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Software and systems engineering — Tools and methods for product line requirements engineering

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National foreword

This British Standard is the UK implementation of ISO/IEC 26551:2016. It supersedes BS ISO/IEC 26551:2012 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee IST/15, Software and systems engineering.

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Second edition
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Software and systems engineering — Tools and methods for product line requirements engineering

Ingénierie du logiciel et des systèmes — Outils et méthodes pour l'ingénierie d'exigences pour gammes de produits

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Foreword

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

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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, Subcommittee SC 7, *Software and systems engineering*.

This second edition of ISO/IEC 26551 cancels and replaces the first edition (ISO/IEC 26551:2012), which has been technically revised.

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Introduction

The main purpose of this International Standard is to establish a baseline for the capabilities of tools and methods of software and systems product line (SSPL) requirements engineering. This International Standard defines how the tools and methods can support the software and systems product line specific requirements engineering processes.

A decision for the initial boundaries of domain is made to define a product line scope before initiating domain requirements engineering processes. Domain requirements engineering is carried out in a comprehensive manner because common and variable requirements and captured variabilities have consequential impacts on member products in a product line. The outcomes of domain requirements engineering processes are transferred into the requirements of a family of products at the application requirements engineering processes. Therefore, requirements engineering tools and methods are to be considered (both engineering processes), namely domain requirements engineering, and application requirements engineering.

Product line requirements engineering can be differentiated from a single product requirement engineering because of the following reasons:

— There are two core processes in requirements engineering, domain requirements engineering and application requirements engineering. The major aims of the domain requirements engineering processes are to analyse commonality and variability for a family of products and to prepare necessary variability information for variability modelling. The major aims of the application requirements engineering processes are to define application specific requirements and bind variability defined in domain requirements engineering processes;

— It is essential to analyse the costs and benefits estimate of a product line and thereby, an organization can make a go/no-go decision. Moreover, the costs and benefits estimate plays a pivotal role as an indicator for assessing the effectiveness and efficiency of a product line.

A detailed comparison showing the differences in requirements engineeing tasks between single product and product line is described in Annex A.

This International Standard can be used in the following modes:

— by the users of this International Standard: to benefit people who develop, operate, and manage requirements engineering for software and systems product lines;

— by a product line organization: to provide guidance in the evaluation and selection for tools and methods for product line requirements engineering;

— by providers of tools and methods: to provide guidance in implementing or developing tools and methods by providing a comprehensive set of the capabilities of tools and methods for product line requirements engineering.

The ISO/IEC 26550 family of standards addresses both engineering and management processes and covers the key characteristics of product line development. The ISO/IEC 26550 family of standards provides an overview of the consecutive International Standards (i.e. this International Standard through ISO/IEC 26599), as well as the structure of the model:

ISO/IEC 26550, ISO/IEC 26551 and ISO/IEC 26555 are published. ISO/IEC 26557, ISO/IEC 26558 and ISO/IEC 26559 are to be published. ISO/IEC 26552, ISO/IEC 26553, ISO/IEC 26554, ISO/IEC 26556, ISO/IEC 26560, ISO/IEC 26561, ISO/IEC 26562, ISO/IEC 26563 are planned International Standards.

— Processes and capabilities of methods and tools for domain requirements engineering and application requirements engineering are provided in this International Standard;

— Processes and capabilities of methods and tools for domain design and application design are provided in ISO/IEC 26552 (International Standard under development);

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— Processes and capabilities of methods and tools for domain realization and application realization are provided in ISO/IEC 26553 (International Standard under development);

— Processes and capabilities of methods and tools for domain testing and application testing are provided in ISO/IEC 26554 (International Standard under development);

— 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 (International Standard under development);

— 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 modeling 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 (International Standard under development);

— Processes and capabilities of methods and tools for technical probe are provided in ISO/IEC 26561 (International Standard under development);

— Processes and capabilities of methods and tools for transition management are provided in ISO/IEC 26562 (International Standard under development);

— Processes and capabilities of methods and tools for configuration management of asset are provided in ISO/IEC 26563 (International Standard under development);

— Others (ISO/IEC 26564 to ISO/IEC 26599): To be developed.

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INTERNATIONAL STANDARD ISO/IEC 26551:2016(E)

Software and systems engineering — Tools and methods for product line requirements engineering

1 Scope

This International Standard, within the context of tools and methods of requirements engineering for software and systems product lines:

— provides the terms and definitions specific to requirements engineering for software and systems product lines and associated member products;

— defines process groups and their processes performed during product line requirements engineering (those processes are described in terms of purpose, inputs, tasks, and outcomes);

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

— defines tool capabilities to automate/semi-automate tasks or defined method capabilities.

This International Standard concerns processes and capabilities of requirements tools and methods for a family of products, not for a single system.

This International Standard is not applicable to physical artefacts. Instead, system-level artefacts and software lifecycle artefacts such as requirements documents, architectural data, validation plans, behavioural models, etc. are produced using methods and tools in this International Standard. In the case of the software components of a system, this International Standard can apply twice: once to handle the system elements of the product line and a second time to handle the software elements of the product line, if any. The product line processes are recursive within the different levels of products.

NOTE The requirements in this International Standard apply to the family of systems, software or services.

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.

3.1
application assets in requirements
application specific artefacts produced during application requirements engineering such as *application requirements specifications* (3.4) and application requirements models

3.2
application requirements elicitation
subprocess for identifying stakeholders relevant to an application, eliciting application specific requirements, and binding the appropriate variants

3.3
application requirements analysis
subprocess that understands all *application specific requirements* (3.8), scrutinizes incorrect and inconsistent application requirements through modelling, and then analyses and negotiates application requirements that cannot be satisfied through the domain requirements

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3.4
application requirements specification
subprocess that documents the *application specific requirements* (3.8) and integrates it with the *domain requirements specification* (3.12) whose variants are bound

3.5
application requirements verification and validation
subprocess that confirms that the *application specific requirements* (3.8) are consistent and feasible and ensures that the bound variants satisfy the specific product's requirements

3.6
application requirements management
subprocess that manages traceability and changes on application requirements

3.7
aspect
special consideration within product line engineering process groups and tasks to which we can associate specialized methods and tools

3.8
asset proposal
artefact that includes major assets (functional areas and high-level common and variable features of all applications) that can be included in a product line with their quantified costs and benefits, and estimate results

3.9
application specific requirements
requirements specific to an application or requirements not covered in domain requirements

3.10
domain assets in requirements
reusable artefacts produced during domain requirements engineering such as *asset proposals* (3.7), *domain requirements specifications* (3.12), and domain requirements models

3.11
domain requirements elicitation
subprocess that identifies initial requirements from domain stakeholders for a product line

3.12
domain requirements analysis
subprocess that models domain requirements so as to analyse and scrutinize commonality/variability of a product line in requirements

3.13
domain requirements specification
subprocess that documents domain requirements for a product line based on domain analysis results

3.14
domain requirements verification and validation
subprocess that confirms that domain requirements are correct, consistent, and complete

3.15
domain requirements management
subprocess that manages traceability and changes with respect to domain requirements and their relevant domain/application artefacts

3.16
functional domain
categorized functions that are generally used together

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3.17
production plan
description of how domain assets are to be used to develop member products in a product line

3.18
requirements traceability
traceabilities in domain and application requirements respectively and those between them

3.19
texture
architectural texture
collection of common development rules and constraints for realising the applications of a product line

3.20
variability in requirements
external and internal variability in requirements engineering

Note 1 to entry: Variability modelling and traceability with domain requirements artefacts are also addressed.

4 Reference model for product line requirements engineering

The methods and tools for product line requirements engineering should support systematic management and interaction of the domain and application requirements engineering processes. They also need to be adequately integrated with the other product line engineering lifecycle processes in order to enable traceability between all requirements artefacts and the related design, realization, and testing artefacts. In the rest of this International Standard, product line requirements engineering practices, methods, and tools are described in accordance with a framework focusing on product line requirements engineering (Figure 1).

Product line scoping leads and controls all work on a product line by creating and maintaining the product line scope through ongoing interactions with the domain and application requirements engineering.

Domain requirements engineering serves to:

— decompose features defined in product line scoping into initial requirements and elicit additional requirements and derived requirements from stakeholders and domain experts;

— analyse domain requirements with variabilities in requirements;

— model and simulate the static and behavioural constructs of domain requirements;

— document domain requirements specifications that can be bound by specific member products of a product line.

The complexity of variability grows in accordance with the complexity of a product line. Separating variability from domain requirements engineering mitigates this problem. Defining variability in requirements independently leads to a clear understanding of the necessary capabilities of tools and methods, and thus helps in selecting tools that support product line requirements engineering.

Application requirements engineering serves to:

— identify gaps between domain features and application specific features;

— reuse domain requirements from the asset repository and elicit application specific requirements;

— define application variability model by binding domain variability model and adding application specific variability;

— analyse and document application specific requirements;

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— provide feedback to product line scoping and domain requirements engineering for the evolution of a product line.

The reference model for product line requirements engineering in Figure 1 is structured into five *processes: product line scoping, domain requirements engineering, variability management in requirements engineering, asset management in requirements engineering, and application requirements engineering*. Each process is divided into subprocesses to address technical management issues, 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.

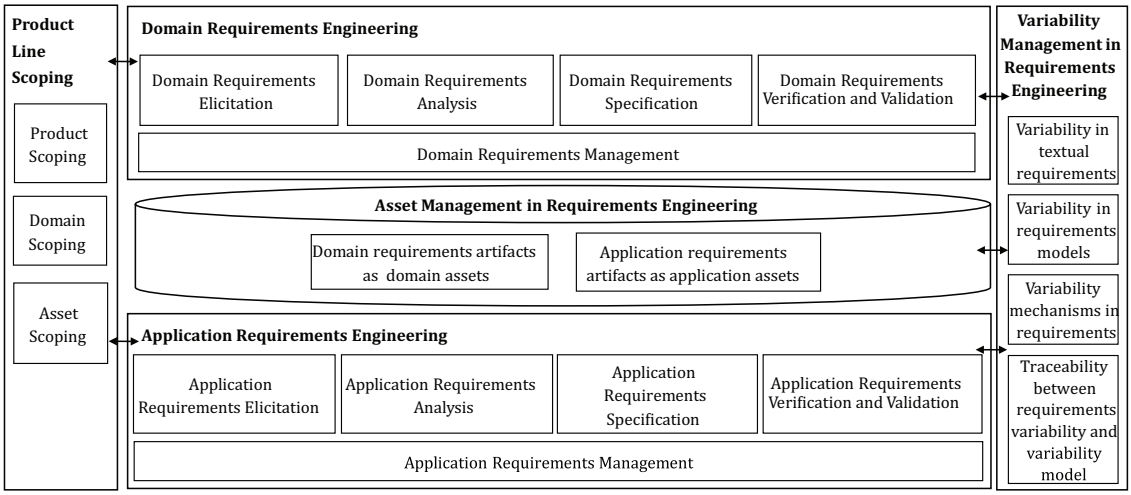

Figure 1 — Product line requirements engineering

Product line scoping defines the member products and their major (externally visible) features, analyses the products from an economic point of view, and controls and schedules producing the product line and its products. The major result of this process is the asset proposals. Asset proposal includes major assets (functional domains and high-level common and variable features) for a product line with their quantified costs and benefits, and ROIs expected from a product line development. More than one asset proposal can be made to find out an optimal set of products and assets. Domain and application requirements engineering start from the features defined in the asset proposals. Product line scoping shall serve to do the following and to define the capabilities of tools and methods for supporting them:

— *Product scoping* determines the product portfolio definition, and provides a roadmap for releasing specific applications to customers or to market;

— *Domain scoping* identifies and bounds the functional domains to provide sufficient reuse potential;

— *Asset scoping* identifies reusable assets, estimates the cost/benefit to justify the product line initiation.

Domain requirements engineering begins with using the outcomes of product line scoping. It comprehensively captures the initial domain requirements for a product line, and constructs an initial-requirements specification including a variability model. It also provides feedback on the changes required in the feature sets and the product roadmap as a whole to organizational business management process group. Domain requirements engineering documents domain requirements specifications for the later use in domain design and in application requirements engineering. Domain

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requirements engineering shall serve to do the following and to define the capabilities of tools and methods for supporting them:

— *Domain requirements elicitation* captures initial domain requirements and anticipated variations of those requirements;

— *Domain requirements analysis* identifies functional and non-functional requirements with the variabilities of those requirements;

— *Domain requirements specification* documents domain requirements based on analysis results;

— *Domain requirements validation and verification* confirms that the specified domain requirements are consistent and feasible, and ensures that all products' requirements within a product line are well understood;

— *Domain requirements management* provides management services for the dual nature of the requirements engineering, i.e. domain and application requirements engineering.

Variability management in requirements engineering should be conducted in parallel with domain requirements engineering because variability models are clarified and modified gradually together with the domain and application requirements. Variability modelling starts as part of domain requirements elicitation and continuously evolves throughout the product line life-cycle. This process is responsible for a variability model which documents the external variability explicitly. As domain requirements engineering activities proceed, some additional internal variabilities may be added to the variability model. Variability management in requirements engineering shall serve to do the following and to define the capabilities of tools and methods for supporting them:

— *Variability in textual requirements* expresses and documents variability in requirements using natural language and makes them explicit;

— *Variability in requirements model* expresses and documents variability in requirements using modelling language and makes them explicit;

— *Variability mechanisms in requirements* categorize variability mechanisms that are to be used as part of requirements;

— *Traceability between requirements variability and a variability model* establishes and maintains links between *textual requirements /requirements models* and a variability model.

During asset management in requirements engineering, requirements artefacts resulting from domain requirements engineering are structured as domain assets. Variability, as well as commonality in requirements, is managed as domain assets. In addition, application requirements artefacts with high reusability potentials are identified as potential domain assets. Asset management in requirements engineering adds or develops extra elaborations and glues to requirements assets to be used effectively and efficiently. The relationship among requirements domain assets for being reused successfully or managing changes on them is also analysed in this process area. Processes for configuring domain assets and managing them in asset repository refer to asset management of ISO/IEC 26555. Asset management in requirements engineering shall serve to do the following and to define the capabilities of tools and methods for supporting them:

— *Domain requirements artefacts* as domain assets identify and develop necessary information to help application engineers reuse requirements assets in their application development;

— *Application requirements artefacts* as application assets identify and manage application requirements artefacts as assets to be referred by the application later.

Application requirements engineering identifies specific requirements for each product line member. It starts to assess the reusability of existing common and variable requirements to fully leverage a product line platform. It can also provide feedback to domain requirements engineering so as to make a decision on incorporating application requirements assets into domain assets. Application

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requirements engineering shall serve to do the following and to define the capabilities of tools and methods for supporting them:

— *Application requirements elicitation* identifies gaps between domain features and application specific features, reuses domain requirements from the asset repository, and elicits application specific requirements;

— *Application requirements analysis* abstracts, organizes, and models application specific requirements. This subprocess has to ensure that all requirements of the application stakeholders are understood, and has to scrutinize the correctness, completeness, and consistencies of application requirements;

— *Application requirements specification* documents the analysed application specific requirements with the bound portion of domain requirements specification;

— *Application requirements verification and validation* confirms that the specific product requirements are consistent and feasible, and ensures that the bound variants are relevant to the specific product requirements;

— *Application requirements management* provides management services for subsequent changes of the member product's requirements.

NOTE 1 Processes of product line requirements engineering are compatible with ISO/IEC 12207 and ISO/IEC/IEEE 15288 as depicted in process mapping with ISO/IEC 12207, ISO/IEC/IEEE 15288, and ISO/IEC 29148 (Annex B).

The identification and analysis of the aspects for the product line requirements engineering enable an organization to understand the requirements engineering processes and to formulate a strategy for the successful implementation of the concept. Requirements engineering processes for product lines should be defined in terms of these aspects, and capabilities of tools and methods for supporting these processes should be identified on the bases of these aspects:

NOTE 2 The relationship between sub processes, key aspects, and associated tool and method capabilities is depicted in Annex C.

Table 1 shows the key aspects for each characteristic of product line requirements engineering.

Table 1 — Key aspects for identifying product line-specific requirements engineering tasks

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

— *Application engineering:* Domain requirements should be reused and external variability for specific application should be bound. As a result, application requirements are specified;

— *Asset:* Domain requirements engineering provides a common portion of requirements (domain requirements) to application engineering through asset repository. Therefore, the domain assets of requirements engineering and management is a distinguished aspect;

— *Binding:* Binding in requirements engineering should consider reflecting the external variability. Thus, binding is a distinct aspect of the product line development;

— *Collaboration:* Since the domain requirements engineering and application requirements engineering can be performed in parallel, collaborations are necessary between engineering teams, as well as those among processes such as domain assets, variability management, product management, scoping, etc. This makes collaboration an important aspect in a product line development environment;

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— *Configuration:* Configuration of products and artefacts of product line requirements engineering can be multidimensional, i.e. exist in time and space. Maintaining the integrity of those dimensions is an important aspect;

— *Domain architecture:* Domain requirements engineering provides domain requirements as a major input for establishing reference architecture;

— *Domain engineering:* Domain requirements engineering process does not exist in a single product development. However, this process is necessary for a product line;

— *Enabling technology support:* Technologies that are needed to enable product line requirements engineering are a key success factor of product line implementation;

— *Measurement and tracking:* In product line requirements engineering, data collection, measures, and tracking need to consider domain engineering, application engineering, product management, and domain assets. This means that the measurements for product line are multidimensional and thus the required activities, roles, procedures, tools, and methods should be considered;

— *Platform:* Platform enables to reuse common elements (e.g. artefacts, components, connectors, etc.) among products. Product line requirements engineering artefacts are key elements of a platform;

— *Product management:* Requirements engineering should deal with reusability of the product line from the foreseen product line strategy. Since requirements continuously evolve in accordance with risks and opportunities, product management should monitor and support the evolution of requirements;

— *Reusability:* The reusability of assets from requirements engineering processes is closely related to achieve the overall goal of a product line. Achieving reusability throughout the product line requirements engineering is a differentiating aspect;

— *Texture:* Product line requirements are major inputs for establishing texture. Particularly for developing rules and specific detail of functional and non-functional requirements, corresponding architectural texture have to be established;

— *Traceability:* There exist various kinds of trace links between variabilities and the artefacts from domain/application requirements engineering. It is necessary to develop a traceability scheme to handle tracing;

— *Validation and verification:* In product line development environments, provisioning of objective evidences for validation and verification of requirements from various viewpoints (e.g. domain, application, variability, domain assets, etc.) is an important aspect, so differentiated schemes with single product development should be provided;

— *Variability:* Variability in requirements engineering mainly deals with external variability related to a reusability strategy, which is not a concern of single product development.

5 Product line scoping

A product line organization needs to determine with which products and features constitute a product line, and thereafter the organization determines which features are implemented by reusing or adapting legacy assets or which of them are newly developed. Using objective and quantitative endeavours, the organization estimates economic benefits expected from a product line and makes a go/no-go decision for product line initiation base on the economic benefits. A product line scoping process includes three key sub processes:

— *Product scoping* determines the potential member products and initial common and variable features of those base on market inputs;

— *Domain scoping* decomposes domains into subdomains (or functional domains) and maps the initial features determined in product scoping to the subdomains;

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— *Asset scoping* identifies reusable assets, calculates the cost/benefit estimate to justify the product line initiation, and provides a roadmap of a product line.

The above three types of scoping can be iterative.

5.1 Product scoping

5.1.1 Purpose of product scoping

The purpose of product scoping is to determine product portfolio definition:

1) The products that the product line organization should be developing, producing, marketing, and selling;

2) The common and variable features that the products should provide in satisfying customer needs and reaching the long and short term business objectives of the product line organization; and

3) A schedule for introducing the products to markets.

5.1.1.1 Inputs

— *A Product definition strategy:* two main types are customer-driven and producer-driven strategies. In a customer-driven strategy, member products of a product line are defined on demand based on market inputs especially based on customer needs and wants. In a producer-driven strategy, the product line organization defines the products.

— *Market information:* for the product scoping period, which comes from the following:

  — market segments, their characteristics and expected future evolutions;

  — customer needs and their expected evolutions;

  — technologies and their expected evolutions;

  — existing and potential competitors; and

  — competitive products and their expected evolutions.

— *Other internal information:* necessary to develop and maintain an understanding and control of the product line organization as a whole.

5.1.1.2 Outcomes

— *Product portfolio definition,* i.e. a (initial) product roadmap including products, their externally visible common and variable feature sets, and a schedule for market introduction is established.

— A *High-level production plan* is defined.

5.1.1.3 Tasks

— *Structure information to be used for scoping*. Market information, information of candidate member products of a product line, and business goals are structured in a form that is easy to refer for processing further scoping activities.

— *Identify products*. Identification of potential member products, including existing ones and new ones, is performed to meet market requirements and business goals. Existing products, prototypes, and other assets that may be reused are identified and analysed. Information about the products may be gathered from internal (e.g. domain experts) and external (e.g. outside experts of component vendors) resources.

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— *Analyse common and variable features*. An initial description of a set of systems is made by analysing which features are inside or outside the product line.

— *Define the product portfolio*. Member products and features that constitute a product line are determined. The decision of the product portfolio should be consistent with an organizational product definition strategy (e.g. *customer-driven or producer-driven strategies*).

5.1.2 Structure information to be used for scoping

Information to be used for scoping is extracted and structured so that participants in scoping make a correct decision.

The method should support structuring information to be used for scoping with the following capabilities:

— selecting information to be used for scoping;

— providing a template for structuring necessary information;

— figuring out relationship among selected information set and their rationale;

— reorganizing information in accordance with the provided template.

A tool should support structuring information to be used for scoping by allowing the user to do the following:

— accessing information to be used for scoping (or providing interfaces for accessing);

— allowing documentation using the template;

— supporting maintenance of the structured information;

— allowing reuse of the structured information.

5.1.3 Identify products

The goal of this task is to find member products for a product line, a release plan, and their high level features.

The method should support identifying member products with the following capabilities:

— identifying existing and/or future member products that may be produced in the product line;

— generating a possible member products list;

— analysing the generated possible member products list (using goals, market definition, etc.);

— selecting and defining an initial member products list;

— verifying the defined initial member products list.

A tool should support the identification of member products through the following means:

— supporting team collaboration;

— supporting the documentation of the process for identifying member products.

And it should allow the user to do the following:

— collect information for existing and/or future products that may be produced in the product line;

— cluster collected candidate products information;

— manage clustered candidate products information;

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— visualize, model, and organize information about existing, future, and hypothetical products as candidates for inclusion in a product line.

5.1.4 Analyse common and variable features

The common and variable features that are analysed in this task have high-level abstractions. These common and variable features including product quality are used for confirming whether or not the product line satisfies an organizational expectation on cost reduction through reuse.

The method should support analysing common and variable features with the following capabilities:

— analysing features (high level) characterizing products in the product line;

— analysing product quality (that can be refined as quality attributes in domain requirement engineering);

— discriminating common and variable features;

— modelling features (using an appropriate feature modelling notation);

— evaluating common and variable features for ensuring that major features of products are identified (through workshops, brainstorming and categorizing, etc.);

— providing a document template for documenting common and variable features.

A tool should support analysing common and variable features by allowing the user to do the following:

— visualizing common/variable features and product qualities;

— allowing documentation using the template;

— allowing the analysed results being referred in the further scoping and requirements engineering activities;

— supporting documentation of the rationale relate to the decision making and making it be referred in the further scoping and requirements engineering activities.

5.1.5 Define a product portfolio

The method should support defining a product portfolio with the following capabilities:

— structuring issues concerning market information, an initial products list, and their high level features;

— making decisions using a decision process (e.g. brainstorming, Nominal Group technique, Delphi);

— verifying the decision;

— providing checklists for verifying decisions.

A tool should support defining a product portfolio through the following means:

— providing templates for assisting in decision making;

— documenting the defined product portfolio.

5.2 Domain scoping

5.2.1 Purpose of domain scoping

The purpose of domain scoping is to decompose functional domains and map initial features to the functional domains to reduce complexity and to promote reusability of a product line.

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5.2.1.1 Inputs

— *Product portfolio definition.*

— *Information collected from domain experts and existing products experiences.*

5.2.1.2 Outcomes

— *A domain scope definition* (including functional (sub-functional) domains and their common and variable features) is established.

— *A set of high-level features* is defined.

— *The product portfolio definition* is refined.

5.2.1.3 Tasks

— *Identify functional domains.* Find, analyse, and categorize functions to maximize reusability. Functional domains may be derived by grouping features and hierarchically defined (i.e. including sub-areas).

— *Map features to functional domains.* Identified features are distributed to identified functional domains.

— *Define domain scope.* Assess and select functional domains that best lend themselves to reuse.

5.2.2 Identify functional domains

Functional domains are identified and classified by experts with sufficient experience and knowledge of products in a product line. The technical feasibility of functional domains and features is validated and features are further refined.

The method should support identifying functional domains with the following capabilities:

— analysing the functionalities of domains of the product line (rules of inclusion or exclusion, structure diagram, context diagram, etc. are example approaches for defining boundary of domain);

— categorizing functionalities that are used together;

— documenting and structuring identified functional domains;

— verifying categorized functional domains.

A tool should support identifying functional domains with the following capabilities:

— supporting team collaboration;

— displaying analysed and categorized results.

And it should allow the user to do the following:

— manage analysed and categorized functional domains consistently;

— document the functional domains;

— manage the relationship between functional domains and associated analyses.

5.2.3 Map features to functional domains

A mapping table for identified functional domains, products, and features is established for representing the relationships among them.

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The method should support mapping functional domains to features with the following capabilities:

— analysing relationships between functional domains and features;

— mapping features to functional domains;

— refining functional domains and features;

— validating the mapping results.

A tool should support mapping functional domains to features with the following capabilities:

— displaying functional domains and features (e.g. an excel worksheet composed of a functional domains column and a features row);

— allowing documentation of the rationale for defining functional domain;

and it should allow the user to do the following:

— create a relationship between functional domains and features;

— manage the relationship between functional domains and features.

5.2.4 Define domain scope

A domain scope is defined for relationships among the functional domains, products, and features.

The method should support defining a domain scope with the following capabilities:

— assessing functional domains according to the variability and performance dimensions;

— selecting functional domains using an appropriate decision-making process (e.g. brainstorming, Nominal Group Technique (NGT), Delphi);

— managing issues relating to functional domain selection;

— verifying the defined domain scope.

A tool should support defining a domain scope with the following capabilities:

— displaying a domain scope definition;

— providing a collaboration environment for reviewing, commenting, and communicating;

and it should allow the user to do the following:

— assess, verify, and document the domain scope definition;

— raise and resolve issues relating to the domain scope.

5.3 Asset scoping

5.3.1 Purpose of asset scoping

The purpose of asset scoping is to identify potential reusable assets and to estimate the economic benefits from reusing the proposed assets. Assets are evaluated based on the effort required to engineer them, quantified using effort estimate functions derived from historical data collected from existing related products and domain experts.

5.3.1.1 Inputs

— *A Domain scope definition* (including functional domains and their common and variable features).

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— *Estimate models and/or other information of current practices.*

— *Available measurement data* (i.e. historical data for related domains).

5.3.1.2 Outcomes

— *Asset proposals* (including functions, features, and effort estimates) are proposed.

— *A quantified domain definition* is established.

— *ROI estimates* are produced.

— *List of existing assets* is provided.

5.3.1.3 Tasks

— *Gather historical data from existing single products.* Identity and gather information about existing products to better understand the domain and identify potentially reusable assets.

— *Estimate additional effort required to adapt potential assets.* Estimate the additional effort required for adapting potential assets to the product line.

— *Estimate expected development effort for new products in the product portfolio definition.* Estimate the cost, effort, and risk of including new products into the product portfolio. This calculation is based on learning from existing related products, development constraints, systems/software attributes, and market attributes.

— *Estimate economic benefits from reusing proposed assets.* Estimate the economic benefit from reusing existing assets, from reusing newly developed domain assets, and from reducing rework and failure due to quality improvements.

— *Derive asset proposals from economic evaluation results.* Define the asset proposals including assets (functional domains and features) and their economic evaluation results. Establish asset proposals by extending the domain definition. Create detailed and quantified effort estimates for all assets in the domain.

5.3.2 Gather historical data from existing single products

Effort estimate can be conducted based on the historical data such as measurement data cumulated from existing relevant products for a specified period of time.

The method should support gathering historical data from existing single products with the following capabilities:

— defining what kinds of historical data should be collected;

— integrating data from various sources;

— searching data;

— verifying the validity of collected data.

A tool should support gathering historical data from existing single products by allowing the user to do the following:

— allowing documentation for the results of gathering historical data from existing single products;

— importing sources from other tools;

— providing management capability for historical data.

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5.3.3 Estimate additional effort required to adapt potential assets

While some assets are reused as they are, some others can be reused after adaptation. Therefore, estimating adaptation efforts is necessary before developing them as domain assets because if adaptation efforts are too high, it is difficult to expect benefits from domain asset reuse.

The method should support estimating additional effort required to adapt potential assets with the following capabilities:

— analysing relationships between existing and new products;

— analysing factors for expected development effort for the new products;

— defining effort estimate functions for the new products;

— providing metrics that can be used for effort estimates;

— allowing adding a new metric if necessary.

A tool should support estimating expected additional efforts required to adapt potential assets with the following capabilities:

— displaying the relationship between assets, functional domains, features, and products, and its influence on economic benefit;

— providing metrics to be used to estimate so that tool users can choose among them;

— allowing adding a new metric if necessary.

5.3.4 Estimate expected development effort for new products in the product portfolio definition

Some products included in a product portfolio definition are new ones, so the efforts for them have to be estimated based on the measurement data gathered from existing relevant products. This estimate should be considered separately for estimating the whole benefits from a product line.

The method should support estimating the expected development effort for new products in the product portfolio definition with the following capabilities:

— analysing relationships between existing and new products;

— analysing factors for the expected development effort for the new products;

— defining effort estimate functions for the new products.

A tool should support estimating expected development efforts for new products in the product portfolio definition with the following capabilities:

— providing metrics for effort estimate that tool users can choose;

— allowing adding a new metric if necessary;

— displaying the relationship between assets, functional domains, features, and products, and its influence on the economic benefit.

And it should allow the user to do the following:

— document estimated results of expected economic benefits for new products.

5.3.5 Estimate economic benefits from reusing proposed assets

Effort estimate functions for calculating the costs and benefits expected from proposed assets are developed based on historical data and experiences.

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