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Software and systems engineering — Methods and tools for product line measurement

Ingénierie du logiciel et des systèmes — Méthodes et outils pour les mesures de gammes de produits

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

Introduction

Software and systems product line (SSPL) engineering and management creates, exploits and manages a common platform to develop a family of products (e.g. software products, systems architectures) at a lower cost, with reduced time to market and better quality. As a result, it has gained increasing global attention since the 1990s.

For the successful adoption of the SSPL approach, quantitative management of a product line is essential. For quantitative management, the quality of product line processes and their work products should be measured. This is important because a product line deals with products as a portfolio, and its quality is not limited to a single product but multiple different products. Product line measurements deal with the quality of domain assets, the quality of individual products associated with the quality of a product line, and the quality of a product. Besides, for variability management, a product line should measure the number of variabilities and their impacts on the success of a product line. Methods and tools of product line measurements should consider these product line specific aspects.

This document can be used in the following modes:

— to provide guidance on how to perform product line measurement by organizations that want to adopt SSPL for producing their products;

— to provide guidance on the evaluation and selection for methods and tools for product line measurement by a product line organization;

— to provide guidance on implementing or developing methods and/or tools by specifying a comprehensive set of methods and tools capabilities for supporting product line measurement by either providers of methods or tools, or both.

The ISO/IEC 26550 family of standards addresses both engineering and management processes and capabilities of methods and tools in terms of the critical characteristics of product line development. This document provides processes and capabilities of methods and tools for variability modelling in product lines.

Other standards in the ISO/IEC 26550 family are as follows: ISO/IEC 26550, ISO/IEC 26551, ISO/IEC 26552, ISO/IEC 26553, ISO/IEC 26554, ISO/IEC 26555, ISO/IEC 26556, ISO/IEC 26557, ISO/IEC 26558, ISO/IEC 26559, ISO/IEC 26560, ISO/IEC 26561, ISO/IEC 26562 and ISO/IEC 26563.

— Processes and capabilities of methods and tools for domain requirements engineering and application requirements engineering are provided in ISO/IEC 26551.

— Processes and capabilities of methods and tools for domain design and application design are provided in ISO/IEC 26552.

— Processes and capabilities of methods and tools for domain realization and application realization are provided in ISO/IEC 26553.

— Processes and capabilities of methods and tools for domain testing and application testing are provided in ISO/IEC 26554.

— Processes and capabilities of methods and tools for technical management are provided in ISO/IEC 26555.

— Processes and capabilities of methods and tools for organizational management are provided in ISO/IEC 26556.

— Processes and capabilities of methods and tools for variability mechanisms are provided in ISO/IEC 26557.

— Processes and capabilities of methods and tools for variability modelling are provided in ISO/IEC 26558.

— Processes and capabilities of methods and tools for variability traceability are provided in ISO/IEC 26559.

— Processes and capabilities of methods and tools for product management are provided in ISO/IEC 26560.

— Processes and capabilities of methods and tools for product line technical probe are provided in ISO/IEC 26561.

— Processes and capabilities of methods and tools for product line transition management are provided in ISO/IEC 26562.

— Processes and capabilities of methods and tools for product line configuration management are provided in ISO/IEC 26563.

Software and systems engineering — Methods and tools for product line measurement

1 Scope

This document, within the context of methods and tools that support the product line measurement and management and that demonstrate the quality of the products and a product line:

— specifies processes for product line measurement (the processes are described in terms of purpose, inputs, tasks and outcomes);

— specifies method capabilities to support the defined tasks of each process;

— specifies tool capabilities that automate or semi-automate tasks and methods.

This document does not concern the processes and capabilities of tools and methods for a single system but rather deals with those for a family of products.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
application asset
output of a specific application engineering process (e.g. application realization) that may be exploited in other lifecycle processes of application engineering and may be adapted as a *domain asset* (3.3) based on a product management decision

[SOURCE: ISO/IEC 26550:2015, 3.2, modified — Notes to entry have been removed.]

3.2
commonality index
index that captures the level of commonality of a feature, subsystem, component or a product line

Note 1 to entry: Commonality index is calculated as a formula such as *measure* (3.4) or combination of measures (function). The formula for calculating the commonality index reflects the relative size, effort, complexity, or importance of features, subsystems, components, or a product line as weights.

Note 2 to entry: Function points is one of the candidate cost estimation methods used to calculate efforts required for establishing core assets or product line development. A commonality index is used in conjunction with a function point.

Note 3 to entry: Annex A elaborates on the meaning of commonality and commonality index of the product line.

3.3
domain asset
output of domain engineering life cycle processes that can be reused in producing products during application engineering

[SOURCE: ISO/IEC 26550:2015, 3.11, modified — The alternative preferred term "core asset" and notes to entry have been removed.]

3.4
measure
variable to which a value is assigned as the result of *measurement* (3.5)

Note 1 to entry: The term "measures" is used to refer collectively to base measures, derived measures, and indicators.

[SOURCE: ISO/IEC 25000:2014, 4.18]

3.5
measurement
set of operations having the object of determining a value of a *measure* (3.4)

Note 1 to entry: Measurement can include assigning a qualitative category such as the language of a source program (ADA, C, Java, etc.).

[SOURCE: ISO/IEC 25000:2014, 4.20]

3.6
variability index
index that captures the level of variations across features, subsystems, components, products, or product lines

Note 1 to entry: Variability index is calculated as a formula such as *measure* (3.4) or combination of measures (function). The formula for calculating the variability index reflects the relative size, effort, complexity, or importance of features, subsystems, components, or product lines as weights.

Note 2 to entry: Function points is one of the candidate cost estimation methods used to calculate the additional efforts required for product development. A variability index is used in conjunction with a function point.

Note 3 to entry: Annex A elaborates on the meaning of variability and variability index of the product line.

4 Reference model for product line measurement

4.1 Overview

Measurements allow an organization to manage characteristics of software or systems quantifiably or countably. Measurements are necessary for measuring performance, estimating and planning work items, and measuring productivity. Software and systems product line (SSPL) engineering and management manage common platforms and variability and derive individual products based on the common platform and managed variability. These concepts are not necessary for the development of single systems and are not considered in single system measurement.

NOTE ISO/IEC/IEEE 15939 describes concepts of measurement for software and systems engineering projects.

In SSPL, different measures from single system measurement should be established to characterize the properties of SSPL. Product line (PL) measurements include commonality- and variability-aware measurement processes, tasks, and their supporting methods' and tools' capabilities. Product line measurement also includes measurements for the variability model because they are linked to all processes of product line lifecycles.

Product line measurement aims to establish and improve a product line organization's ability to achieve product line objectives through measurement results to planning, organizing, controlling, or evolving a product line.

4.2 Reference model for product line measurement

The reference model specifies the structure of supporting processes and subprocesses for a product line measurement. Figure 1 shows that a product line measurement can be structured into three processes: product line measurement management, product line measurement operationalization, and product line measurement support. In the rest of this document, tasks, methods, and tools are described for processes and subprocesses defined in the reference model.

Each process is divided into subprocesses, and each subprocess is described in terms of the following attributes:

— the title of the subprocess;

— the purpose of the subprocess;

— the inputs to produce the outcomes;

— the tasks to achieve the outcomes;

— the outcomes of the subprocess.

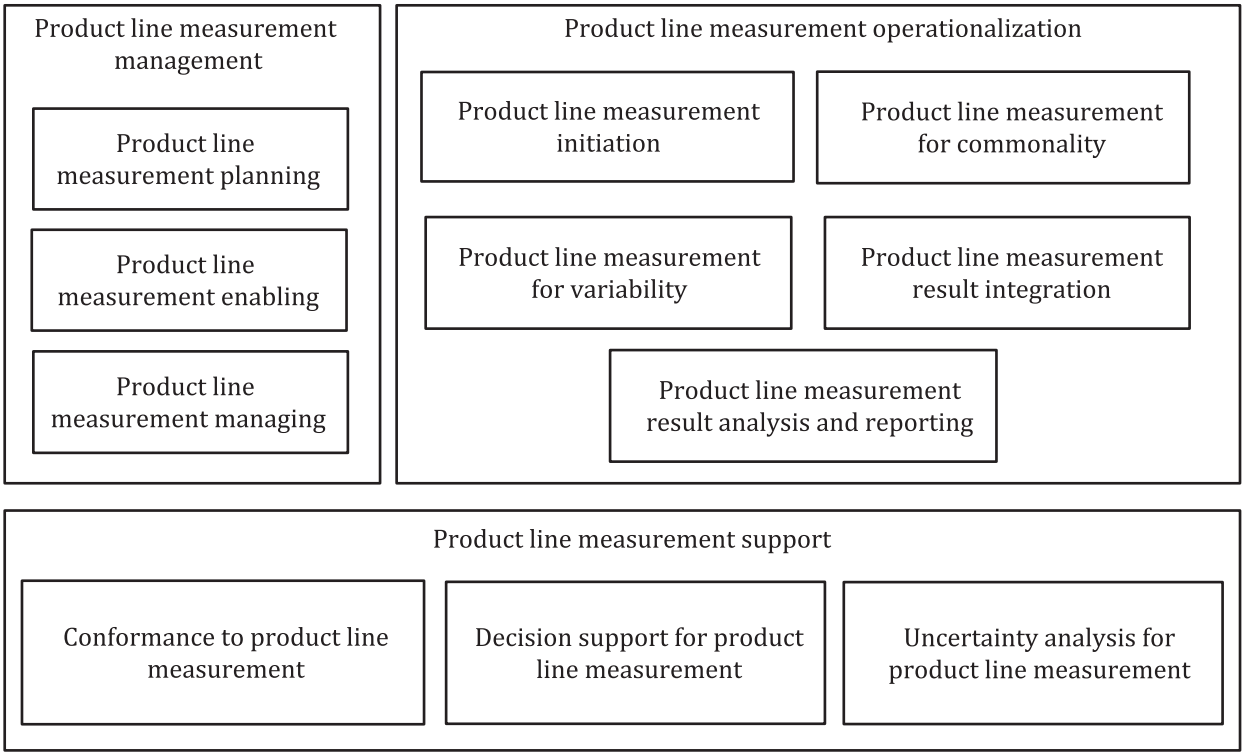

Figure 1 — Reference model for the product line measurement

The product line measurement management process provides managerial supports for planning product line measurement (e.g. resource estimation, responsibility allocation, success measures), supports for providing necessary resources, tools, and infrastructures for deploying measurement plans, and supports for analysing the plan versus the actual status of product line measurement. The product line measurement management does the following:

— product line measurement planning establishes plans for initiating, operationalizing, and supporting product line measurement; product line measurement plan includes scope, measurement

and performance objectives, and strategies of product line measurement, outcomes of major measurement activities, schedules for product line measurement, and required resources;

— product line measurement enabling defines, maintains, and assures the availability of environments, guidance, and resources necessary to performing product line measurement; environments include tools to automate the measurement process, collaborative environment, repository to store and maintain historical data, collected data, calculated results, and reports;

— product line measurement managing provides integrated management for the measurement operationalization; this subprocess reviews the measurement operationalization's actual status against plans, measurement and performance objectives, controls issues, and takes corrective actions if necessary.

The product line measurement operationalization process performs measurement operations for quantifiable or countable management of product line engineering and management. This process performs measurements for variability model, commonality, variability, and individual products and integrates results to assess product line engineering and management processes and identify opportunities for improvements. The product line measurement operationalization does the following:

— product line measurement initiation performs pilot PL measurements and gradually expands PL measurement throughout the entire PL organization; during initiation, participants with specific responsibilities for data collection are identified; resources are mobilized to start PL measurement; the PL measurement enablers can be improved after pilot PL measurement;

— product line measurement for commonality performs measurements for processes and artefacts concerning commonality of a product line; commonality index and formula are defined and measured throughout domain engineering and application engineering;

— product line measurement for variability performs measurements for processes and artefacts concerning variabilities of a product line; variability index and formula are defined and measured throughout domain engineering and application engineering;

— product line measurement result integration integrates measurement results of commonality and variability to characterize properties of a PL; integration protocol is applied to integrate measurement results of commonality and variability that have gaps in relative sizes, complexities, and efforts;

— product line measurement results analysis and reporting perform statistical analysis of measurement results from process stability, capability, and performance; create analysis reports, and communicate with stakeholders to identify improvement opportunities for stable and capable product line process appropriate to achieve PL objectives.

The product line measurement support process provides the supports required to perform the product line measurement operations and produce reliable measurement results for a product line. To achieve these, the product line measurement support does the following:

— conformance to product line measurement objectively evaluates the conformance to the measurement of relevant domain engineering assets and application engineering assets; actions are taken to resolve nonconformity issues;

— decision support for product line measurement supports decision making required during product line measurement operations such as selecting appropriate measures, interpreting measurement results, and fining improvement opportunities;

— uncertainty analysis for product line measurement calculates uncertainties of measurement processes and measurement components used to determine the acceptability of product line measurement; acceptability of product line measurement is assessed through confidence interval of commonality and variability measurement results.

Identifying and analysing the key differentiators between single-system engineering and management and product line engineering and management can help the organizations understand the product

line and formulate a strategy for the successful implementation of product line engineering and management. The key aspects have been defined in ISO/IEC 26550; and Table 1 shows the category of the critical aspects.

Table 1 — Key aspects for identifying product line measurement tasks

Category	Aspects
Reuse management	application engineering, domain assets, domain engineering, product management, platform, reusability
Variability management	binding, variability
Complexity management	collaboration, configuration, enabling technology support, reference architecture, texture, traceability
Quality management	measurement and tracking, cross-functional verification and validation

The following is the description for each aspect concerning product line measurement. The product line measurement processes and tasks shall be identified based on these aspects. The product line measurement concerns are to enable the organization to understand product line measurement processes, subprocesses, tasks, methods, and tools' capabilities.

— Application engineering: Not only individual products produced through application engineering need to be measured like a single system, but application engineering processes should also participate in measurements of variability models, commonality, and variability.

— Binding: Impacts of binding times on product line objectives such as reusability and flexibility should be measured or considered when a product line is characterized.

— Collaboration: Participants of domain and application engineering should closely collaborate with each other and with management roles because product line measurement activities are performed between relevant subprocesses of two engineering processes.

— Configuration: Measures to characterize configuration complexity, configuration space, or configurability should be selected, and appropriate data should be collected.

— Domain asset: Measures to characterize domain assets should be selected, and proper data should be obtained.

— Domain engineering: Domain engineering processes should participate in measurements of variability models, commonality, and variability.

— Enabling technology support: Resources and infrastructures necessary to initiate, operate, and support product line measurement should be enabled.

— Measurement and tracking: Product line measurement processes and their artefacts should be measured and controlled.

— Platform: Measures to characterize platforms are selected, and appropriate data should be collected.

— Product management: Decisions and outcomes of product management should be measured to determine their influences on the achievement of product line objectives.

— Reference architecture: The impact of decisions made for designing a reference architecture should be measured for identifying improvement opportunities.

— Reusability: Reusability is one of the significant measurement objects in product line measurement.

— Texture: Measurements for commonality and variability should consider textures concerning their efficiencies, supporting the reusability of a product line.

— Traceability: Traceability is one of the significant measurement objects in product line measurement.

— Cross-functional validation and verification: Artefacts, processes, and tasks related to product line measurement should be validated and verified when the needs arise.

— Variability: Variability is one of the significant measurement objects in product line measurement.

5 Product line measurement management

5.1 General

The product line measurement management supports the following:

a) product line measurement planning;

b) product line measurement enabling;

c) product line measurement managing.

5.2 Product line measurement planning

5.2.1 Principal constituents

5.2.1.1 Purpose

The purpose of this subprocess is to produce and coordinate a practical and workable product line measurement plan.

The product line measurement planning determines the scope of the measurement, goals of product line measurement, strategies of product line measurement, product line objective measures, outcomes of major measurement activities, success measures, schedules for measurement including entry/exit criteria, and required resources to accomplish the purpose of measurement.

The scope and strategies of product line measurement include how the measurements of commonality and variability of a product line are performed at processes when an important decision is made, such as product line technical probe, product line transition, and scoping.

5.2.1.2 Inputs

The following inputs should be available to perform the process:

a) PL business objectives;

b) product line transition plan (from ISO/IEC 26562);

c) organizational standard PL processes.

NOTE Annex B provides an exemplary measurement for quantitatively clarifying the objectives of SSPL adoption.

5.2.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Product line measurement is planned, including the scope, measurement and performance objectives, and strategies of product line measurement, outcomes of major measurement activities, schedules for product line measurement, and required resources.

b) Product line measurement plans are approved.

c) Required resources and supporting technologies are formally requested and committed.

Measurement and performance objectives are described as quantitative or qualitative objectives. The objectives can include the use of statistical and other quantitative techniques or can possibly not include them.

5.2.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Identify strategies for measurement operationalization: Define product line measurement scopes and measurement and performance objectives from selected PL business objectives, and thereafter identify strategies that guide measurement operationalization.

b) Assign responsibility for measurement operationalization: Define roles, responsibilities and general principles, and management expectations for performing PL measurement operation.

c) Define success measures for measurement operationalization: Define measures, including quality criteria used for quality evaluation and insight into product line measurement performance.

d) Estimate adequate resources needed for measurement operationalization: Identify resources, efforts, schedule, supporting technologies, and costs for product line measurement to be performed.

d) Document product line measurement plans: Consolidate, review, approve, and document the PL measurement plans. Acquire formal commitment for the required resources and supporting technologies. Plans include PL measurement responsibilities and authorities, criteria for identifying configuration items, applicable policies, PL-specific measurement process, schedule, support tools, and resources.

5.2.2 Identify strategies for measurement operationalization

NOTE Measurement and performance objectives are primarily able to track PL business objectives. A mature PL organization uses statistical and quantitative techniques to develop the measurement and performance objectives traceable to the achievement of PL business objectives.

a) The method should support the task with the following capabilities:

   1) analysing product line context based on PL business objectives and the product line transition plan;

   2) assessing the organization's ability to achieve PL business objectives;

   3) tailoring PL organization's product line measurement process;

   4) establishing a strategy for product line measurement, including measurement and performance objectives, success measures, evaluation criteria, and measures for strategy evaluation.

b) A tool should support the task by allowing the user to:

   1) access PL business objectives and product line transition plans;

   2) refer to statistical and quantitative measurement and performance data of single product development or a PL development if possible;

   3) allow communication and discussion about alternatives of PL strategies with participants for selecting crucial components of a measurement strategy.

5.2.3 Assign responsibility for measurement operationalization

NOTE PL measurement has two additional dimensions, i.e. the measurement for commonality and variability. Business performance primarily depends on the performance of commonality- and variability-relevant processes. The degree of product line commonality and variability and performance are acquired from mature manageable, controllable, and predictable processes. Roles and responsibilities for measurement operations are defined from the two additional dimensions and those for managing and controlling performance at other various work levels.

a) The method should support the task with the following capabilities:

   1) analysing critical roles, responsibilities, general principles/rules for measurement data collection, and expectations for PL measurement;

   2) collating required roles, responsibilities, and general principles/rules for measurement data collection, and expectations with their candidate roles and responsibilities of the PL organization structure;

   3) deciding on roles and responsibilities of measurement data collection, reporting, and who takes the reports, including general principles and rules adhered to.

b) A tool should support the task by allowing the user to:

   1) access the PL organization structure;

   2) distribute defined roles and responsibilities, including their general principles and rules adhered to relevant participants of a PL.

5.2.4 Define success measures for measurement operationalization

a) The method should support the task with the following capabilities:

   1) defining success measures that can tie measurement operations of multiple dimensions to measurement goals;

   2) defining formulae of success measures covering associated measures of product line management, domain engineering, and application engineering measurement activities;

   3) identifying actionable product line management processes and tying them to success measures;

   4) establishing tracking mechanisms with measurement operations of multiple dimensions and management processes to collect and support success measures.

b) A tool should support the task by allowing the user to:

   1) access the overall objectives of a product line, strategies, and processes;

   2) collect and support success measures through established tracking mechanisms.

5.2.5 Estimate adequate resources needed for measurement operationalization

a) The method should support the task with the following capabilities:

   1) providing factors that should be considered for the estimation of PL measurement;

   2) analysing relations among factors using historical data built for the previous PL or for products produced before adopting PL.

b) A tool should support the task by allowing the user to:

   1) access historical data for managing the performance of the previous PL and appropriate single products;

2) (semi-)automatically calculate estimation results;

3) store estimation results for the further improvement of estimation for the next product line.

5.2.6 Document product line measurement plans

a) The method should support the task with the following capabilities:

1) providing the documentation standard for a product line measurement plan (the contents of the plan include stakeholder, measurement strategy, measurement processes used, and estimates, staffing including required training);

2) providing examples for each product line measurement plan item.

b) A tool should support the task by allowing the user to:

1) edit/fill out a product line measurement plan using an editable and changeable template;

2) maintain the version control of the product line measurement plan documents;

3) share the product line measurement plan with the stakeholders.

5.3 Product line measurement enabling

5.3.1 Principal constituents

5.3.1.1 Purpose

The purpose of this subprocess is to establish the product line organization's ability to accomplish product line measurement and performance objectives toward achieving PL business objectives by providing the required environments and resources necessary to support and operationalize product line measurement.

5.3.1.2 Inputs

The following inputs should be available to perform the process:

a) product line measurement plan;

b) an organization's possible infrastructure and human resources.

5.3.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Product line measurement environments and resources are enabled.

b) Guidance for measurement operationalization is provided.

NOTE Product line measurement environments include tools, approaches, methods, and communication channels among different measurement roles, responsibilities, and accountabilities of varying levels of abstractions, i.e. product line organization level, domain level, and member product level. Measurement environments include resources necessary for product line measurement. Resources include facilities, skilled staff, and logistics required to measure integrated software and systems product line as a whole, each member product, and system or software modules.

5.3.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Enable product line measurement environment: Provide infrastructure and human resources necessary to carry out the product line measurement plan.

b) Define index, formula, and integration protocol for commonality and variability measurement: Identify index, formulae, and integration protocols to manage commonality and variability in the organization's set of standard PL processes. If a PL organization has statistically analysed results, indices and formulae are defined using statistical analysis results. Integration protocol is an accurate and reliable means for quantifying business objectives' overall achievements by combining commonality and variability measurements measured with different measurement protocols.

c) Provide guidance for measurement operationalization: Define guidance for accurate and consistent data collection and measurement throughout domain engineering, application engineering, and management processes and provide guidance for coordinating commonality and variability measurement issues among roles and responsibilities of management, domain engineering, and application engineering.

d) Enable measurement environments for quantifying measurement operationalization: Establish a product line organization's ability to quantitatively manage the performance of measurement operations.

5.3.2 Enable product line measurement environment

a) The method should support the task with the following capabilities:

   1) estimating required infrastructures and human resources with essential capabilities based on product line measurement plans; estimation can be done using historical data, product line community benchmark, or divide and conquer;

   2) mobilizing estimated required infrastructures and human resources.

b) A tool should support the task by allowing the user to:

   1) access information necessary for estimating required infrastructures and human resources with essential capabilities based on product line measurement plans;

   2) tie mobilized infrastructures and human resources for integrating measurement results collected multiple dimensions of a product line.

5.3.3 Define index, formula, and integration protocol for commonality and variability measurement

a) The method should support the task with the following capabilities:

   1) defining measures for a product line objective balanced across multiple dimensions of a product line (dimensions include commonality and variability management);

   2) defining indices and formulae based on measures that provide insight into commonality and variability issues or concepts; Formulae can be defined at product level and PL level;

   3) validating indices, formulae, and measures whether they are easily understood, communicated, quantified, and collected;

   4) identifying actionable product line management processes and tying them to measures for a product line objective;

   5) defining ways to combine commonality and variability measurements performed with different measurement protocols to quantify the overall achievements of business objectives;

6) establishing tracking mechanisms to collect and support measures for a product line objective.

b) A tool should support the task by allowing the user to:

1) share product line objectives, measurement and performance objectives, and organizational standard PL processes;

2) provide data collection form and record the collected data with the form;

3) (semi-)automatically calculate the values of measure and formulae, and determine the degrees of indices;

4) provide data pre-processing (outliers, consistency check, cross-reference check, etc.);

5) analyze measurement results (quantitatively and statistically);

6) express the results with appropriate charts;

7) collect and support success measures through established tracking mechanisms.

5.3.4 Provide guidance for measurement operationalization

a) The method should support the task with the following capabilities:

1) defining what to measure, why measured, when, how, and who perform measurements from organizational management, domain engineering, and application engineering, asset management, and technical management dimensions by considering both their artifacts and processes;

2) guiding follow-up key actions after product line measurement;

3) developing exemplary product line measurements in each dimension, including how different dimensions are linked.

b) A tool should support the task by allowing the user to:

1) access a product line context, knowledge, and experiences of measurements in both product line engineering and single product development;

2) edit guidance and share it for product line measurement operationalization.

5.3.5 Enable measurement environments for quantifying measurement operationalization

a) The method should support the task with the following capabilities:

1) refining actionable measurement tasks for quantifying product line measurement operations;

2) establishing measurement mechanisms for quantifying product line measurement operationalization.

b) A tool should support the task by allowing the user to:

1) access best practices or benchmarks of quantifying measurement operations of a product line;

2) accrue measured data from product line measurement operations;

3) connect a stable measurement environment with communication channels to share measurement issues concerning quantification and resolve conflicts.

5.4 Product line measurement managing

5.4.1 Principal constituents

5.4.1.1 Purpose

The purpose of this subprocess is to monitor, control, and improve product line measurement planning, measurement enabling, operationalization, and support. This subprocess monitors measurement tasks and their effectiveness and correctness concerning commonality and variability. Appropriate corrective actions and improvements are made following their consequent achievements.

5.4.1.2 Inputs

The following inputs should be available to perform the process:

a) product line measurement plan, including measurement objectives and success measures of measurement operations;

b) enabled product line measurement environments;

c) guidance for product line measurement operationalization;

d) data elements collected from each measurement role, responsibility, and accountability.

5.4.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process: appropriate corrective actions and improvements are made.

5.4.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Review measurement operationalization status with success measures: Integrate data elements from measurement tasks and reports from the roles and responsibilities that use measurement results and then determine the value of success measures to know the measurement operationalization status.

b) Control issues on measurement operationalization: Identify root causes of obstacles of successful measurement operations and supports and determine appropriate corrective actions to achieve product line measurement goals and their consequent achievement of product line objectives.

c) Make corrective actions on measurement operationalization: Enable corrective or improvement actions on product line measurement operations and supports, track the results of corrective actions, and record lessons learned.

5.4.2 Review measurement operationalization status with success measures

a) The method should support the task with the following capabilities:

   1) defining right data elements and their right collection points (source of data elements required) of product line measurement operations;

   2) ensuring that data elements and collection points are well-harmonized across product line organization management, domain engineering processes, application engineering processes, and asset management processes;

   3) defining success measures (e.g. measurement accuracy variance when a success measure is measurement accuracy);

4) estimating the baseline of the defined success measures;

5) representing the status of product line measurement operations with the success measures based on baselines versus actual values.

b) A tool should support the task by allowing the user to:

1) collect and calculate formulae of success measures (semi-)automatically;

2) generate and express degrees of success of product line measurement operations graphically;

3) share degrees of success of product line measurement operations with relevant roles.

5.4.3 Control issues on measurement operationalization

a) The method should support the task with the following capability: identifying product line measurement activities that should be controlled after finding control issues on product line measurement operationalization based on degrees of success.

b) A tool should support the task by allowing the user to notify product line measurement activities to be controlled.

5.4.4 Make corrective actions on measurement operationalization

a) The method should support the task with the following capabilities:

1) analysing root causes of the gaps between plan versus actual values of success measures;

2) deriving improvement needs and action items for product line measurement operations;

3) decomposing and assigning refined roles and responsibilities (i.e. product line engineers, domain engineers, application engineers, or configurators) to the relevant product line management, domain engineering, and application engineering participants of measurement operations.

b) A tool should support the task by allowing the user to:

1) find roles related to action items for the assignment;

2) let relevant participants know their roles and responsibilities for delivering corrective actions;

3) share relations of action items with related roles.

6 Product line measurement operationalization

6.1 General

The product line measurement operationalization supports the following:

a) product line measurement initiation;

b) product line measurement for commonality;

c) product line measurement for variability;

d) product line measurement results integration;

e) product line measurement results analysis and reporting.

6.2 Product line measurement initiation

6.2.1 Principal constituents

6.2.1.1 Purpose

The purpose of this subprocess is to simulate and check PL measurement enablers, i.e. environments and resources, against PL measurement plans. This subprocess ensures that the enabled PL measurement settings are able to understand PL development and operation progresses toward achieving the PL business objectives.

6.2.1.2 Inputs

The following inputs should be available to perform the process:

a) product line measurement plan;

b) guidance for measurement operationalization;

c) enabled product line measurement environments and resources.

6.2.1.3 Outcomes

The following outcome shall be available as a result of the successful implementation of the process: Revised PL measurement guidance and enablers are initiated.

6.2.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Identify PL measurement participants: Determine who collect data, to whom data are reported, and stakeholders who are affected by the measurement analysis results. Participants include persons responsible to collect data, persons to integrate, analyse, and manage the collected data, and persons who use the results to improve organizational PL process improvements.

b) Mobilize resources for PL measurement operation: Share inputs for PL initiation with PL measurement participants.

c) Initiate PL measurement operation: Integrate and implement for starting enabled PL measurement for collecting, recording, tracking, and reporting of PL measurement operations within and across participants of PL.

d) Perform preliminary PL measurement: Start pilot PL measurement with initiated PL measurement operation for evaluating and improve PL measurement participants, environments, and resources in advance if necessary.

6.2.2 Identify PL measurement participants

a) The method should support the task with the following capabilities:

   1) assigning measurement roles and responsibilities to appropriate PL organization units of a PL organization chart;

   2) assigning data collection responsibility to an appropriate PL participant of a PL organization unit.

b) A tool should support the task by allowing the user to:

   1) access PL organization chart;

2) share measurement guidance appropriate to its responsibility with each participant.

6.2.3 Mobilize resources for PL measurement operation

a) The method should support the task with the following capabilities:

1) training qualified human resources for necessary responsibilities of PL measurement;

2) checking qualifications of human resources for PL measurement;

3) aligning gaps between required and mobilized qualifications of human resources;

4) defining/refining evaluation criteria for the efficiency of mobilized human resources.

b) A tool should support the task by allowing the user to:

1) access the qualification of human resources to be mobilized;

2) record gaps between required and mobilized qualifications of human resources to have a chance to improve their qualifications;

3) monitor the efficiency of mobilized human resources following evaluation criteria.

6.2.4 Initiate PL measurement operation

a) The method should support the task with the following capability: integrating PL measurement participants and enablers for collecting data within and across PLs, integrating and analysing measurement results, and reporting and managing the performance of achieving business objectives.

b) A tool should support the task by allowing the user to:

1) interconnect support tools of enabled PL measurement environments and resources for starting PL measurement procedures;

2) check and change the interconnected support tool settings for PL measurement operation.

6.2.5 Perform preliminary PL measurement

a) The method should support the task with the following capabilities:

1) evaluating that preliminary PL measurement results and their interpretation fed to relevant processes are appropriate to improve its process and take corrective actions;

2) finding inadequate PL measurement enablers and recommending improvement actions.

b) A tool should support the task by allowing the user to:

1) collect feedback from measurement users;

2) record and share agreed on improvement actions for PL measurement enablers.

6.3 Product line measurement for commonality

6.3.1 Principal constituents

6.3.1.1 Purpose

The purpose of this subprocess is to quantify the characteristics of commonality and evaluate the performance of PL commonality against the associated PL business objectives, measurement and performance objectives, risks, and problems.

6.3.1.2 Inputs

The following inputs should be available to perform the process:

a) commonality indices, formulae and other measures;

b) guidance for measurement operationalization;

c) enabled product line measurement environments and resources.

6.3.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Indices, formulae, and other measures for commonality are selected or newly defined.

b) Degree of commonality index is determined by integrating commonality measurement results with the integration protocol.

c) Quality of commonality measurement and improvement actions are documented.

6.3.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Identify commonality for measurement: Analyse common elements of domain assets (e.g. components, interfaces, ports, textures), their reuse structures, and their relationships within the structure for measuring the degree of commonality at product level and PL level. Select commonality indices, formulae, and other measures if necessary, and Acquire approval for the selections from the management role.

b) Apply commonality index and formula for PL measurement: Determine the point of times or phases or iterations of a product line to start and finish data collection and compute the value of commonality index. Data for determining commonality index are collected with the identified commonality structures and relationships among elements of the structure.

d) Measure and determine the degree of PL commonality: Integrate the formulae to determine the degree of product line commonality. The formula for integrating commonality formulae can be required and the formula should be defined by the PL Measurement Enabling process.

e) Communicate and escalate commonality measurement issues to relevant roles and responsibilities (R&R): Evaluate determined degrees of commonality indices, the values of measures, and performed measurement procedures against the specified quality criteria and derive potential improvements of measures, indices, formulae, procedures, environments, and resources for commonality measurement.

NOTE 1 Commonalities, their reuse structures, and their relationships within the structure for software systems are obtained from the feature model, product line architecture, and detailed domain design.

NOTE 2 Formulae are defined for computing the degree of commonality at product level and at PL level, respectively. The degree of commonality index at product level is integrated into the degree of commonality index at PL level.

Commonality index (CI) of a component can be calculated with the formula in Example 1.

EXAMPLE 1

$$C_i = r_i \times P_i$$

where

C_i is the CI of a component *i*;

P_i is the priority of a component *i* (e.g. Strategic: 1, High-priority: 1/2, Basic: 1/3);

r_i is the number of products of a product line that reuse the component *i*.

The CI score for a component takes a value between 0 and *N*, where *N* is the number of products of a product line. CI value for a product line, C_P can be calculated with the formula in Example 2.

EXAMPLE 2

$$C_P = \frac{\sum_{i=1}^{N_C} C_i}{N}$$

where

C_p is the CI score for a product line;

N_C is the total number of components of a product line;

N is the total number of products of a product line.

Product line effort, P_e, can be estimated using CI and function point (FP) of a component.

EXAMPLE 3

$$P_e = \sum_{i=1}^{NC}\left(F_i \times \frac{1}{C_i}\right)$$

where

P_e is the PL effort;

F_i is the FP for component *i.*

The value of the P_e is between $\frac{\sum_{i=1}^{NC} F_i}{N^{NC}}$ and $\frac{\sum_{i=1}^{NC} F_i}{\sim 0}$.

6.3.2 Identify commonality for measurement

a) The method should support the task with the following capabilities:

1) deriving measurement objectives for commonality (e.g. cost reduction through optimized commonality) from overall measurement and performance objectives and product line business objectives;

2) keeping derived measurement objectives for commonality traceable to overall measurement and performance objectives and product line business objectives;

3) identifying and prioritizing the information needs for understanding characteristics and sub-characteristics of commonality (e.g. optimized amount of commonality for preventing carnivalization from organization aspect);

4) selecting or newly defining indices, formulae, or other measures if necessary, that satisfy the information needs of commonality measurement; Statistical and quantitative techniques can be used;

5) selecting common elements (e.g. components, interfaces, ports, textures) of domain assets by analysing commonalities, their reuse structures, and their relationships within the structure for measuring the degree of commonality;

6) checking the feasibility of formulae, e.g. whether weights of a formula and relation among dependent and independent variables are appropriate or have reasonable rationales;

7) identifying data collection requirements (i.e. data elements and source) of commonality measurement;

8) adapting data quality criteria to commonality measurement.

b) A tool should support the task by allowing the user to:

1) record measurement objectives for commonality and keep them traceable and updated;

2) edit/fill out a template or a document for defining objectives, information needs, characteristics, sub-characteristics, and data collection requirements of commonality measurement;

3) place indices, formulae, and other measures for automatic calculation;

4) use necessary enabling systems or services for measurement, raw data collection, data pre-processing and analysis, result representation, and corrective actions.

6.3.3 Apply commonality index and formula for PL measurement

a) The method should support the task with the following capabilities:

1) integrating measurement processes for raw data collection into the relevant product line engineering processes;

2) defining ways to integrate distributed data for applying the commonality index and formula.

b) A tool should support the task by allowing the user to:

1) capture and record (manually or automatically under tool support) required raw measurement data from data sources in product line engineering processes for commonality measurement;

2) compute the values of commonality indices at product level and PL level;

3) compute the values of defined formulae for measuring commonality at product level and PL level.

6.3.4 Measure and determine the degree of PL commonality

a) The method should support the task with the following capabilities:

1) validating collected data, values of commonality indices, and formulae used for measuring and determining the degree of PL commonality;

2) defining ways to integrate distributed data, values commonality indices, and formulae.

b) A tool should support the task by allowing the user to:

1) access and integrate distributed data and values necessary to compute the degree of PL commonality;

2) compute and record the degree of PL commonality using the defined formula.

6.3.5 Communicate and escalate commonality measurement issues to relevant roles and responsibilities (R&R)

a) The method should support the task with the following capabilities:

1) checking data integrity collected from product line engineering processes (data quality evaluation criteria can be used);

2) evaluating whether commonality measurement results are appropriate to perform causal analysis and define corrective actions;

3) analysing commonality measurement issues according to PL business objectives, measurement and performance objectives related to commonality, etc.

b) A tool should support the task by allowing the user to:

1) collect voice of participants during commonality measurement;

2) share measurement issues for PL commonality from commonality index to the degree of PL commonality with appropriate participants and stakeholders;

3) record communication results of PL commonality measurement issues.

6.4 Product line measurement for variability

6.4.1 Principal constituents

6.4.1.1 Purpose

The purpose of this subprocess is to quantify the characteristics of PL variability associated with product line objectives, goals, risks, and problems.

6.4.1.2 Inputs

The following inputs should be available to perform the process:

a) commonality indices, formulae, other measures;

b) guidance for measurement operationalization;

c) enabled product line measurement environments and resources.

6.4.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Indices, formulae, and other measures for variability are selected or newly defined.

b) Degree of commonality index is determined by integrating variability measurement results with the integration protocol.

c) Quality of variability measurement and improvement actions are documented.

6.4.1.4 Tasks

The organization shall implement the following tasks with respect to the process.

a) Identify variability for measurement: Analyse variable elements of domain assets (e.g. components, interfaces, ports, textures), application-specific variable elements, their reuse structures, and their relationships within the structure for measuring the degree of variability at product level and PL level. Select variability indices, formulae, and other measures if necessary, and acquire approval for the selections from the management role.

b) Apply variability index and formula for PL measurement: Determine the point of times or phases or iterations of a product line to start and finish data collection and compute the value of variability index. Data for determining variability index are collected with the identified variability structures and relationships among elements of the structure.

d) Measure and determine the degree of PL variability: Integrate the formulae to determine the degree of product line variability. The formula for integrating variability formulae can be required, and the PL measurement enabling process should define the formula.

e) Communicate and escalate variability measurement issues to relevant R&R: Evaluate determined degrees of variability indices, the values of measures, and performed measurement procedures against the specified quality criteria and derive potential improvements of measures, indices, formulae, procedures, environments, and resources for variability measurement.

Variability index (VI) score of a component can be calculated with the formula in Example 1.

EXAMPLE 1

$$V_i = (N - r_i) \times P_i$$

where

V_i is the VI score of a component *i*;

P_i is the priority of a component *i* (e.g. Strategic: 1, High-priority: 1/2, Basic: 1/3);

r_i is the number of products of a product line that reuse the component *i*;

N is the total number of products in a product line.

The VI score for a component takes a value between 0 and *N*. VI for a product line can be calculated with the formula in Example 2.

EXAMPLE 2

$$V_P = \frac{\sum_{i=1}^{N_C} V_i}{N}$$

where

V_P is the VI score for a product line;

N_C is the total number of components of a product line;

N is the total number of products of a product line.

6.4.2 Identify variability for measurement

a) The method should support the task with the following capabilities:

1) deriving measurement objectives for variability (e.g. cost reduction through optimized variability) from overall measurement and performance objectives and product line business objectives;

2) keeping derived measurement objectives for variability traceable to overall measurement and performance objectives and product line business objectives;

3) identifying and prioritizing the information needs based on objectives for understanding characteristics and sub-characteristics of variability;

4) selecting or newly defining indices, formulae, or other measures if necessary that satisfy the information needs of variability measurement; statistical and quantitative techniques can be used;

5) selecting variable elements (e.g. components, interfaces, ports, textures) of domain assets by analysing variabilities, their reuse structures, and their relationships within the structure for measuring the degree of variability;

6) checking the feasibility of formulae, e.g. whether weights of formula and relation among dependent and independent variables are appropriate or have reasonable rationales;

7) identifying data collection requirements (i.e. data elements and source) of variability measurement;

8) adapting data quality criteria to variability measurement.

b) A tool should support the task by allowing the user to:

1) record measurement objectives for variability and keep them traceable and updated;

2) edit/fill out a template or a document for defining objectives, information needs, characteristics, sub-characteristics, and data collection requirements of variability measurement;

3) place indices, formulae, and other measures for automatic calculation;

4) use necessary enabling systems or services for measurement, raw data collection, data pre-processing and analysis, result representation, and corrective actions.

6.4.3 Apply variability index and formula for PL measurement

a) The method should support the task with the following capabilities:

1) integrating measurement processes for raw data collection into the relevant product line engineering processes;

2) defining ways to integrate distributed data for applying variability index and formula.

b) A tool should support the task by allowing the user to:

1) capture and record (manually or automatically under tool support) required raw measurement data from data sources in product line engineering processes for variability measurement;

2) computing the values of variability indices at product level and PL level;

3) computing the values of defined formulae for measuring variability at product level and PL level.

6.4.4 Measure and determine the degree of PL variability

a) The method should support the task with the following capabilities:

1) validating collected data, values of variability indices, and formulae used for measuring and determining the degree of PL variability;

2) defining ways to integrate distributed data, values variability indices, and formulae.

b) A tool should support the task by allowing the user to:

1) access and integrate distributed data and values necessary to compute the degree of PL variability;

2) compute and record the degree of PL variability using the defined formula.

6.4.5 Communicate and escalate variability measurement issues to relevant roles and responsibilities (R&R)

a) The method should support the task with the following capabilities:

1) checking data integrity collected from product line engineering processes (data quality evaluation criteria can be used);

2) evaluating whether variability measurement results are appropriate to perform causal analysis and define corrective actions;

3) analysing variability measurement issues according to PL business objectives, measurement and performance objectives related to variability, etc.

b) A tool should support the task by allowing the user to:

1) collect voice of participants during variability measurement;

2) share measurement issues for PL variability from variability index to the degree of PL variability with appropriate participants and stakeholders;

3) record communication results of variability measurement issues.

6.5 Product line measurement result integration

6.5.1 Principal constituents

6.5.1.1 Purpose

The purpose of this subprocess is to quantify the characteristics of a product line concerning measurement and performance objectives and product line business objectives.

6.5.1.2 Inputs

The following inputs should be available to perform the process:

a) PL measurement plans;

b) results of PL measurement for commonality and variability;

c) defined integration protocol;

d) enabled product line measurement environments and resources.

6.5.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Formulae reflecting the gaps between commonality and variability indices are selected or newly defined.

b) PL measurement results are integrated and computed.

c) Quality of PL measurement and improvement actions are documented.

6.5.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Identify gaps for integration among commonality and variability indices: Determine weights for commonality and variability indices of different complexities, efforts, and sizes.

b) Integrate commonality and variability indices: Select or newly define integration formulae by applying integration protocol and quantify the overall achievements of business objectives by combining commonality and variability measurements measured with different measurement protocols.

c) Communicate and escalate PL measurement issues to relevant R&R: Share measurement and interpreted results with relevant R&R so that R&R uses the measurement results to make decisions and take corrective actions, manage risks, and improve processes.

6.5.2 Identify gaps for integration among commonality and variability indices

a) The method should support the task with the following capabilities:

   1) determining commonality and variability indices used for checking the achievement of the specific business objective;

   2) determining benchmark, weights, and formulae for integration among commonality and variability indices (aggregated index can be used to ensure that the importance of individual indices is not ignored);

   3) selecting ways to test existing gaps between selected commonality and variability indices;

   4) selecting or newly defining appropriate formulae reflecting the gaps between commonality and variability indices.

      NOTE Integration protocol includes formulae for integration, where formulae are defined by using weights and selected commonality and variability indices.

b) A tool should support the task by allowing the user to:

   1) test gaps between selected commonality and variability indices;

   2) compare candidate formulae to select an appropriate one.

6.5.3 Integrate commonality and variability indices

a) The method should support the task with the following capabilities:

   1) providing ways to apply integration protocol;

   2) quantifying the overall achievements of business objectives by combining commonality and variability measurements using formulae.

b) A tool should support the task by allowing the user to:

   1) access and integrate values of commonality and variability indices;

   2) compute and record the degree of PL variability using the defined formulae.

6.5.4 Communicate and escalate PL measurement issues to relevant roles and responsibilities (R&R)

a) The method should support the task with the following capabilities:

   1) checking integrity of collected data at PL level;

   2) evaluating whether PL measurement results are appropriate to perform causal analysis and define corrective actions;

   3) consolidating commonality and variability measurement issues at PL level.

b) A tool should support the task by allowing the user to:

   1) collect voice of participants during PL measurement;

   2) share PL measurement issues with appropriate participants and stakeholders;

   3) record communication results of PL measurement issues.

6.6 Product line measurement result analysis and reporting

6.6.1 Principal constituents

6.6.1.1 Purpose

The purpose of this subprocess is to analyse PL measurement results and report the results to relevant stakeholders in a timely, usable way to support decision making and take corrective actions, manage risks, and proceed with improvements.

Results are reported to decision process participants, technical and management review participants, and product line and process improvement process owners (ISO/IEC/IEEE 12207).

NOTE Annex C provides example capability maturity levels of SSPL measurement process. SSPL measurement process improvement can be planned with the current and desired maturity level.

6.6.1.2 Inputs

The following inputs should be available to perform the process:

a) outcomes of the product line measurement for commonality;

b) outcomes of the product line measurement for variability;

c) outcomes of the product line measurement result integration;

d) product line measurement plan.

6.6.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Report for PL measurement results is documented.

b) PL measurement indices are refined and revised.

6.6.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Analyse PL measurement results with PL objectives: Analyse PL performance against established PL objectives by combining results of commonality and variability measurement and PL measurement integration.

b) Report PL measurement results: Report PL measurement analysis results to decision process participants, technical and management review participants, and product line and improvement process owners.

c) Identify improvement opportunities for defined indices of PL measurement: Review PL measurement indices and redefine inappropriate indices of PL measurement.

6.6.2 Analyse PL measurement results with PL objectives

a) The method should support the task with the following capabilities:

   1) evaluating PL process stability, capability, and performance (e.g. using appropriate control charts, using appropriate calculations to determine the centre lines and control limits for the performance characteristics);

   2) detecting instabilities and out-of-control situations (e.g. using appropriate control charts);

3) identifying causes when a process is not stable, or process performance does not achieve PL objectives (e.g. causal analysis, statistical inference);

4) removing root causes of PL process instability and inadequate performance against PL objectives (PL process improvement actions are taken).

b) A tool should support the task by allowing the user to:

1) compute process performance using selected calculations based on measurement data;

2) plot the measurement data (e.g. on the control chart chosen).

NOTE Tools for finding root causes and solutions include the following:

— scatter diagram;

— run chart;

— cause-and-effect diagrams;

— histograms;

— bar charts;

— pareto charts.

6.6.3 Report PL measurement results

a) The method should support the task with the following capabilities:

1) consolidating analysis results of PL measurement and interpreting the results;

2) providing a template for the PL measurement result report.

b) A tool should support the task by allowing the user to:

1) edit/fill template for documenting PL measurement result report;

2) retain measurement data to identify trends and establish baselines for future measurement planning and PL process improvements (i.e. a repository containing PL development process, resources, PL data, and member product data).

6.6.4 Identify improvement opportunities for defined indices of PL measurement

a) The method should support the task with the following capabilities:

1) reviewing whether PL objectives and PL processes drive defined PL measurement indices;

2) reviewing whether defined PL measurement indices have clearly stated operational definitions;

3) refining or revising defined indices of PL measurement.

b) A tool should support the task by allowing the user to:

1) communicate online about defined indices of PL measurement among measurement participants;

2) share refined or revised indices of PL measurement with measurement participants.

7 Product line measurement support

7.1 General

The product line measurement support supports the following:

a) conformance to product line measurement;

b) decision support for product line measurement;

c) uncertainty analysis for product line measurement.

7.2 Conformance to product line measurement

7.2.1 Principal constituents

7.2.1.1 Purpose

The purpose of this subprocess is to evaluate product line measurement processes and their artefacts objectively.

7.2.1.2 Inputs

The following inputs should be available to perform the process:

a) measurement processes applied to product line measurement;

b) work products of product line measurement;

c) quality criteria defined at the product line measurement planning.

7.2.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Evidence of the product line measurement quality are produced.

b) Non-conformance issues with their status and results of the product line measurement are produced and managed.

c) Status reports of corrective actions for the product line measurement are produced and managed.

d) Status reports of quality trends for the product line measurement are produced and managed.

7.2.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Objectively assure the conformance to the measurement of relevant domain engineering assets: Assure that measurements of domain engineering assets performed to measure commonality and variability comply with the organization's process descriptions, standards, guidance (including data collection rules), textures, and procedures.

b) Objectively assure the conformance to the measurement of relevant application engineering assets: Assure that measurements of application engineering assets performed to measure commonality and variability comply with the organization's process descriptions, standards, guidance (including data collection rules), textures, and procedures.

c) Communicate and resolve non-compliance issues: Document nonconformity issues and their resolutions for communicating with stakeholders and perform actions to resolve the issues.

Overlapped measurement activities between domain and application engineering processes are also identified and resolved.

d) Establish records on conformity assurance activities: Create records and status reports on corrective actions, and quality trends analysed in accordance with organizational quality criteria.

7.2.2 Objectively assure the conformance to the measurement of relevant domain engineering assets

a) The method should support the task with the following capabilities:

   1) selecting or sampling product line measurement activities from commonality and variability measurement of domain asset development;

   2) tracing measurement activities of different measurements related to the same measures;

   3) evaluating measurement activities (with clearly stated criteria) and identifying non-compliance issues (especially issues in closely related measurement activities of different measurements related to the same measures);

   4) identifying and integrating quality risks of product line measurement operationalization (e.g. a template including elements examined or identified for quality risk estimation).

b) A tool should support the task by allowing the user to:

   1) access and trace evidence of measurement activities from each measurement of product line measurement operationalization (especially, measurement activities related to measures that require data collection from several different measurements of product line measurement operationalization) and defined measurement processes (e.g. process descriptions, standards, and procedures);

   2) edit/fill out non-compliance issues of product line measurement activities;

   3) edit/fill out quality risk assessment template for measurement activities of each and integrated measurements of product line measurement operationalization.

7.2.3 Objectively assure the conformance to the measurement of relevant application engineering assets

a) The method should support the task with the following capabilities:

   1) selecting or sampling product line measurement activities from commonality and variability measurement of application asset development (e.g. selection criteria or sampling method);

   2) tracing measurement activities of different measurements related to the same measures;

   3) evaluating measurement activities (with clearly stated criteria) and identifying non-compliance issues (especially issues in closely related measurement activities of different measurements related to the same measures);

   4) identifying and integrating quality risks of product line measurement operationalization (e.g. a template including elements examined or identified for quality risk estimation).

b) A tool should support the task by allowing the user to:

   1) access and trace work products of product line measurement activities from several different measurements of product line measurement operationalization;

   2) edit/fill out non-compliance issues of product line measurement work products.

7.2.4 Communicate and resolve non-compliance issues

a) The method should support the task with the following capabilities:

   1) establishing escalation lines for resolving non-compliance issues;

   2) tracking non-compliance issues throughout the established escalation lines;

   3) enabling continuous process improvement of product line measurement.

b) A tool should support the task by allowing the user to:

   1) edit/fill out a document for non-compliance issues;

   2) enable communication links among participants and managers within the established escalation lines;

   3) share the status of non-compliance issues among staffs and managers within the established escalation lines;

   4) analyse statistically quality trends of product line measurement process and work products.

7.2.5 Establish records on conformity assurance activities

a) The method should support the task with the following capabilities: providing guidance for creating records and reports.

b) A tool should support the task by allowing the user to:

   1) create records and reports of conformity assurance activities;

   2) maintain, store, and distribute conformity assurance records and status reports.

7.3 Decision support for product line measurement

7.3.1 Principal constituents

7.3.1.1 Purpose

The purpose of this subprocess is to provide a structural, analytical framework for objectively identifying and evaluating a set of decision alternatives at the product line measurement.

7.3.1.2 Inputs

The following inputs should be available to perform the process:

a) issues required to make a decision;

b) organizational decision-making process.

7.3.1.3 Outcomes

The following outcome shall be available as the result of the successful implementation of the process: the selection of an optimal alternative.

7.3.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Establish decision support policy for PL measurement: Select a decision support policy and identify product lie circumstances, needs, and stakeholders who can give knowledge and experience.

b) Tailor decision procedure for PL measurement: Determine customization factors that reflect the decision-making context of PL measurement and Customize the organizational decision-making process accordingly.

c) Guide the decision execution for PL measurement: Provide rules and constraints adhered to when decision-makers decide for PL measurement.

d) Document the rationale for PL measurement decisions: Specify and record justifications for decisions made during the product line measurement.

NOTE Guidance for decision making includes measurable alternative selection criteria and trade-off analysis for quantifying decision alternatives.

7.3.2 Establish decision support policy for PL measurement

a) The method should support the task with the following capability: defining policies for generation, evaluation and selection of decision alternatives for PL measurement based on an organization's decision management policy.

b) A tool should support the task by allowing the user to document and share an established decision support policy with relevant stakeholders.

7.3.3 Tailor decision procedure for PL measurement

a) The method should support the task with the following capabilities:

   1) tailoring decision-making procedures of an organization to the specific characteristics of product line measurement (e.g. decisions of product line measurement are about measurement objectives, the number of measures, appropriate data elements, and data collection points in accordance with decision constraints such as resource constraints, cost, and effectiveness);

   2) defining core entities to be referred to when making decisions related to product line measurement.

b) A tool should support the task by allowing the user to:

   1) edit/fill out a document or template including placeholders for tailoring specific possible parts of decision procedures of product line measurement;

   2) enrol relevant product line measurement stakeholders of product line measurement to participate in decision-making procedures.

7.3.4 Guide the decision execution for PL measurement

a) The method should support the task with the following capabilities:

   1) coordinating decision executions that should be made by different decision-makers of several different measurements of product line measurement operationalization (e.g. separate but related decisions made in the product line measurements);

   2) analysing trade-offs of decision alternatives following decision constraints of product line measurement.

b) A tool should support the task by allowing the user to:

   1) collect and visualize data to be referred to make decisions for product line measurement;

   2) communicate decision alternatives and decisions through channels and mechanisms implemented following the decision-making structure and tailored decision procedures.

7.3.5 Document the rationale for decisions concerning PL measurement

a) The method should support the task with the following capabilities:

   1) creating objective evidence for decisions made in product line measurement;

   2) quantifying and evaluating the consequences due to decisions made in product line measurement;

   3) reviewing gaps and extracting lessons for decision-making practices in product line measurement.

b) A tool should support the task by allowing the user to:

   1) edit/fill out a document or template for making decisions;

   2) communicate and take feedback on the decisions made with relevant stakeholders in product line measurement;

   3) report the results to appropriate decision process participants, technical and management review participants of product line measurement, and process improvement.

7.4 Uncertainty analysis for product line measurement

7.4.1 Principal constituents

7.4.1.1 Purpose

The purpose of this subprocess is to estimate the uncertainty of product line measurement in order to determine the reliability of measurement and figure out components that dominate the uncertainty of product line measurement. Uncertainty analysis results are used to make relevant decisions or improve the accuracy of measurement by controlling the uncertainties of the components.

Uncertainty is the state, even partial, of deficiency of information related to understanding or knowledge of an event, its consequence, or likelihood. See ISO Guide 73:2009, 1.1.

7.4.1.2 Inputs

The following inputs should be available to perform the process:

a) sources used for uncertainty analysis;

b) measures, indices, indicators, functions, and product line measurement results;

c) history data useful for prediction.

7.4.1.3 Outcomes

The following outcomes shall be available as a result of the successful implementation of the process:

a) Principles of product line measurement uncertainty are established.

b) Calculated quantities of the confidence level of commonality and variability measurement are produced.

c) Quality of uncertainty analysis and improvement actions are documented.

7.4.1.4 Tasks

The organization shall implement the following tasks with respect to the process:

a) Quantify uncertainty in PL measurement: Establish the principles of product line measurement uncertainty and confidence level and collect known uncertainties of measurement components.

b) Assess the confidence level of commonality measurement results: Identify nonconforming in the commonality measurement; Compute confidence intervals for the true fraction nonconforming.

c) Assess the confidence level of variability measurement results: Identify nonconforming in the variability measurement; Compute confidence intervals for the true fraction nonconforming.

d) Evaluate and improve uncertainty analysis in PL measurement: Assess deviations of the predicted uncertainties, principles established, methods used, and uncertainty prediction processes, and derive potential improvements.

7.4.2 Quantify uncertainty in PL measurement

a) The method should support the task with the following capabilities:

   1) developing an error model for PL measurement; error models in this task are selected separately by commonality and variability measurement, product level and PL level commonality and variability measurement, and PL measurement;

   2) identifying error sources from separated but closely related measurement processes or elements of measurements of a product line around commonality and variability;

   3) understanding the relationship between error and measurement uncertainty to define formulae for estimating product line measurement uncertainties from separated but closely related error sources around commonality and variability;

   4) characterizing distributions of product line measurement uncertainty.

b) A tool should support the task by allowing the user to:

   1) collect and record data from the defined error sources of separated but closely related product line measurement processes or elements of measurements;

   2) place a formula for an error model for automated calculation of product line measurement uncertainty;

   3) display level of the uncertainty of a product line measurement results including error distribution using a graphical method such as charts and plots for each and combined view of separated but closely related product line measurement;

   4) express cross-correlations among uncertainties of closely related uncertainties of product line measurements around commonality and variability.

7.4.3 Assess the confidence level of commonality measurement results

a) The method should support the task with the following capabilities:

   1) quantifying the fraction of the overall commonality measurement results that are not conforming in a stable PL process (namely, fraction nonconforming);

2) computing confidence intervals for the observed fraction nonconforming in measurement results of commonality.

b) A tool should support the task by allowing the user to:

1) collect and record (or access if already collected and recorded) data to observe the fraction nonconforming;

2) compute confidence intervals.

7.4.4 Assess the confidence level of variability measurement results

a) The method should support the task with the following capabilities:

1) quantifying the fraction of the overall variability measurement results that are not conforming in a stable PL process (namely, fraction nonconforming);

2) computing confidence intervals for the observed fraction nonconforming in measurement results of variability.

b) A tool should support the task by allowing the user to:

1) collect and record (or access if already collected and recorded) data to observe the fraction nonconforming;

2) compute confidence intervals.

7.4.5 Evaluate and improve uncertainty analysis in PL measurement

a) The method should support the task with the following capabilities:

1) summarizing the results of uncertainty analysis for a product line measurement around commonality and variability;

2) evaluating all used materials, including error models, uncertainty estimates, and parameters for improving uncertainty analysis of product line measurement.

b) A tool should support the task by allowing the user to produce a report for uncertainty analysis results for a product line measurement around commonality and variability.

Annex A
(informative)

Commonality/variability analysis matrix

The commonality/variability analysis matrix is a generic matrix of the application–requirements matrix[23]. The matrix gives an approximation of the commonality and the variability for a given set of product line elements, i.e. features, requirements, or components. The matrix lists the elements of the considered products in the first column and lists the products in the top row. 'X' or '–' is marked in the body of the matrix for checking which elements of a certain product are mandatory (X) or not (–).

Table A.1 — Cost estimate of producing and maintaining products without PL engineering

Products Elements	Product_1	Product_2	...	Product_N
Element_1	X	X		X
Element_2	X	–		X
...				
Element_K	X	–		–

Commonality is an element that is shared by all products belonging to the product line while variability is an element that differs among members of a product line. In the matrix presented in Table A.1, Element_1 is mandatory for all products and is thus a candidate to be defined as a commonality of the product line. Whereas Element_K is not required in Product_2 and Product_N. It is share by few numbers of products thus it is a candidate to be classified as a variability for the product line.

Commonality or variability index is calculated using the number of common or variable elements in the first column or the matrix. Variability index become low when commonality index of a product line become high.

Annex B
(informative)

Exemplary measurement for SSPL adoption

SSPL organization should clarify the objectives of adopting SSPL; and SSPL measurements carry out the feasibility check of SSPL adoption based on these objectives to justify SSPL adoption. It is not essential to define the organizational standard measurement process for the feasibility check of SSPL adoption. Still, the organization shall have available data with measures that the organization is measuring and tracking.

For example, if the objective of an organization's SSPL adoption is to reduce maintenance costs, an organization should have a list of modules/subsystems/programs and historical data on their size (lines of code, LOC), development costs, and maintenance costs. Based on this historical data and domain expert's experience, the organization can estimate the values for measures as follows:

— most often used modules/subsystems;

— degree of reuse of the selected modules/subsystems;

— cost, schedule, and effort for reusing the selected modules/subsystems;

— cost, schedule, and effort for updating the selected modules/subsystems.

The organization calculates the cost of producing and maintaining products without PL engineering based on historical data. Table B.1 is a result of maintenance cost estimates made based on historical data and the programs that consist of system A.

Table B.1 — Cost estimate of producing and maintaining products without PL engineering

Program name	Size (kilo lines of code, KLOC)	Development cost ($10/line)	Maintenance cost per year (10 % of development cost)	Number of years in maintenance	Total cost with maintenance
SA_M_A	500	5 000K	500K	10	5 500K
SA_Sub_B	350	3 500K	350K	20	3 850K
MA_Sub_C	200	2 000K	200K	15	2 200K
Total	-	**10 500**K	-	-	**11 550**K

Based on this estimate, the organization re-estimates maintenance costs if PL is introduced as shown in Table B.2. Programs in these modules contain significant duplicate code. The PL to be deployed provides 70 % of each program as a common asset.

Table B.2 — Cost estimate of producing and maintaining products under the PL adoption

Program name	Size of reuse (kilo lines of code, KLOC)	Development cost by reuse (25 % cost of reuse)	Development cost for application-specific part (150 % cost of adjustment)	Total development cost	Maintenance cost per year (10 % of development cost)	Total cost with maintenance
MA_P_A	350	875K	1 575K	2 450K	245K	2 695K
MA_P_B	245	612,5K	1102,5K	1 715K	171,5K	1 886,5K
MA_P_C	140	350K	630K	980K	98K	1 078K
Total	-	-	-	**5 145K**	-	**5 659,5K**

If an organization adopts PL, it is estimated that even with conservative assumptions, development costs will be reduced by 5 355*K* at the cost of 49 %, and maintenance costs will be reduced to a similar level.

As an organization performs transition to SSPL, these estimates become more sophisticated and accurate. Besides, an organization should ensure that the business objectives established have been achieved through the SSPL adoption and continue to improve the SSPL performance to ensure that the business objectives are achieved.

Annex C
(informative)

Capability maturity of SSPL measurement

An organization at SSPL maturity level 2 performs improvements by selecting processes that require improvements based on the SSPL technical probe or SSPL process assessment results, and the organization measures its performance. Alternatively, an organization at this level measures its performance by selecting critical processes to achieve the business objectives that the organization seeks to achieve through SSPL adoption. At this level, measures are taken to discover and solve the underlying causes of issues in domain engineering processes and application engineering processes.

An organization at SSPL maturity level 3 develops operational definitions for measures commonly used by domain engineering and application engineering. The organization provides rules and constraints (texture) for participants to comply. Domain engineering and application engineering perform performance analysis and improvement needs analysis at the overall PL level according to the operational definitions for measures developed under the organization's standard SSPL process.

An organization at SSPL maturity level 4 manages the quality and process performance of domain assets with good synchronization between domain engineering and application engineering, and leveraging statistical and quantitative techniques. The organization develops, maintains and utilizes the quality of domain assets and performance baselines of domain engineering processes.

An organization at SSPL maturity level 5 chooses domain engineering and application engineering process improvement proposals based on statistical and quantitative analysis of PL's effectiveness in achieving business objectives. The organization implements continuous improvements.

Table C.1 is an example of the capability maturity of the SSPL process from the measurement and performance perspective.

Table C.1 — Capability maturity of SSPL measurement and analysis

Maturity level	Measurement and analysis
Level 5: Optimizing	— Select platform development process improvement proposals based on statistical and quantitative analysis of the expected effectiveness of PL's proposed improvements on domain asset development processes and implement continuous improvements. — Quantitatively manage and continuously improve application development processes based on established business objectives.
Level 4: Quantitatively managed	— Use statistics and other quantitative techniques to manage domain asset quality and domain engineering process performance quantitatively. — Develop, maintain, and leverage domain asset quality and domain engineering process performance baselines. — Predict reusability of domain assets in application engineering and determine or predict objectives for the entire PL accordingly. — Manage application engineering process performance quantitatively in sync with domain engineering processes. — If bottleneck occurs, discuss improvement actions with participants in the relevant domain engineering process.

Table C.1 *(continued)*

Maturity level	Measurement and analysis
Level 3: Defined	— Develop, maintain and utilize measurement and performance objectives that can track the SSPL business objectives. — Develop operational definitions for measure according to the organization's SSPL standard processes and provide rules and constraints (textures) that application engineering uses and adheres to the operational definitions for measure. — Measure domain engineering processes based on operational definitions for measure. — Communicate with application engineering but not in a well-synchronized manner. — Analyse performance and improvement needs, and do regular communication across the SSPL. — Application engineering performs consistent measurement activities by following the operational definitions for measure provided by domain engineering but adding application-specific measurement activities within the rules and constraints' scope.
Level 2: Managed	— Perform measurement activities from the overall SSPL perspective. — Deriving measurement and performance objectives from the SSPL business objectives and perform measurements according to operational definitions for measure. — Measure domain engineering processes based on operational definitions for measure. — Track the utilization of domain assets in application engineering and take action to address related issues. — Measurement activities of application engineering performed by PL member products can possibly not be consistent while measuring domain asset reuse.
Level 1: Initial	— Measurement activities in domain engineering and application engineering are not distinguished. — Collect measurements and record performance (e.g. costs, efforts). — Identify and address performance issues.

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