the measurement process

The purpose of the measurement process defined in this International Standard is to collect, analyze, and report data relating to the products developed and processes implemented within the organizational unit, to support effective management of the processes, and to objectively demonstrate the quality of the products. As a result of successful implementation of the measurement process:

- organizational commitment for measurement is established and sustained;
- the information needs of technical and management processes are identified;
- an appropriate set of measures, driven by the information needs are identified and/or developed;
- measurement activities are identified;
- identified measurement activities are planned;
- the required data is collected, stored, analyzed, and the results interpreted;
- information products are used to support decisions and provide an objective basis for communication;
- the measurement process and measures are evaluated; and
- improvements are communicated to the measurement process owner.

3.2 Overview of this International Standard

This International Standard defines the activities and tasks necessary to implement a measurement process. An activity is a set of related tasks that contributes towards achieving the purpose and outcomes of the measurement process (see Clause 3.1). A task is a well-defined segment of work. Each activity is comprised of one or more tasks. This International Standard does not specify the details of *how* to perform the tasks included in the activities.

The properties of the activities of the measurement process that are defined in this International Standard are the same properties defined in ISO/IEC 15288:2008 and ISO/IEC 12207:2008. This means that other properties such as entry and exit criteria for each of the activities are *not* defined in this International Standard.

NOTE 1 This measurement process supports the measurement requirement defined in ISO 9001:2000, 8.2.

NOTE 2 This International Standard provides an elaboration of the measurement process from ISO/IEC 15288:2008 and ISO/IEC 12207:2008. More detail is provided via additional activities and tasks. As part of this elaboration, one additional outcome (commitment is established and sustained) is added, with associated activities and tasks. This outcome is addressed in ISO/IEC 15288:2008 and ISO/IEC 12207:2008 at the enterprise level.

The measurement process consists of four activities as illustrated in the process model in Figure 1. The activities are sequenced in an iterative cycle allowing for continuous feedback and improvement of the measurement process. The measurement process model in Figure 1 is an adaptation of the Plan-Do-Check-Act cycle commonly used as the basis for quality improvement. Within activities, the tasks are also iterative.

The “Technical and Management Processes” of an organizational unit or project are not within the scope of this International Standard, although they are an important external interface to the measurement activities that are included in this International Standard.

Two activities are considered to be the Core Measurement Process: Plan the Measurement Process, and Perform the Measurement Process. These activities mainly address the concerns of the measurement user. The other two activities, Establish and Sustain Measurement Commitment and Evaluate Measurement, provide a foundation for the Core Measurement Process and provide feedback to it. These latter two activities address the concerns of the measurement process owner.

Figure 1 shows that the Core Measurement Process is driven by the information needs of the organization. For each information need, the Core Measurement Process produces an *information product* that satisfies the information need. The information product is conveyed to the organization as a basis for decision-making. The link between measures and an information need is described as the *Measurement Information Model* in Annex A. This annex also includes examples.

Performance of the normative activities and tasks defined in this International Standard satisfies *at least* the Capability Level 1 requirements in ISO/IEC 15504-2:2003. However, the guidance included in this International Standard provides the basis for implementing the measurement process at progressively higher levels of capability.

The process defined in this International Standard includes an evaluation activity, as shown in Figure 1. The intent is to emphasize that evaluation and feedback are an essential component of the measurement process, and should lead to improvements of the measurement process and measures. Evaluation can be simple, and performed in an ad hoc manner when capability is low, or it can be quantitative with sophisticated statistical techniques to evaluate the quality of the measurement process and its outputs when capability is high. Measures should be evaluated in terms of the added value they provide for the organization, and only deployed where the benefit can be identified.

Included in the cycle is the “Measurement Experience Base”. This is intended to capture information products from past iterations of the cycle, previous evaluations of information products, and evaluations of previous iterations of the measurement process. This would include the measures that have been found to be useful in the organizational unit. No assumptions are made about the nature or technology of this “Measurement Experience Base”, only that it be a persistent storage. Artefacts (for example, information products, historical data, and lessons learned) stored in the “Measurement Experience Base” are intended to be reused in future iterations of the measurement process.

Since the process model is cyclical, subsequent iterations may only update measurement products and practices. This International Standard does not imply that measurement products and practices need to be developed and implemented for each iteration of the process. The wording used in this International Standard adopts the convention that one is implementing the measurement process for the first time (i.e., the first iteration). During subsequent iterations, this wording should be interpreted as updating or changing documentation and current practices.

The typical functional roles mentioned in this International Standard are: stakeholder, sponsor, measurement user, measurement analyst, measurement librarian, data provider, and measurement process owner. These are defined in Clause 2 of this International Standard.

A number of work products are produced during the performance of the measurement process. The work products are described in Annex B, and mapped to the tasks that produce them.

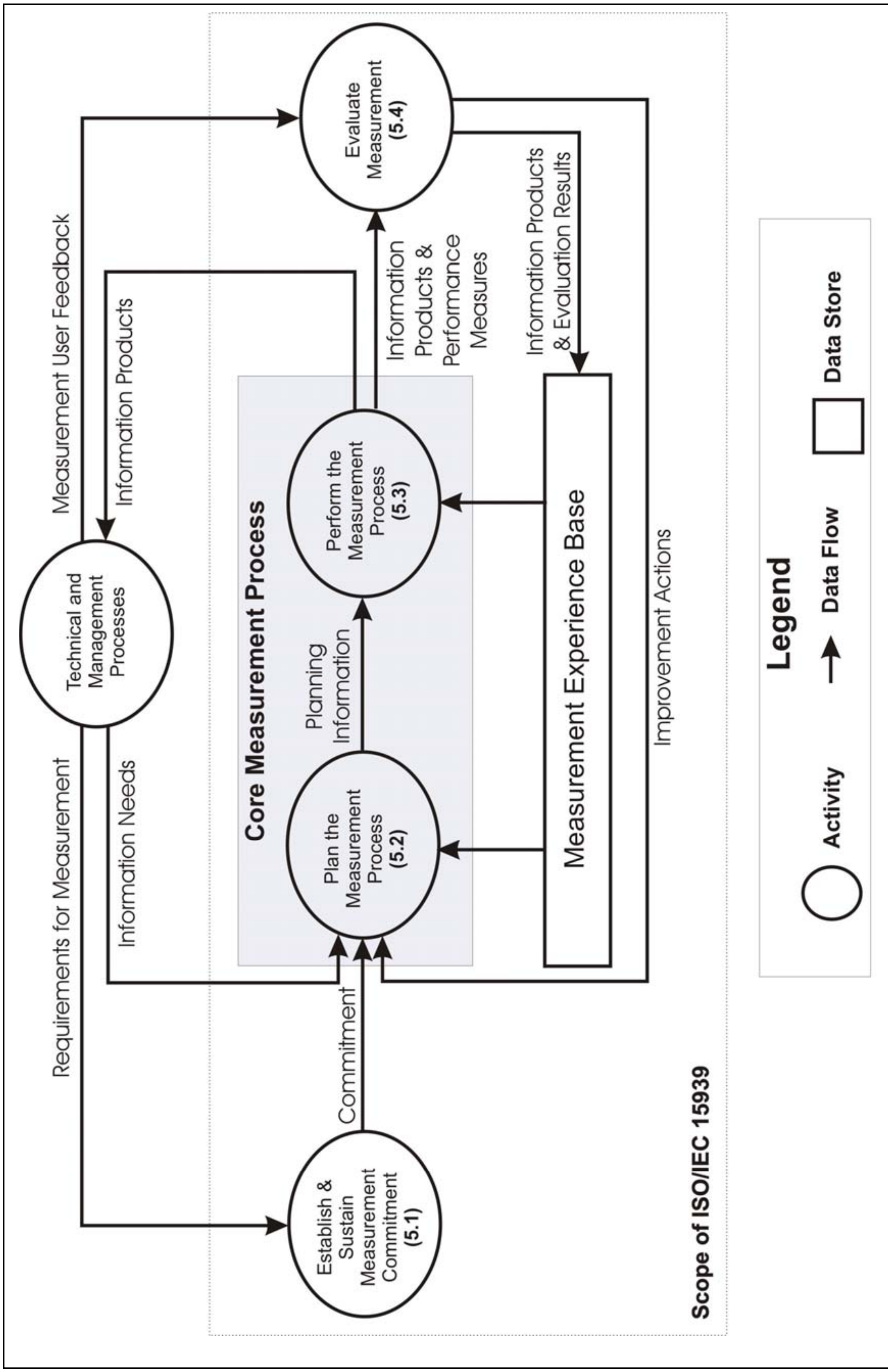

Figure 1: Measurement Process Model.

3.3 Organization of this International Standard

In this International Standard, clauses "4.a" denotes an activity, and "4.a.b" a task. Clauses labelled "4.a.b.c" are normative for the particular task. The outline structure of the activities and their constituent tasks is as follows:

4.1: Establish and sustain measurement commitment

- 4.1.1: Accept the requirements for measurement
  - 4.1.1.1: The scope of measurement shall be identified.
  - 4.1.1.2: Commitment of management and staff to measurement shall be established.
  - 4.1.1.3: Commitment shall be communicated to the organizational unit.
- 4.1.2: Assign resources
  - 4.1.2.1: Individuals shall be assigned responsibility for the measurement process within the organizational unit.
  - 4.1.2.2: The assigned individuals shall be provided with resources to plan the measurement process.

4.2: Plan the measurement process

- 4.2.1: Characterize organizational unit
  - 4.2.1.1: Characteristics of the organizational unit that are relevant to selecting measures and interpreting the information products shall be explicitly described.
- 4.2.2: Identify information needs
  - 4.2.2.1: Information needs for measurement shall be identified.
  - 4.2.2.2: The identified information needs shall be prioritized.
  - 4.2.2.3: Information needs to be addressed shall be selected.
  - 4.2.2.4: Selected information needs shall be documented and communicated.
- 4.2.3: Select measures
  - 4.2.3.1: Candidate measures that satisfy the selected information needs shall be identified.
  - 4.2.3.2: Measures shall be selected from the candidate measures.
  - 4.2.3.3: Selected measures shall be documented by their name, the unit of measurement, their formal definition, the method of data collection, and their link to the information needs.
- 4.2.4: Define data collection, analysis, and reporting procedures
  - 4.2.4.1: Procedures for data collection, including storage and verification shall be defined.
  - 4.2.4.2: Procedures for data analysis and reporting of information products shall be defined.
  - 4.2.4.3: Configuration management procedures shall be defined.
- 4.2.5: Define criteria for evaluating the information products and the measurement process
  - 4.2.5.1: Criteria for evaluating information products shall be defined.
  - 4.2.5.2: Criteria for evaluating the measurement process shall be defined.
- 4.2.6: Review, approve, and provide resources for measurement tasks
  - 4.2.6.1: The results of measurement planning shall be reviewed and approved.
  - 4.2.6.2: Resources shall be made available for implementing the planned measurement tasks.
- 4.2.7: Acquire and deploy supporting technologies
  - 4.2.7.1: Available supporting technologies shall be evaluated and appropriate ones selected.
  - 4.2.7.2: The selected supporting technologies shall be acquired and deployed

4.3: Perform the measurement process

4.3.1: Integrate procedures

4.3.1.1: Data generation and collection shall be integrated into the relevant processes.

4.3.1.2: The integrated data collection procedures shall be communicated to the data providers.

4.3.1.3: Data analysis and reporting shall be integrated into the relevant processes.

4.3.2: Collect data

4.3.2.1: Data shall be collected.

4.3.2.2: The collected data shall be stored, including any context information necessary to verify, understand, or evaluate the data.

4.3.2.3: The collected data shall be verified.

4.3.3: Analyze data and develop information products

4.3.3.1: The collected data shall be analyzed.

4.3.3.2: The data analysis results shall be interpreted.

4.3.3.3: The information products shall be reviewed.

4.3.4: Communicate results

4.3.4.1: The information products shall be documented.

4.3.4.2: The information products shall be communicated to the measurement users.

4.4: Evaluate measurement

4.4.1: Evaluate information products and the measurement process

4.4.1.1: The information products shall be evaluated against the specified evaluation criteria and conclusions on strengths and weaknesses of the information products drawn.

4.4.1.2: The measurement process shall be evaluated against the specified evaluation criteria and conclusions on strengths and weaknesses of the measurement process drawn.

4.4.1.3: Lessons learned from the evaluation shall be stored in the “Measurement Experience Base”.

4.4.2: Identify potential improvements

4.4.2.1: Potential improvements to the information products shall be identified.

4.4.2.2: Potential improvements to the measurement process shall be identified.

4.4.2.3: Potential improvements shall be communicated.

The activities are described in the order in which they usually are performed. However, iteration from one activity to the preceding activity frequently occurs. The order in which the tasks for each activity are presented does not necessarily imply an order of implementation of the tasks. For each task, one or more normative requirements on the implementation of the task are defined. For many tasks there is also informative guidance to help with the interpretation of the normative requirements and the tasks’ implementation in practice. This guidance is presented in *italics*.

The informative lists within the task definitions and in the annexes are not presumed to be exhaustive — they are intended only as examples.

4 Description of the activities

In implementing a measurement process in compliance with this International Standard, the organizational unit shall perform the activities described below. The “Requirements for Measurement” from the Technical and Management processes trigger the measurement process.

4.1 Establish and sustain measurement commitment

This activity consists of the following tasks:

1) Accept the requirements for measurement.

2) Assign resources.

4.1.1 Accept the requirements for measurement

4.1.1.1 The scope of measurement shall be identified.

The scope of measurement defines an organizational unit for purposes of this standard. This may be a single project, a functional area, the whole enterprise, a single site, or a multi-site organization. This may consist of projects or supporting processes, or both. All subsequent measurement tasks should be within the defined scope.

The scope of the organizational unit can be identified through interviews and the inspection of documentation, such as organizational charts.

In addition, all stakeholders should be identified. For example, these may be project managers, the Information Systems manager, or the head of Quality Management. The stakeholders may be internal or external to the organizational unit.

The purpose for measurement should be identified by the stakeholders.

4.1.1.2 Commitment of management and staff to measurement shall be established.

Commitment should be established when "Requirements for Measurement" are defined (see Figure 1).

This includes the commitment of resources to the measurement process and the willingness to maintain this commitment. The organizational unit should demonstrate its commitment through, for example, a measurement policy for the organizational unit, allocation of responsibility and duties, training, and the allocation of budget and other resources. Commitment may also come in the form of a contract with an acquirer requiring measurement.

4.1.1.3 Commitment shall be communicated to the organizational unit.

This can be achieved, for example, through organizational unit-wide announcements or newsletters.

4.1.2 Assign resources

4.1.2.1 Individuals shall be assigned responsibility for the measurement process within the organizational unit.

The sponsor of measurement should ensure that this responsibility is assigned to competent individuals. Competent individuals may be acquired through transfer, coaching, training, sub-contracting and/or hiring. Competence includes knowledge of the principles of measurement, how to collect data, perform data analysis, and communicate the information products. At a minimum, individuals should be assigned the responsibility for the following typical roles:

- *measurement user;*
- *measurement analyst;*
- *measurement librarian.*

The number of roles shown above does not imply the specific number of people needed to perform the roles. The number of people is dependent on the size and structure of the organizational unit. These roles could be performed by as few as one person for a small project.

4.1.2.2 The assigned individuals shall be provided with resources to plan the measurement process.

The sponsor of measurement should be responsible for ensuring that resources are provided. Resources include funding and staff. Resource allocations may be updated in the course of activity 4.2.

4.2 Plan the measurement process

This activity consists of the following tasks:

1) Characterize organizational unit.

2) Identify information needs.

3) Select measures.

4) Define data collection, analysis, and reporting procedures.

5) Define criteria for evaluating the information products and the measurement process.

6) Review, approve, and provide resources for measurement tasks.

7) Acquire and deploy supporting technologies.

Information products and evaluation results in the “Measurement Experience Base” should be consulted during the performance of this activity.

Examples of the measurement planning details that need to be addressed during this activity are described in Annex F.

4.2.1 Characterize organizational unit

4.2.1.1 Characteristics of the organizational unit that are relevant to selecting measures and interpreting the information products shall be explicitly described.

The organizational unit provides the context for measurement, and therefore it is important to make explicit this context and the assumptions that it embodies and constraints that it imposes. Characterization can be in terms of organizational processes, application domains, technology, interfaces amongst divisions/departments and organizational structure. Processes may be characterized in the form of a descriptive process model.

This task is similar in nature to task 4.1.1.1. However, this task produces more detailed information than the scoping performed in task 4.1.1.1.

The organizational unit characterization should be taken into account in all subsequent activities and tasks.

4.2.2 Identify information needs

4.2.2.1 Information needs for measurement shall be identified.

Information needs originate from the technical and management processes. Information needs are based on: goals, constraints, risks, and problems of the organizational unit. The information needs may be derived from the business, organizational, regulatory (such as legal or governmental), product and/or project objectives.

Information needs may address questions such as: “how do I estimate the productivity of a future project?”, “how do I evaluate the product quality during design?”, and “how do I know the status of the coding activity?”.

Useful guidance on risks that may be a source for information needs can be found in ISO/IEC 16085:2006.

4.2.2.2 The identified information needs shall be prioritized.

This prioritization is normally accomplished by, or in conjunction with, the stakeholders. Only a subset of the initial information needs may be pursued further. This is particularly relevant if measurement is being tried for the first time within an organizational unit, where it is preferable to start small.

An example of a simple and concrete prioritization approach is to ask a group of stakeholders to rank the information needs. For each information need calculate the average rank. Then order the average ranks. This ordering provides a prioritization of the information needs.

4.2.2.3 Information needs to be addressed shall be selected.

From the prioritized information needs, a subset is selected to be addressed during the measurement process. This selection is likely driven by a trade-off among resource constraints, and criticality/urgency of information needs.

In large development efforts, information that is needed later may be identified, but not fully defined nor implemented until it is required by the measurement users.

4.2.2.4 Selected information needs shall be documented and communicated.

No assumptions are made about the type of documentation. It can be paper or electronic. It is only necessary that the documentation is retrievable.

The selected information needs should be communicated to all stakeholders. This is to ensure that they understand why certain data are to be collected and how they are to be used.

4.2.3 Select measures

4.2.3.1 Candidate measures that satisfy the selected information needs shall be identified.

There should be a clear link between the information needs and the candidate measures. Such a link can be made using the measurement information model described in Annex A.

New measures should be defined in sufficient detail to allow for a selection decision (task 4.2.3.2). Other International Standards, see the Bibliography, describe some commonly used measures and requirements for their definition.

A new measure may involve an adaptation of an existing measure.

4.2.3.2 Measures shall be selected from the candidate measures.

The selected measures should reflect the priority of the information needs. Further example criteria that may be used for the selection of measures are included in Annex C.

Context information necessary to interpret or normalize measures also should be considered. For example, when comparing "lines of code" from different sources, the programming language has to be specified or when comparing requirements information from different sources, attributes of the system should be specified.

4.2.3.3 Selected measures shall be documented by their name, the unit of measurement, their formal definition, the method of data collection, and their link to the information needs.

Measures that have been selected should be fully specified. This may involve the definition of objective measures, for example, a product size measure, or subjective measures, such as a user satisfaction questionnaire to meet new information needs.

An example of a unit of measurement is "hour".

The formal definition describes exactly how the values are to be computed, including input measures and constants for derived measures. Note that such definitions may already exist in the "Measurement Experience Base".

The method of data collection may be, for example, a performance analysis or diagnostic data capture tool, a data collection form, or a questionnaire.

Annex A provides guidelines for linking the measures to the information needs through the measurement information model.

4.2.4 Define data collection, analysis, and reporting procedures

4.2.4.1 Procedures for data collection, including storage and verification shall be defined.

The procedures should specify how data are to be collected, as well as how and where they will be stored. Data verification may be accomplished through an audit. See Annex F for more detailed suggestions of items to be defined.

4.2.4.2 Procedures for data analysis and reporting of information products shall be defined.

The procedures should specify the data analysis method(s), and format and methods for reporting the information products.

The range of tools that would be needed to perform the data analysis should be identified. Useful guidance on the selection of statistical procedures can be found in ISO/TR 10017:2003.

4.2.4.3 Configuration management procedures shall be defined.

Items such as the raw data, information products, and selected information needs should be placed under configuration management. This may be the same configuration management procedure used in other parts of the organizational unit.

4.2.5 Define criteria for evaluating the information products and the measurement process

4.2.5.1 Criteria for evaluating information products shall be defined.

These criteria would allow one to determine whether the data that are needed have been collected and analyzed with sufficient quality to satisfy the information needs. The criteria need to be defined at the beginning of the project or process, and act as success criteria.

The criteria need to be defined within the context of the technical and business objectives of the organizational unit. Example criteria for the evaluation of information products are the accuracy of a measurement procedure and the reliability of a measurement method. Further criteria are included in Annex D. However, it may be necessary to define new criteria and measures for evaluating the information products.

4.2.5.2 Criteria for evaluating the measurement process shall be defined.

The criteria need to be defined within the context of the technical and business objectives of the organizational unit. Examples of such criteria are timeliness and efficiency of the measurement process. Further criteria are provided in Annex E. However, it may be necessary to define additional criteria and measures for evaluating the measurement process.

4.2.6 Review, approve, and provide resources for measurement tasks

4.2.6.1 The results of measurement planning shall be reviewed and approved.

The measurement planning tasks constitute all tasks from Clause 4.2.1 to Clause 4.2.5. The results of measurement planning include the data collection procedures, storage, analysis and reporting procedures, evaluation criteria, schedules and responsibilities. Details of the elements of measurement planning are included in Annex F.

Measurement planning should take into consideration improvements and updates proposed from previous measurement cycles ("Improvement Actions" in Figure 1), as well as relevant experiences in the "Measurement Experience Base". Criteria such as the feasibility of making changes to existing plans in the short-term, the availability of resources and tools for the realization of changes, and any potential disruptions to projects from which data are collected should be considered when selecting proposed improvements to implement.

If measurement planning information already exists, for example, from a previous measurement cycle, then it may only need to be updated as opposed to being "developed". Also, if measurement planning information already exists, then some of the elements in Annex F may not be necessary. For instance, if an update involves deleting a measure, then a pilot implementation of the changes may not be necessary.

Stakeholders should review and comment on the measurement planning information. The sponsor of measurement should then approve the measurement planning information. Approval demonstrates commitment to measurement.

4.2.6.2 Resources shall be made available for implementing the planned measurement tasks.

The measurement planning information should be agreed to by the management of the organizational unit, and resources allocated. For approval, the planning information may undergo a number of iterations. Note that measurement may be piloted on individual projects before committing to organization-wide use. Therefore, resource availability may be staged.

4.2.7 Acquire and deploy supporting technologies

4.2.7.1 Available supporting technologies shall be evaluated and appropriate ones selected.

Supporting technology may consist of, for example, automated tools and training courses.

The types of automated tools that may be needed include graphical presentation tools, data analysis tools, and databases. Tools for collecting data may also be required. This may involve the modification, and/or extension of existing tools, and the calibration and testing of the tools.

Based on the evaluation and selection of supporting technologies, the measurement planning information may have to be updated.

4.2.7.2 The selected supporting technologies shall be acquired and deployed.

If the supporting technologies concern the infrastructure for data management, then access rights to the data should be implemented in accordance with organizational security policies, and any additional confidentiality constraints.

4.3 Perform the measurement process

This activity consists of the following tasks:

1) Integrate procedures.

2) Collect data.

3) Analyze data and develop information products.

4) Communicate results.

These tasks are intended to be performed in accordance with the planning information produced during the tasks described in Clause 4.2. Examples of measurement planning information are described in Annex F.

Information products and evaluation results in the “Measurement Experience Base” should be consulted during the performance of this activity.

4.3.1 Integrate procedures

4.3.1.1 Data generation and collection shall be integrated into the relevant processes.

Integration may involve slightly modifying current processes to accommodate data generation and collection activities. For example, the inspection process may be changed to require that the moderator of an inspection provide the preparation effort sheets and defect logs to the measurement librarian at the closure of every inspection. This would then necessitate modifying inspection procedures accordingly. Integration involves a trade-off between the extent of impact on existing processes that can be tolerated and the needs of the measurement process. Changes with moderate to large impacts on the existing processes are usually not cost effective and may disrupt efficiency or effectiveness. The required changes to collect data should be minimized.

The extent of integration varies depending on the type of measures and the information needs. For example, a one-time staff morale survey requires little integration. Alternatively, filling in time sheets at the end of every week requires integration with Work Breakdown Structures or cost accounts and accounting procedures.

The data that need to be collected may include extra measures defined specifically to evaluate the information products or performance measures to evaluate the measurement process.

4.3.1.2 The integrated data collection procedures shall be communicated to the data providers.

This communication may be accomplished during, for example, staff training, an orientation session, or via an organization’s newsletter.

The objective of communicating the data collection procedures is to ensure that the data providers are competent in the required data collection. Competence may be achieved, for example, through training in the data collection procedures. This increases confidence that data providers understand exactly the type of data that are required, the format that is required, the tools to use, when to provide data, and how frequently. For example, the data providers may be trained on how to complete a defect data form, to ensure that they understand the defect classification scheme, and the meanings of different types of effort (such as isolation and correction effort).

4.3.1.3 Data analysis and reporting shall be integrated into the relevant processes.

Data analysis and reporting usually is performed on a regular basis. This requires that data analysis and reporting be integrated into the current organizational and project processes.

4.3.2 Collect data

4.3.2.1 Data shall be collected.

The selected attributes are measured using the designated measurement method. The data collection may be accomplished by manual or automated means. Data may be collected by automated means, for example, with a requirements management tool every time the requirements database is updated. Data also may be collected manually, for example, by completing a defect data form and sending it to the measurement librarian.

4.3.2.2 The collected data shall be stored, including any context information necessary to verify, understand, or evaluate the data.

The data store does not have to be an automated tool. It is possible to have a paper-based data store, for example, in the situation where only a few measures are collected for a short period of time in a small organization.

4.3.2.3 The collected data shall be verified.

Data verification may be performed by inspecting the data against a checklist. The checklist should be constructed to verify that missing data are minimal, and that the values make sense. Examples of the latter include checking that a defect classification is valid, or that the size of a component is not ten times greater than all previously entered components. In case of anomalies, the data provider(s) should be consulted and corrections to the raw data made where necessary. Automated range and type checks may be used.

Data verification may be the responsibility of the measurement librarian in conjunction with the data provider(s).

4.3.3 Analyze data and develop information products

4.3.3.1 The collected data shall be analyzed.

Data may be aggregated, transformed, normalized, or re-coded prior to analysis. During this task, data are processed to produce the planned indicators. The amount of rigor in the analysis should be determined by the nature of the data and the information needs.

Guidance for performing statistical analysis may be found in ISO/TR 10017:2003.

4.3.3.2 The data analysis results shall be interpreted.

The measurement analyst(s) should be able to draw some initial conclusions based on the results. However, since the analyst(s) may not be directly involved in the technical and management processes, such conclusions need to be reviewed by other stakeholders as well (see Clause 4.3.3.3).

All interpretations should take into account the context of the measures.

The data analysis results, indicators, interpretations, and supporting information make up the information products.

4.3.3.3 The information products shall be reviewed.

The review is intended to ensure that the analysis was performed and interpreted properly and that the information needs were satisfied. It may be an informal "self review", or a more formal inspection process. Examples of the types of things to look for during such a review are provided in Annex G.

The information products should be reviewed with the data providers and the measurement users. This is to ensure that they are meaningful, and if possible, actionable. Qualitative information should be considered as a support to interpreting quantitative results.

4.3.4 Communicate results

4.3.4.1 The information products shall be documented.

Example guidelines for reporting information products are provided in Annex G.

4.3.4.2 The information products shall be communicated to the measurement users.

The information products should be made available to the data providers, and other stakeholders.

Feedback should be provided to the stakeholders, as well as being sought from the stakeholders. This ensures useful input for evaluating the information products and the measurement process. Tasks 4.3.3 and 4.3.4 are typically performed in an iterative manner.

Useful guidance on communicating measurement results as an input to the risk management process can be found in ISO/IEC 16085:2006.

4.4 Evaluate measurement

This activity consists of the following tasks:

1) Evaluate information products and the measurement process.

2) Identify potential improvements.

4.4.1 Evaluate information products and the measurement process

4.4.1.1 The information products shall be evaluated against the specified evaluation criteria and conclusions on strengths and weaknesses of the information products drawn.

The evaluation of information products may be accomplished through an internal or independent audit. Example criteria for the evaluation of information products are included in Annex D. The evaluation criteria have been defined in Clause 4.2.5.

The inputs to this evaluation are the performance measures, the information products, and the measurement user feedback.

The evaluation of information products may conclude that some measures ought to be removed, for example, if they no longer meet a current information need.

4.4.1.2 The measurement process shall be evaluated against the specified evaluation criteria and conclusions on strengths and weaknesses of the measurement process drawn.

The evaluation of measurement process may be accomplished through an internal or independent audit. Example criteria for the evaluation of the performance of the measurement process are included in Annex E. The evaluation criteria have been defined in Clause 4.2.5.

The quality of the measurement process influences the quality of the information products.

The inputs to this evaluation are the performance measures, the information products, and the measurement user feedback.

4.4.1.3 Lessons learned from the evaluation shall be stored in the “Measurement Experience Base”.

Lessons learned may take the form of strengths and weaknesses of the information products, of the measurement process, of the evaluation criteria themselves, and/or experiences in measurement planning (for example, “there was great resistance by the data providers to collecting a specific measure at a specific frequency”).

4.4.2 Identify potential improvements

4.4.2.1 Potential improvements to the information products shall be identified.

Examples of changes to information products are changing the format of an indicator; changing from a linear measure to an area measure; minutes to hours, months, or years; or a line of code size measure to a functional size measure; or reclassification of defect categories.

Some changes to the information products may require changes to the measurement process.

4.4.2.2 Potential improvements to the measurement process shall be identified.

Such "Improvement Actions" should be used in future instances of the "Plan the Measurement Process" activity.

The costs and benefits of potential improvements should be considered when selecting the "Improvement Actions" to implement. It should be noted that making a particular improvement may not be cost effective or the measurement process may be good as it is, and therefore no potential improvements may be identified.

4.4.2.3 Potential improvements shall be communicated.

Measurement process changes usually are provided to the process owner, and measurement product changes are usually provided to the measurement analyst(s).

If no potential improvements are identified in Clause 4.4.2.1, then that should be communicated.

Annex A
(informative)

The measurement information model

A.1 General

The measurement information model is a structure linking information needs to the relevant entities and attributes of concern. Entities include processes, products, projects, and resources. The measurement information model describes how the relevant attributes are quantified and converted to indicators that provide a basis for decision making.

The selection or definition of appropriate measures to address an information need begins with a measurable concept: an idea of which measurable attributes are related to an information need and how they are related. The measurement planner defines measurement constructs that link these attributes to a specified information need. This measurement information model (see Figure A.1) identifies basic terms and concepts. The measurement information model helps to determine what the measurement planner needs to specify during measurement planning, performance, and evaluation.

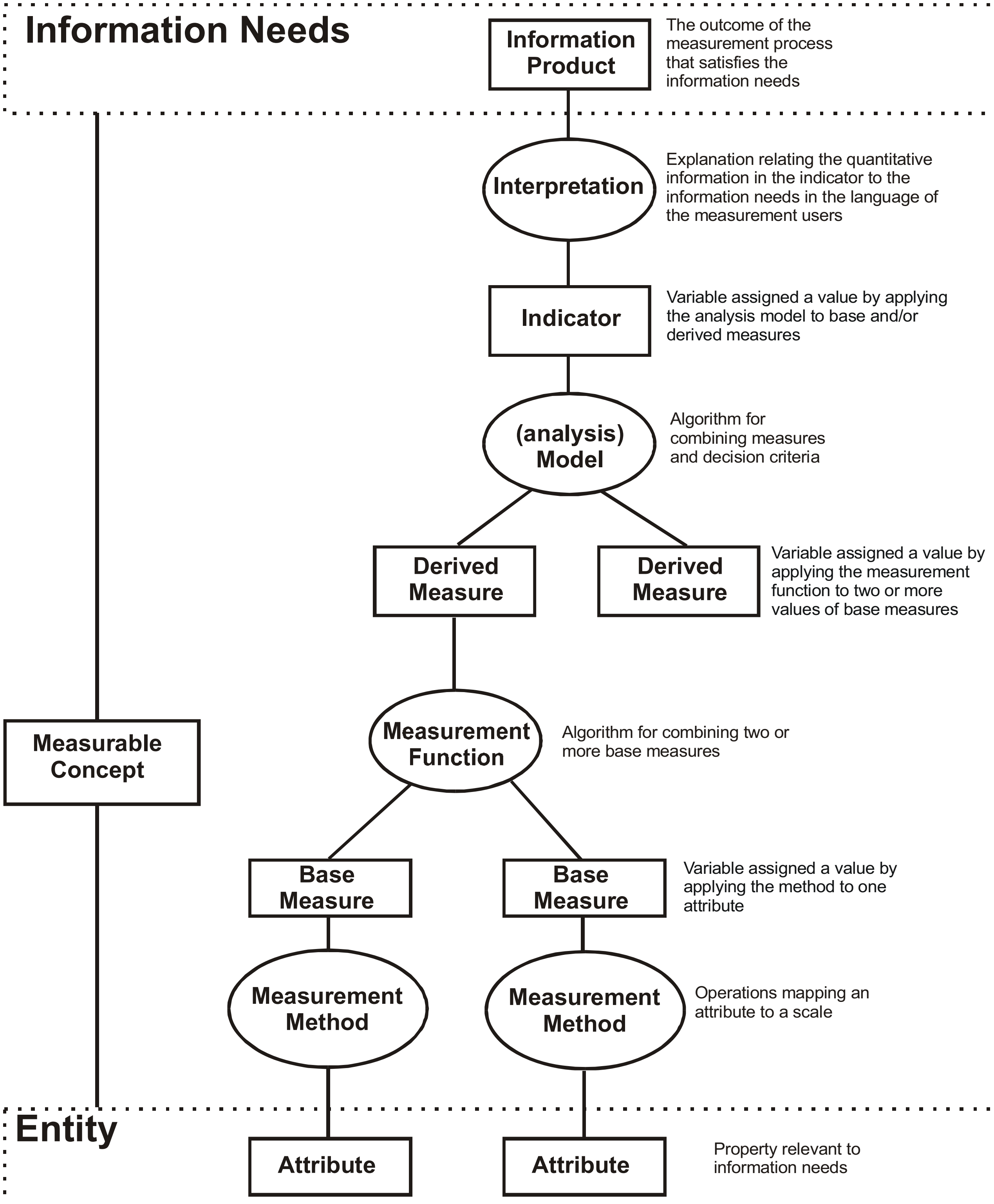

Figure A.1 — Key relationships in the measurement information model

A.2 Model description

Figure A.1 illustrates the relationships among the key components of the measurement information model. The model defines three types of measures: base measures, derived measures, and indicators. The information content of measures increases as they become closer in the model to the information need. Clause A.3 provides examples of instantiations of the model that address specific information needs. The individual components of the generic information model are described below.

A.2.1 Entity

An entity is an object (for example, a process, product, project, or resource) that is to be characterized by measuring its attributes. Typical engineering objects can be classified as products (e.g., design document, network, source code, and test case), processes (e.g., design process, testing process, requirements analysis process), projects, and resources (e.g., the systems engineers, the software engineers, the programmers and the testers). An entity may have one or more properties that are of interest to meet the information needs. In practice, an entity can be classified into more than one of the above categories.

A.2.2 Attribute

An attribute is a property or characteristic of an entity that can be distinguished quantitatively or qualitatively by human or automated means. An entity may have many attributes, only some of which may be of interest for measurement. The first step in defining a specific instantiation of the measurement information model is to select the attributes that are most relevant to the measurement user's information needs. A given attribute may be incorporated in multiple measurement constructs supporting different information needs.

A.2.3 Base measure

A measure defined in terms of an attribute and the method for quantifying it. (A measure is a variable to which a value is assigned.) A base measure is functionally independent of other measures. A base measure captures information about a single attribute. Data collection involves assigning values to base measures. Specifying the expected range and/or type of values of a base measure helps to verify the quality of the data collected.

A.2.3.1 Measurement method

A measurement method is a logical sequence of operations, described generically, used in quantifying an attribute with respect to a specified scale. The operations may involve activities such as counting occurrences or observing the passage of time. The same measurement method may be applied to multiple attributes. However, each unique combination of an attribute and a method produces a different base measure. Some measurement methods may be implemented in multiple ways. A measurement procedure describes the specific implementation of a measurement method within a given organizational context.

A.2.3.1.1 Type of measurement method

The type of measurement method depends on the nature of the operations used to quantify an attribute. Two types of method may be distinguished:

- Subjective — quantification involving human judgment.
- Objective — quantification based on numerical rules such as counting. These rules may be implemented via human or automated means.

A.2.3.1.2 Scale

A scale is an ordered set of values, continuous or discrete, or a set of categories to which the attribute is mapped. The measurement method maps the magnitude of the measured attribute to a value on a scale. A unit of measurement often is associated with a scale.

A.2.3.1.2.1 Type of scale

The type of scale depends on the nature of the relationship between values on the scale. Four types of scale are commonly defined:[1)]

Nominal — the measurement values are categorical. For example, the classification of defects by their type does not imply order among the categories.

Ordinal — the measurement values are rankings. For example, the assignment of defects to a severity level is a ranking.

Interval — the measurement values have equal distances corresponding to equal quantities of the attribute. For example, cyclomatic complexity has the minimum value of one, but each increment represents an additional path. The value of zero is not possible.

Ratio — the measurement values have equal distances corresponding to equal quantities of the attribute where the value of zero corresponds to none of the attribute. For example, the size in terms of the number of requirements is a ratio scale because the value of zero corresponds to no requirements and each additional requirement defined represents an equal incremental quantity.

The method of measurement usually affects the type of scale that can be used reliably with a given attribute. For example, subjective methods of measurement usually only support ordinal or nominal scales.

A.2.3.1.2.2 Unit of measurement

A particular quantity, defined and adopted by convention, with which other quantities of the same kind are compared in order to express their magnitude relative to that quantity. Only quantities expressed in the same units of measurement are directly comparable. Examples of units include the hour and the meter.

A.2.4 Derived measure

A derived measure is a measure that is defined as a function of two or more values of base measures. Derived measures capture information about more than one attribute or the same attribute from multiple entities. Simple transformations of base measures (for example, taking the square root of a base measure) do not add information, thus do not produce derived measures. Normalisation of data often involves converting base measures into derived measures that can be used to compare different entities.

A.2.4.1 Measurement Function

A function is an algorithm or calculation performed to combine two or more base measures. The scale and unit of the derived measure depend on the scales and units of the base measures from which it is composed as well as how they are combined by the function.

A.2.5 Indicator

An indicator is a measure that provides an estimate or evaluation of specified attributes derived from a model with respect to defined information needs. Indicators are the basis for analysis and decision-making. These are what should be presented to measurement users. Measurement is always based on imperfect information, so quantifying the uncertainty, accuracy, or importance of indicators is an essential component of presenting the actual indicator value.

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1) These are just examples of the types of scale. Roberts [15] defines more types of scale.

A.2.5.1 Model

An algorithm or calculation combining one or more base and/or derived measures with associated decision criteria. It is based on an understanding of, or assumptions about, the expected relationship between the component measures and/or their behaviour over time. Models produce estimates or evaluations relevant to defined information needs. The scale and measurement method affect the choice of analysis techniques or models used to produce indicators.

A.2.5.1.1 Decision criteria

Decision criteria are numerical thresholds or targets used to determine the need for action or further investigation, or to describe the level of confidence in a given result. Decision criteria help to interpret the results of measurement. Decision criteria may be calculated or based on a conceptual understanding of expected behaviour. Decision criteria may be derived from historical data, plans, and heuristics, or computed as statistical control limits or statistical confidence limits.

A.2.6 Measurable concept

A measurable concept is an abstract relationship between attributes of entities and information needs. For example, an Information Need may be the need to compare the development productivity of a project group against a target rate. The Measurable Concept in this case is “development productivity rate”. To evaluate the concept might require measuring the size of the system or software products and the amount of resource applied to create the products (depending on the chosen model of productivity). Additional examples of Measurable Concepts include quality, risk, performance, capability, maturity, and customer value.

A.3 Examples

The following subclauses provide examples of instantiations of the measurement information model that address specific information needs. These examples are not designed to recommend best measurement practices, but rather to show the applicability of the measurement information model in a variety of common situations.

A.3.1 A productivity example

The decision-maker in this example needs to select a specific productivity level as the basis for project planning. The measurable concept is that productivity is related to effort expended and amount of software produced. Thus, effort and code are the measurable entities of concern. This example assumes that the productivity is estimated based on past performance. Thus, data for the base measures (numbered entries in table below) needs to be collected and the derived measure computed for each project in the data store.

Regardless of how the productivity number is arrived at, the uncertainty inherent in engineering means that there is a considerable probability that the estimated productivity will not be realized exactly. Estimating productivity based on historical data enables the computation of confidence limits that help to assess how close actual results are likely to come to the estimated value.

Information Need	Estimate productivity of future project
Measurable Concept	Project productivity
Relevant Entities	1. Code produced by past projects 2. Effort expended by past projects
Attributes	1. C++ language statements (in code) 2. Timecard entries (recording effort)
Base Measures	1. Project X Lines of Code 2. Project X Hours of Effort
Measurement Method	1. Count semicolons in Project X code 2. Add timecard entries together for Project X
Type of Measurement Method	1. Objective 2. Objective
Scale	1. Integers from zero to infinity 2. Real numbers from zero to infinity
Type of Scale	1. Ratio 2. Ratio
Unit of Measurement	1. Line 2. Hour
Derived Measure	Project X Productivity
Measurement Function	Divide Project X Lines of Code by Project X Hours of Effort
Indicator	Average productivity
Model	Compute mean and standard deviation of all project productivity values.
Decision Criteria	Computed confidence limits based on the standard deviation indicate the likelihood that an actual result close to the average productivity will be achieved. Very wide confidence limits suggest a potentially large departure and the need for contingency planning to deal with this outcome.

Figure A.2 — Measurement construct for “productivity”

A.3.2 A quality example

The decision-maker in this example needs to evaluate detailed design quality as the design is being produced. The measurable concept is that design quality is related to the amount of design produced and the number of defects found. Thus, the design packages and the lists of defects are the entities of concern. Quality of design packages can be normalized by computing defect rate. Thus, data for the base measures (number entries in table below) must be collected and the derived measure computed for each package as it is reviewed.

Since we don’t really expect to get exactly the same defect rate for every package, we can compute control limits to determine if the defect rate on any package is different enough from the average to warrant concern.

Information Need	Evaluate product quality during design
Measurable Concept	Product quality
Relevant Entities	1. Design packages 2. Design inspection reports
Attributes	1. Text of inspection packages 2. Lists of defects found in inspections
Base Measures	1. Package X size 2. Total defects for package X
Measurement Method	1. Count number of lines of text for each package 2. Count number of defects listed in each report
Type of Measurement Method	1. Objective 2. Objective
Scale	1. Integers from zero to infinity 2. Integers from zero to infinity
Type of Scale	1. Ratio 2. Ratio
Unit of Measurement	1. Lines 2. Defects
Derived Measure	Inspection defect density
Measurement Function	Divide Total Defects by Package Size for each package
Indicator	Design defect density
Model	Compute process centre and control limits using values of defect density
Decision Criteria	Results outside the control limits require further investigations

Figure A.3 — Measurement construct for “quality”

A.3.3 A project progress example

The decision-maker in this example needs to evaluate whether or not the rate of progress on a project is sufficient. The measurable concept is that progress is related to the amount of work planned and the amount of work completed. Thus, planned work items (units) are the entities of concern. This example assumes that the status (degree of completion) of each unit is reported by the supplier assigned to it. Thus, data for the base measures (numbered entries in table below) needs to be collected and the derived measure computed for each work item in the plan.

Since the status of units is a subjective assessment, a simple numerical threshold is used as a decision criterion rather than statistical limits.

Information Need	Assess status of testing activity
Measurable Concept	Activity status
Relevant Entities	1. Plan/schedule 2. Units completed or in progress
Attributes	1. Units identified in plan 2. Unit status
Base Measures	1. Units planned to date 2. Unit percent complete
Measurement Method	1. Count number of units scheduled to be completed by this date 2. Ask responsible individual for percent complete of each unit
Type of Measurement Method	1. Objective 2. Subjective
Scale	1. Integers from zero to infinity 2. Integers from zero to one hundred
Type of Scale	1. Ratio 2. Ordinal
Unit of Measurement	1. Unit 2. Percentage
Derived Measure	Progress to date
Measurement Function	Add status for all units planned to be complete to date
Indicator	Status expressed as a ratio
Model	Divide Progress to Date by (Units Planned to Date times 100)
Decision Criteria	Resulting ratio should fall between 0.9 and 1.1 to conclude the project is on schedule

Figure A.4 — Measurement construct for "progress"

Annex B
(informative)

Measurement process work products

This annex contains a mapping between the work products (WPs) mentioned in this International Standard and the activities or tasks that produce them. Note that this annex only presents the final WPs, not all of the intermediate WPs that may need to be produced during the performance of the activities and tasks.

This International Standard is not intended to prescribe the name, format, or explicit content of the documentation to be produced. The International Standard does not imply that documents be stored, packaged, or combined in some fashion. These decisions are left to the user of this International Standard.

Work product	**Activity/Task Producing WP**
Work products produced externally	
Requirements for measurement	Technical and Management Processes
Information Needs	Technical and Management Processes
Measurement User Feedback	Technical and Management Processes
Work products produced by “Plan the Measurement Process”	
Characterization of the Organizational Unit	4.2.1 Characterize Organizational Unit
Selected information needs	4.2.2 Identify Information Needs
Instantiated measurement information model for selected measures	4.2.3 Select Measures
Definition of selected measures	4.2.3 Select Measures
Procedures for data collection, storage, and verification	4.2.4 Define Data Collection, Analysis, and Reporting Procedures
Procedures for data analysis and reporting	4.2.4 Define Data Collection, Analysis, and Reporting Procedures
Configuration management procedures	4.2.4 Define Data Collection, Analysis, and Reporting Procedures
Criteria for the evaluation of the information products	4.2.5 Define Criteria for Evaluating the Information Products and the Measurement Process
Criteria for the evaluation of the measurement process	4.2.5 Define Criteria for Evaluating the Information Products and the Measurement Process
Approved results of measurement planning	4.2.6 Review, approve, and provide resources for measurement tasks
Selected supporting technologies	4.2.7 Acquire and Deploy Supporting Technologies

Work products produced by “Perform the Measurement Process”	
Integrated data collection procedures	4.3.1 Integrate Procedures
Stored data	4.3.2 Collect Data
Data analysis results and interpretations	4.3.3 Analyze data and develop information products
Information products	4.3.4 Communicate results
Work products produced by “Evaluate Measurement”	
Measurement Experience Base (update)	4.4.1 Evaluate Information Products and the Measurement Process
Evaluation results	4.4.1 Evaluate Information Products and the Measurement Process
Improvement actions	4.4.2 Identify potential improvements

Figure B.1 — Work products of measurement activities

Annex C
(informative)

Example criteria for selecting measures

Many different combinations of base measures, derived measures, and indicators may be selected to address a specific information need. The following criteria should be considered when selecting among alternatives:

- relevance to the prioritized information needs;
- feasibility of collecting the data in the organizational unit;
- availability of human resources to collect and manage data;
- ease of data collection;
- extent of intrusion and disruption of staff activities;
- availability of appropriate tools;
- protection of privacy;
- potential resistance from data provider(s);
- number of potentially relevant indicators supported by the base measure;
- increase or reduction of storage requirements;
- ease of interpretation by measurement users and measurement analysts;
- number of users or consumers of the information products utilizing the indicator;
- personal preference (e.g., individuals sometimes have their “favourite measure”);
- life cycle stage applicability;
- evidence (internal or external to the organizational unit) as to the measure’s fitness for purpose or information need, and its utility;
- sensitivity to context (e.g., in some environments measures of inheritance depth for object oriented classes do not exhibit variation because inheritance is not used extensively; such a measure would not exhibit interesting behaviour in this environment).

The costs of collecting, managing, and analysing the data at all levels should also be considered. Costs include the following.[2)]

- Measures utilization costs: associated with each measure are the costs of collecting data, automating the calculation of the measure values (when possible), analysing the data, interpreting the analysis results, and communicating the information products.

2) This is adapted from IEEE Standard for a Software Quality Metrics Methodology, IEEE Std 1061-1998.

- Process Change Costs: the set of measures may imply a change in the development process, for example, through the need for new data acquisition.

- Organizational Structure Change Costs: the set of measures may imply a change in the organizational structure.

- Special Equipment: system, hardware, and/or software tools may have to be located, evaluated, purchased, adapted or developed to implement the measures.

- Training: the quality management/control organization or the entire development team may need training in the use of the measures and data collection procedures. If the implementation of measures causes changes in the development process, the changes needs to be communicated to the staff.

Annex D
(informative)

Example criteria for evaluating an information product

D.1 General

The effectiveness of each measurement construct used by the measurement process needs to be evaluated using pre-defined criteria. The following are examples of such criteria (i.e., this is not an exhaustive list). Some criteria are specific to base measures, derived measures, or indicators. Some of these criteria have been adapted from ISO/IEC TR 9126-2 for the evaluation of product measures. The following criteria are not necessarily independent of each other. In some cases the criteria can be used for a quantitative evaluation, and in other situations a qualitative evaluation may be appropriate. These criteria become even more important when the information products are part of a contractual agreement.

D.2 Use of information products

The extent to which the information products produced by the measurement process are actually used for decision making in the management or technical processes supported by measurement.

For example, if as part of the analysis performed using the measurement data a decision model was constructed to decide whether a reinspection should be performed, and the inspection moderator rarely uses the decision model to make the reinspection decision, then the information products are not used.

Most of the criteria described below have an influence on the use of information products.

D.3 Confidence in an information product

The extent to which the consumers of the information product (measurement users) have confidence in the base measures, derived measures, indicators and interpretations incorporated in the information product.

Confidence is improved when procedures to prevent misuse or misrepresentation of data have been adopted (for example, through traceability of all data items).

Greater confidence can be achieved by ensuring that the analysts are competent and unbiased, they are perceived to be competent and unbiased, and that the measurement users are involved in the process (for example, through regular feedback sessions).

D.4 Evidence of fitness for purpose of an information product

The extent to which the information product can be demonstrated to be effective for the identified information need.

The interpretation of indicators should take into account the context in which measurement is being performed. Not all indicators work well in all situations. Data for a given base measure may be easier or harder to collect under different circumstances, thus affecting the desirability of an information product incorporating it. Confidence in the fitness for purpose of an information product increases as evidence accumulates for its effectiveness in this or similar environments.

Fitness for purpose includes

- the extent to which the measure measures what it purports to measure,
- measures that are used in a predictive sense should have a demonstrated capability to predict what they are supposed to predict.

To the extent that an information product provides comprehensive and appropriate feedback relative to its intended information need, the information product may be judged to be fit for its purpose.

D.5 Understandability of information products

The ease with which the indicators and the interpretations of them can be understood by the intended measurement user.

If the information product is difficult to understand, then it is less likely to be used. This may be caused by the use of jargon in the interpretation or presenting indicators in ways that are not natural to the user. Volume alone may be an obstacle to understandability — lengthy reports are less likely to be read carefully.

D.6 Satisfaction of the assumptions of an indicator model

The extent to which assumptions inherent in the model on which an indicator is based have been satisfied (e.g., data distributions, measurement scales, units of measure, sample size).

Statistical techniques often rely on assumptions about the data input to them. Even simple numerical techniques usually depend on some assumptions about what is being measured. To the extent that violations of these assumptions tend to occur in a specific context, the indicator model dependent of those assumptions should be avoided or at least interpreted with care.

D.7 Accuracy of a measurement procedure

The extent to which the procedure implementing a base measure conforms to the intended measurement method. An accurate procedure produces results similar to the true (or intended) value of the base measure.

Measurement procedures implement the measurement methods described for base measures. These procedures may produce results different from what was intended due to problems such as systematic error in the procedure, random error inherent in the underlying measurement method, and poor execution of the procedure.

The actual human procedure or automated implementation of a base measure may depart from the measure’s definition. For example, a static analysis tool may implement a counting algorithm differently from the way it was originally described in the literature. Discrepancies also may be due to ambiguous definitions of measurement methods, scales, units, etc. Even good measurement procedures may be inconsistently applied, resulting in the loss of data or the introduction of erroneous data.

Subjective methods depend on human interpretation. The formulation of questionnaire items, for example, may leave respondents uncertain about the question and even bias the responses. Clear and concise instructions help to increase the accuracy of surveys.

Accuracy can be enhanced by ensuring that, for example,

- the extent of missing data are within specified thresholds;
- the number of flagged inconsistencies in data entry are within specified thresholds;

- the number of missed measurement opportunities are within specified thresholds (e.g., the number of inspections for which no data were collected);
- inappropriate selection in the sampling process is avoided (e.g., not just satisfied users are surveyed to evaluate user satisfaction, or if only successful projects are evaluated to determine overall productivity);
- all base measures are well-defined and those definitions are communicated to data providers.

Poorly defined measures tend to yield inaccurate data. The repeatability and reproducibility of the underlying measurement method (see below) may also limit the accuracy achievable by a measurement procedure.

D.8 Repeatability of a measurement method

The degree to which the repeated use of the base measure in the same Organizational Unit following the same measurement method under the same conditions (e.g., tools, individuals performing the measurement) produces results that can be accepted as being identical. Subjective measurement methods tend to experience lower repeatability than objective methods. Random measurement error reduces repeatability.

D.9 Reproducibility of a measurement method

The degree to which the repeated use of the base measure in the same Organizational Unit following the same measurement method under different conditions (e.g., tools, individuals performing the measurement) produces results that can be accepted as being identical. Subjective measurement methods tend to experience lower reproducibility than objective methods. Random measurement error reduces reproducibility.

Annex E
(informative)

Example criteria for evaluating the performance of the measurement process

E.1 General

The goodness of a process may be judged by assessing its capability (as described in ISO/IEC 15504) or by measuring and evaluating its performance. While this International Standard, as a whole, may be used as a reference model for assessing the capability of a measurement process, this annex only addresses the evaluation of the performance of the measurement process.

Below is a set of *example* criteria that may be used for evaluating the performance of the measurement process. In some cases the criteria can be used for a quantitative evaluation, and in other situations a qualitative evaluation may be appropriate.

The following criteria may be regarded as potential information needs of the measurement process owner. The measurement process described in this International Standard may be applied to produce information products that address the information needs identified by the measurement process owner.

E.2 Timeliness

The measurement process should provide information products in time to support the needs of the measurement user. Appropriate timing depends on the schedule of the management or technical process being supported.

E.3 Efficiency

The measurement process should not cost more to perform than the value of the information that it provides. The more efficient the process, the lower its cost, and the greater the cost/benefit.

E.4 Defect containment

The measurement process should minimize the introduction of erroneous data and results, while removing any that do get introduced as thoroughly and soon as possible.

E.5 Customer satisfaction

The users of information products should be satisfied with the quality of the information products (see Annex D) and the performance of the measurement process in terms of timeliness, efficiency, and defect containment. Satisfaction may be affected by the user’s expectation of the level of quality and performance to be provided.

E.6 Process compliance

The execution of measurement activities should comply with any plans and procedures developed to describe the intended measurement process. This may be judged by quality management audits or process capability assessments.

Annex F
(informative)

Example elements of measurement planning

Clause 4.2 identified the key measurement tasks that should be planned. The results of that planning effort and any other planning efforts may be collected into a measurement plan

The following are example elements that may be included in a measurement plan:

- characterization of the organizational unit;
- business and project objectives;
- prioritized information needs, and how they link to the business, organizational, regulatory, product and/or project objectives;
- definition of the measures and how they relate to the information needs;
- responsibility for data collection and sources of data;
- schedule for data collection (e.g., at the end of each inspection, monthly);
- tools and procedures for data collection (e.g., instructions for executing a static analyzer);
- data storage;
- requirements for data verification;
- data entry and verification procedures;
- data analysis plan including frequency of analysis and reporting;
- necessary organizational and/or process changes to implement the measurement plan;
- criteria for the evaluation of the information products;
- criteria for the evaluation of the measurement process;
- confidentiality constraints on the data and information products, and actions/precautions necessary to ensure confidentiality;
- schedule and responsibilities for the implementation of measurement plan including pilots and organizational unit wide implementation;
- procedures for configuration management of data, measurement experience base, and data definitions.

Annex G
(informative)

Guidelines for reporting information products

The following items constitute a set of general criteria for reporting information products:

- limitations of the results and any other qualifications (e.g., limitations to the validity of the conclusions drawn);
- date or period when the data were collected;
- names and versions of tools used for performing statistical analysis;
- number of observations from which conclusions are drawn;
- sampling procedures that are used;
- assumptions underlying the analysis techniques that are used, and the results of any sensitivity analysis performed to check for robustness to violation of assumptions;
- precisely how aggregates are performed (e.g., average or weighted average);
- unit of observation about which conclusions are drawn (e.g., inspection package, configuration item);
- how missing data and anomalies were dealt with, where applicable;
- how outliers were dealt with during data analysis, where applicable;
- how combining data across different data sets was performed, where applicable;
- for any statistical tests, whether they are one or two sided;
- for any statistical tests, the alpha levels used (amount of acceptable error);
- for any statistical tests, how p values are calculated (the probability of getting the observed result or a more extreme one by chance);
- how confidence intervals are calculated, where applicable;
- statistical methods used (including limits).

Not meeting the above criteria makes it difficult for the sophisticated consumer of the information products to interpret them properly, and to have confidence in the conclusions drawn. Note that further reporting requirements may be necessary for particular data analysis techniques. Also, note that some of these reporting details may be included in appendices of analysis reports if they are not appropriate for the primary audience. The level of analysis may need to be tailored to the level of sophistication of the consumer or user.

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