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Requirements Management @ Rail Infrastucture

RM Process Manual Project Execution

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Document history

Version Ext. ID	Version Int. ID	Date	Author	Sections changed	Change
---	E	2019-03-27	Stefan Jung	all	Complete revision based on a new process version with variants
---	F	2021-04-28	Stefan Jung	all	Adaptation due to organisational changes
				1.4	References updated/revised
				3.1	Overview of the MO RM Process
				4.1	Including the EPIQ number in the project path

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1 Introduction

1.1 Scope and Field of Application

This document describes the Requirements Management (RM) approach for the project execution of MM customer projects. The defined RM tasks are integrated into the PLM phase between milestones PM080 and PM650.

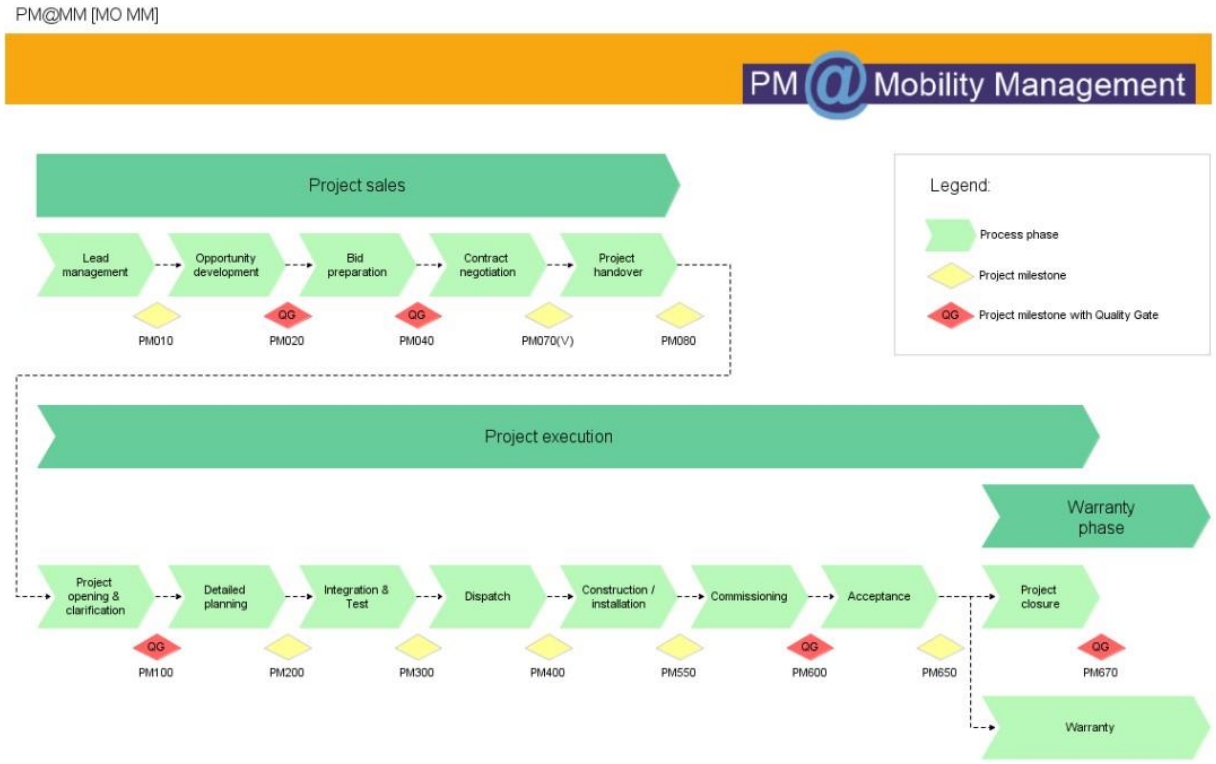

Figure 1 PM Milestone and Work Packages Overview

In chapter 3 the RM activities are described with reference to the respective PLM milestones and to the defined [RM@MM Process].

The process and tasks described in this document are applicable for RM in project execution within the framework of the super ordinate MM process. The regional units and associated companies of MO MM shall analogously apply the process as described in this definition. The normative backgrounds for this document are [EN50126], [EN50128], [EN50129] and [ISO9001].

The Requirements Management tasks of the bid phase are detailed within [RM Manual Bid Phase].

1.2 Validity, Editing and Update

The present document is valid for the Requirements Management (RM) of the project phase (PM080-PM700). This manual is valid and applicable for MM worldwide.

The RM prcoces management is responsible for editing and updating the present document. The head of Business Excellence, who is process owner, releases this document.

The present document will be changed and updated when required. All changes are documented in the change list and identified by means of version update.

1.3 Terms and Abbreviations

Term/Abbreviation	Definition
AR	**A**pplication **R**ules
DLM	**D**esign **L**iaison **M**eeting
DS	**D**esign **S**pecification
LoA	**L**imits **o**f **A**uthority
MM	**M**obility **M**anagement
MO	**Mo**bility Division
MoM	**M**inutes **of M**eeting
PLM	**P**roduct **L**ifecycle **M**anagement
R&D	**R**esearch & **D**evelopment
RAM	**R**eliability, **A**vailability, **M**aintainability
RAMSS	**R**eliability, **A**vailability, **M**aintainability, **S**afety, **S**ecurity
RE	**R**equirements **E**ngineering
RM	**R**equirements **M**anagement
RMiP	**R**equirements **M**anager **i**n **P**roject (siehe [Role RmiP])
RS	**R**equirements **S**pecification
SE	**S**ystem **E**ngineering
SEiP	**S**ystems **E**ngineer **i**n **P**roject (siehe [Role SEiP])
SAR	**S**icherheitsbezogene **A**nwendungs**r**egeln **S**afety related **A**pplication **R**ules
SMiP	**S**ystem **M**anager **i**n **P**roject (siehe [Role SMiP])
SRS	**S**ystem **R**equirements **S**pecification
SSC	**S**tandard **S**ystem **C**onfiguration
VAL	**V**alidation
VC	**V**alidation **C**ondition
VER	**V**erification

Table 1 List of Abbreviations

1.4 References

Title	Document identifier/Link
[CM Process]	https://processworld.siemens.com/bicpublish/I_MO_RA_RELEASE/cp/I_MO_RA_RELEASE?selectedModelGuid=8b39839f-e675-472f-b5fb-934f2b692b65&selectedTabId=0&selectedItemGuid=8c5134cb-845b-11e4-4d0d-adcb4d40def0&centerPage=modelViewDefault&lang=en_US&bmpath=/main/mainwin
[EN50126]	Railway applications - The specification and demonstration of reliability, availability, maintainability and safety (RAMS) EN50126:2017
[EN50128]	Railway applications - Communications, signaling and processing systems - Software for railway control and protection systems EN 50128:2011
[EN50129]	Railway applications: Communication, signaling and processing systems - Safety related electronic systems for signaling EN 50129:2018
[Guideline PM@Mobility]	Guideline "Implementation of PM@Siemens in the Mobility Division worldwide" MO-7257, Version 2.0
[ISO9001]	EN ISO 9001:2008 (December 2008) Quality management systems – Requirements
[Manual Appendices]	MO MM RM Checklist MO MM RM SRS DS MO MM Decision Variants A6Z00028259555
[MM_Milestone_Results]	List of milestone relevant mandatory results for Requirements Management (RM) A6Z00035698017
[PLM/PPM-Process]	https://processworld.siemens.com/bicpublish/I_MO_RA_RELEASE/cp/I_MO_RA_RELEASE?selectedModelGuid=e31d20f2-cef8-4ac8-a0f6-94cc328d491e&selectedTabId=0&selectedItemGuid=bb06357a-49ef-441f-b2ff-35c61c82ae0c&centerPage=modelViewDefault&lang=en_US&bmpath=/main/mainwin
[REQ Definition]	IEEE Computer Society: IEEE Standard Glossary of Software Engineering Terminology. IEEE Computer Society (New York), 1990
[Guideline RE@MM]	Guideline Requirements Engineering@MM, A6Z00040015835 (to be released)
[Requirements Properties]	M. Mannion, B. Keepence: SMART Requirements Software Engineering Research Group, Napier University Edinburgh, 1995
[RM@MM Process]	https://processworld.siemens.com
[RMP Template]	Template “Requirements Management Plan for Project Realization” A6Z00028865579

Title	Document identifier/Link
[RM Manual Bid Phase]	Process Manual Requirements Management, Bid Phase A6Z00011005072
[RM Manual Application Rules]	Process Manual Requirements Management, Application Rules A6Z00033881488
[RM Report Template]	Template for RM reports and metrics (Excel reporting tool) A6Z00029260135
[RM Sharepoint]	https://wse02.siemens.com/content/P0006085
[Role_PLM]	Tasks and Responsibilities of Product Lifecycle Manager; A6Z00031865793
[Role PM]	Tasks and Responsibilities of Project Manager; A6Z00034706698
[Role RmiP]	Tasks and Responsibilities of Requirements Manager; A6Z00031865796
[Role SEiP]	Tasks and Responsibilities of Project System Engineer; A6Z00003927708
[Role SMiP]	Tasks and Responsibilities of Project System Manager; A6Z00002826460
[Role_Test]	Tasks and Responsibilities of Tester; A6Z00033055748
[Role_Val]	Tasks and Responsibilities of Validator; A6Z00033056311
[Role_Ver]	Tasks and Responsibilities of Test Manager; A6Z00032313198
[Templates Manuals]	Sharepoint RM@MM: Process& Methods / Realization Phase / 40_Templates_and_Selection_Lists

Table 2 List of Referenced Documents

1.5 Reviewers

Name	Department	Date	Signature
see SAP-Process	-	-	-

Table 3 List of Reviewers

2 Requirements Management General

2.1 RM Policy

RM is the systematic approach to support

- identification of all requirements
- tracing of all requirements from identification or definition to their verification and validation
- administration of all information that affect and/or supplement the single requirement
- the quality of delivery in projects
- reduction of potential risks and overall project costs

RM requires a defined process and an efficient tool support. The RM tasks will be integrated into the PM process whereas certain results of such tasks are mandatory for passing certain PM milestones / Q-gates (see section **Fehler! Verweisquelle konnte nicht gefunden werden.**).

The detailed approach and implementation will be defined in the project specific RM plan together with standard tool support.

The basis is the process defined in ARIS for the RM in Mobility Management [RM@MM Process], which basically comprises the following process steps as shown in Figure 2:

1. identification requirements
2. requirements analysis and consolidation
3. checking and approving the requirements for processing
4. linking requirements with solutions
5. specifications for solution implementation
6. verification of compliance

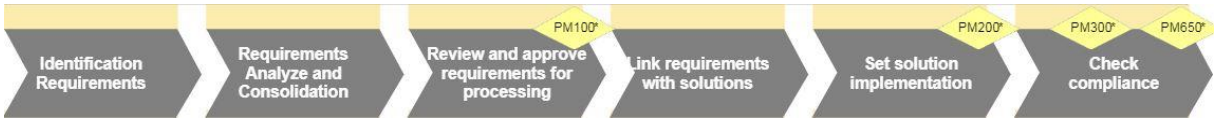

Figure 2 Main Process Steps of the RM@MM Process

2.2 Requirements

The identification, evaluation and documentation of the realization of all requirements are crucial for the success of a project.

Requirements can be obtained by interviews, surveys, statements, technical and non-technical documentation, laws and regulations. Besides from tender and other external sources, requirements may also be derived internally to describe a complete system.

Requirements are divided into

- technical requirements (e.g. system requirements)
- non-technical requirements (e.g. commercial, legal, sales related)

Within the system lifecycle, each single requirement must be

- identified
- captured
- documented
- classified
- assigned to a responsible domain expert
- detailed and apportioned to the applicable system levels
- fulfilled / answered
- closed
- verified
- validated

For further information on the identification and extraction of requirements and how to transform them into well-formed requirements for assessment please refer to [Guideline RE@MM].

2.2.1 Definition of Requirements

In [REQ Definition], the Institute of Electrical and Electronics Engineers (IEEE) defines a requirement as:

1. a condition or capability needed by a user to solve a problem or achieve an objective
2. a condition or capability that must be met or possessed by a system or system component to satisfy a contract, standard, specification, or other formally imposed document
3. a documented representation of a condition or capability as described in a.) or b.)

2.2.2 Characteristics of Requirements

To simplify the specification of a single requirement, requirements should follow the criteria described below (see also [Requirements Properties]):

Specific
A requirement must say exactly what is required. Specificity comprises several areas as follows:

- clarity i.e. that there is no ambiguity;
- consistency i.e. that the same terminology has been used throughout the specification to describe the same system element or concept;
- simplicity i.e. avoid double requirements e.g. X and Y;
- an appropriate level of detail.

Measurable
In the context of requirements engineering, measurable means it is possible, once the system has been constructed, to verify that this requirement has been met. In some software engineering methodologies, the Requirements Engineer is instructed to determine the tests which must be performed in order to satisfy the requirement. If a test is the intended verification method, the requirement should always be expressed in a way allowing for positive testing.

Attainable
An attainable requirement can physically be exhibited by the system under the given conditions. Some requirements may be beyond the bounds of human knowledge. Others may have theoretical solutions but be beyond what is currently achievable. This kind of requirements is not atypical. The consequence of attempting to meet these requirements is that the system will never be accepted or be prohibitively expensive or both. In general terms the following guidelines are recommended:

- Is there a theoretical solution to the problem?
- Has it been done before? If not, why not?
- Has a feasibility study been done?
- Is there an overriding constraint which prohibits this requirement?
- Are there physical constraints on the size of the memory, processor or peripherals?
- Are there environmental constraints such as temperature, compressed air?

It is often the case that the attainable and realizable criteria are often considered in parallel. This does not however make them synonymous.

Realizable
In the context of system and software requirements, realizable means it is possible to achieve this requirement given what is known about the constraints under which the system and the project must be developed.

Traceable
Requirements Traceability is the ability to trace (forwards and backwards) a requirement from its conception through its specification to its subsequent design, implementation and test. This is important for the following reasons:

- so that we can know and understand the reason for each requirement's inclusion within the system;
- so that we can verify that each requirement has been implemented;

- so that necessary modifications can be made without endangering the consistency and completeness of the system.

2.2.3 Types of Requirements

This manual is dealing with 4 basic types of requirements.

- Stakeholder / customer requirements
  - Requirements explicitly defined or hidden expressed by the customer
- Assumptions
  are taken to support the evaluation of a requirement and need to be clarified and agreed with the customer. The assumptions may address
  - implicit requirements which are not expressed by the customer
  - key issues which are essential for the system design but are not defined by the customer
  - surrounding conditions regarding the system environment (climate, EMC, timetables, capability of adjacent/included (sub-)systems etc.)
- Internally derived requirements
  Requirements derived internally to clarify and describe the full functioning system. They are only internally relevant and do not need to be forwarded to the customer but possibly to an external expert.
- Application Rules
  Application rules are requirements which must be considered by the customer or the project using the respective component or subsystem. These rules must be fulfilled to ensure a safe and dependable operation of each component in the system.

2.2.4 Criteria for the Identification of Stakeholder Requirements

In addition to the requirements characteristics mentioned in Section 2.2.2 and the types of requirements listed in Section 2.2.3, there are criteria by which requirements from external documents can be identified. This should be specifically defined in each project in the RM Plan. According to [Guideline RE@MM], the following requirements are recognizable as such by its wording in the sentence context:

- Mandatory requirement: (must or shall)
- Prohibition: may not (must not)
- Very requested, but not mandatory requirement: should be
- Optional requirement: can or may

Because different criteria can be derived from an external document within a sentence, the first step is to assume the formulation that is most mandatory. A corresponding marking as identified requirement - as described in chapter 5.1.4 - must be set in any case.

2.2.5 Handling of Technical Requirements

Technical requirements are the basis for the conception and development of systems. In accordance with [Guideline RE@MM] they describe the system to be supplied and its system environment, i.e. the interfaces for communication with other systems. Technical requirements shall always be managed in accordance with the procedures specified in this document.

2.2.6 Handling of Non-Technical Requirements

Although non-technical requirements have no direct impact on system design, their number and complexity also require appropriate management. In addition, non-technical requirements may be implicit technical requirements (e.g. for formulations such as as build). As a rule, the use of a tool-based RM for non-technical requirements makes sense or is even decisive for the overall success of the project. The process scope to be applied (which can define different procedures for technical and non-technical requirements) depends on the process characteristics. The definition of the characteristics of a project in the RM system and the options to be used are described in detail in Chapter 3.

Although non-technical requirements have no direct influence on the system, they also require evidence of their fulfilment in order to prove contractual conformity to the customer.

2.3 Requirements Traceability

Throughout their lifecycle, requirements are processed and refined, detailed, apportioned, forwarded to sublevels, verified and validated at levels RS (see Section 5.2) and DS (see Section 5.3) (see "Basic Procedure in the RM@MM Process" in Section 3.1). RM creates a closed system across the entire requirements lifecycle from the customer/contract level through the SRS level to the implementation levels and on the right side of the V-Modell through integration and validation levels to the top level (corresponding to the top SRS level). The relationships between the requirements that make up this closed system are represented by traces - from level to level (top-down for RS-DS and bottom-up for VER-VAL) and within levels (horizontal VER-DS and VAL-RS).

Depending on the project-specific requirements (e.g. levels used), the methods for traceability must be precisely defined and documented in the RM plan. This also includes the permitted and forbidden trace directions.

In general, the following trace directions are defined:

1. requirements specification level (RS level) to the corresponding design specification level (DS level) (top-down)
2. design specification level (DS level) to next requirements specification level (RS level) (top-down)
3. requirements verification level (VER level) up to the corresponding validation level (VAL level) (bottom-up)
4. validation level (VAL level) to the next requirements verification level (VER level) (bottom-up).
   (optional: if not testable, to next validation level (VAL level))
5. requirements verification level (VER level) to the corresponding design specification level (DS level) (horizontal trace)
   If the results of the verification are created within the RM tool itself or imported into the RM tool, a trace must be provided. Otherwise, reference must be made to the respective documentation of the evidence showing compliance with the requirement (e.g. via an identifier from SAP or similar archiving instruments).
6. validation level (VAL level) up to the corresponding requirements specification level (RS level) (horizontal trace)

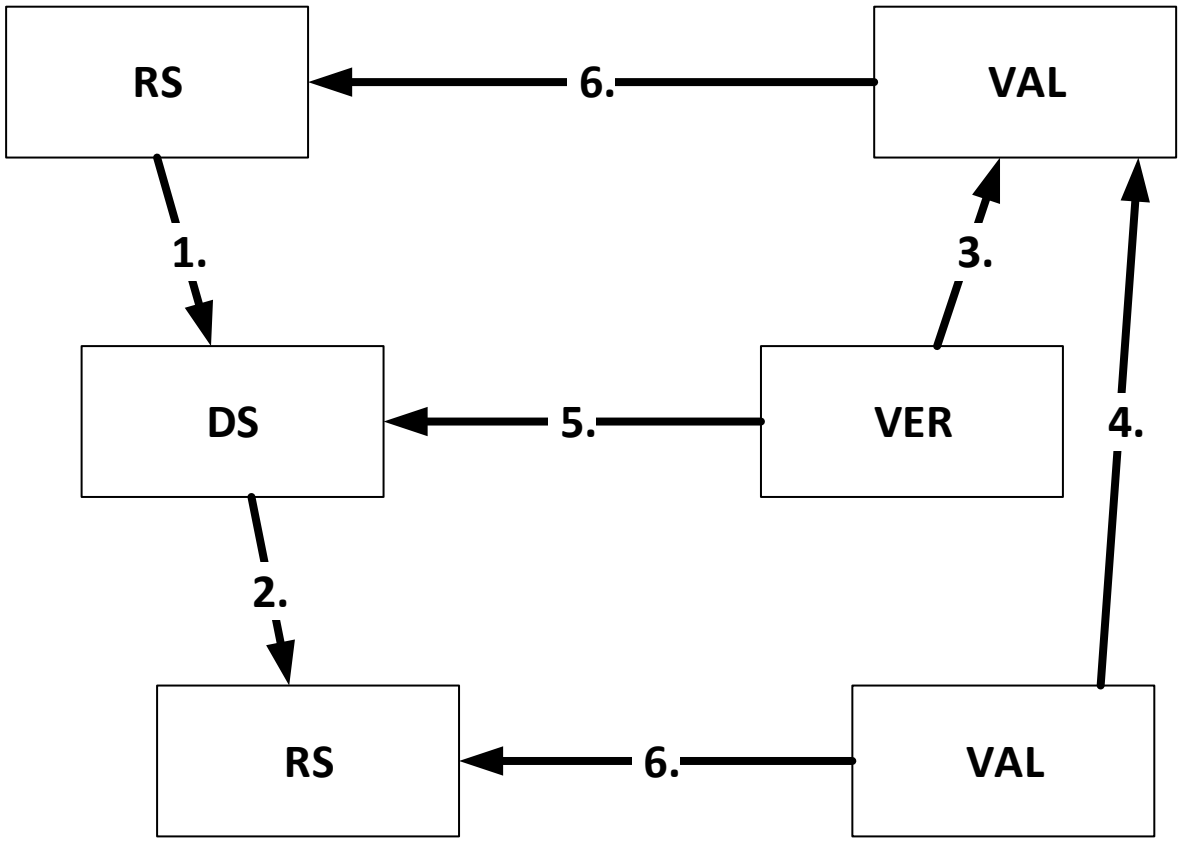

Figure 3 Tracing Directions

For more details on the rules for tracing between and within levels (top-down, bottom-up and horizontal), see separate chapter 7 Tool-supported Tracing. This chapter also lists the restrictions for supporting tracing in an RM system.

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3 Definition of the Characteristics of the Project

3.1 Basic Procedure in the RM@MM Process

For the concrete implementation of the RM in the project, the V-model, which describes the RM lifecycle - from the identification of the requirements to their validation - is first dealt with according to the [RM@MM Process] (see Figure 4) already mentioned in Chapter 1.1. It forms the essential basis for the process steps and tasks of requirements management during project implementation.

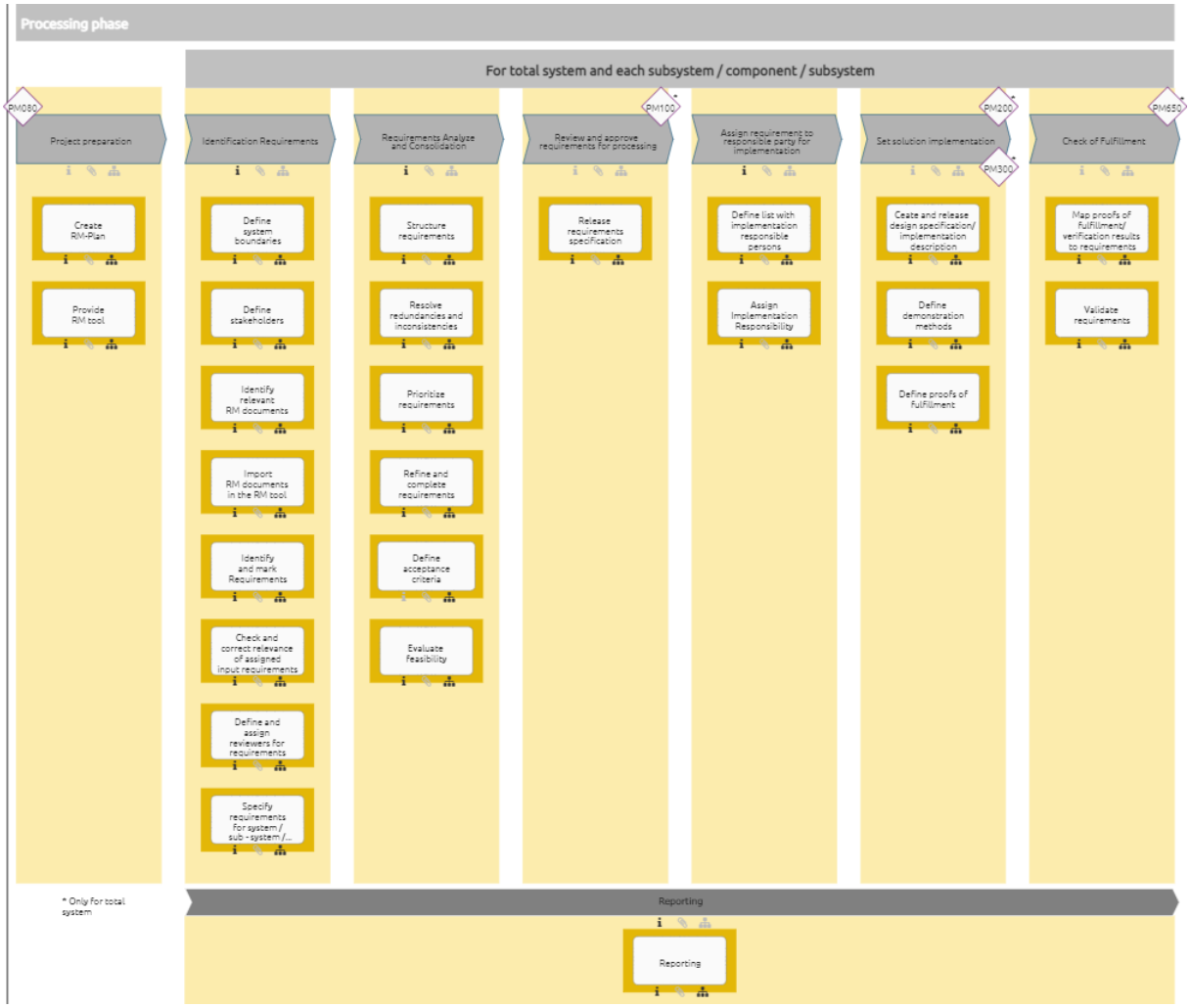

Figure 4 Overview of the RM Process in the Execution Phase

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The levels used in a project depend on the specific structure and architecture of the project. The following Figure 3 shows the standard levels that are usually used in complex projects.

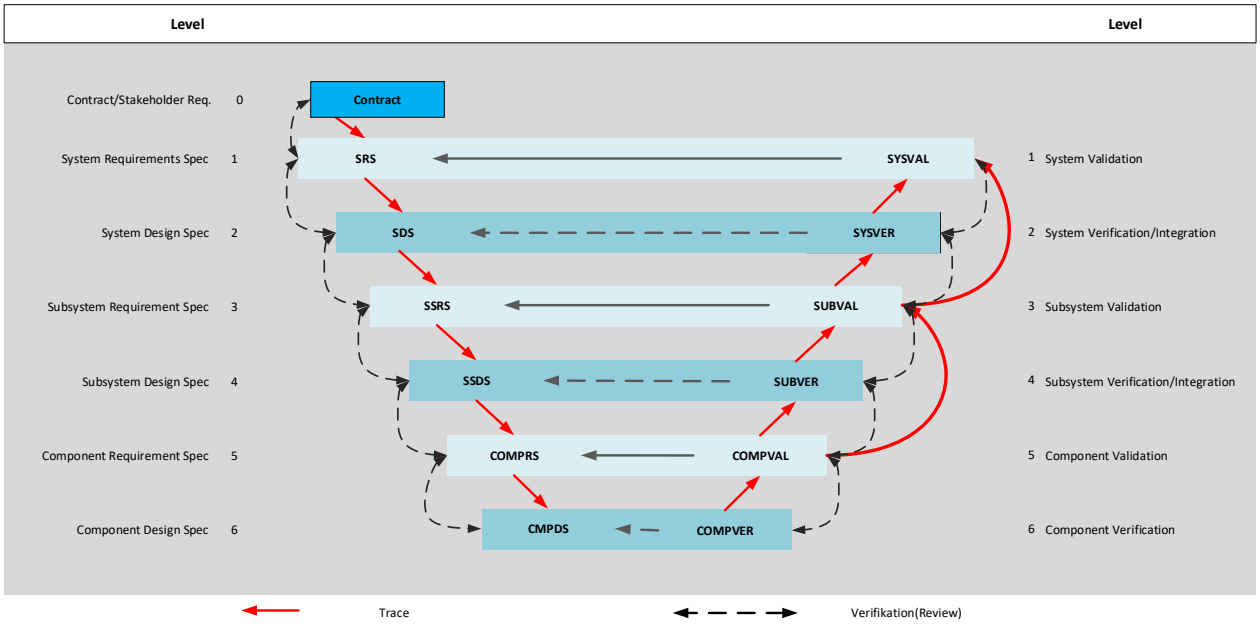

Figure 5 General Standard Structure

The example in Figure 5 shows a detailed structure of the levels for a standard system configuration.

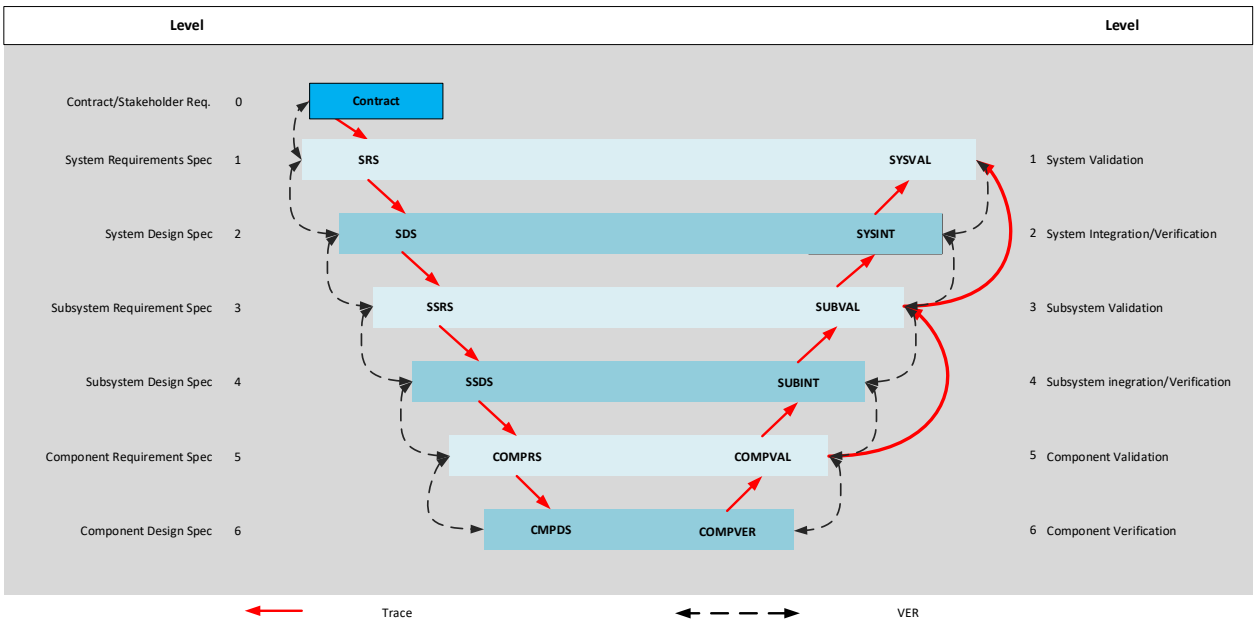

Figure 6 Adapted Standard Structure

If the system consists of standard products or standard platform components according to a standard system configuration, the SRS requirements are assigned to the SSRS via the

SDS. These SSRSs serve as input for development within the R&D according to the GUIDE process. They are equivalent to (Delta-)User Requirements Specification (URS).

Since according to chapter 6.1.8 of the [Guideline PM@Mobility] DOORS has to be used as the obligatory RM system, the further explanations refer to the tool-specific implementation of the project-specific characteristics.

3.2 Selecting a RM Variant

Depending on the structure of the project and the essential parameters

- Project category
- Number of technical subsystems
- Process requirements (e.g. CENELEC)
- Development part by R&D
- New customer or new country

one of three variants for a specific variant in the RM system can be selected at the start of the project:

- Variant 1: Small
- Variant 2: Basic
- Variant 3: Full

A decision tree is used for the concrete application, which takes the above-mentioned parameters into account. This is documented in the attached documents (chapter 11) as [MO_MM_Decision_Variants.pdf].

An overview of the areas covered by each variant is shown in Figure 6.

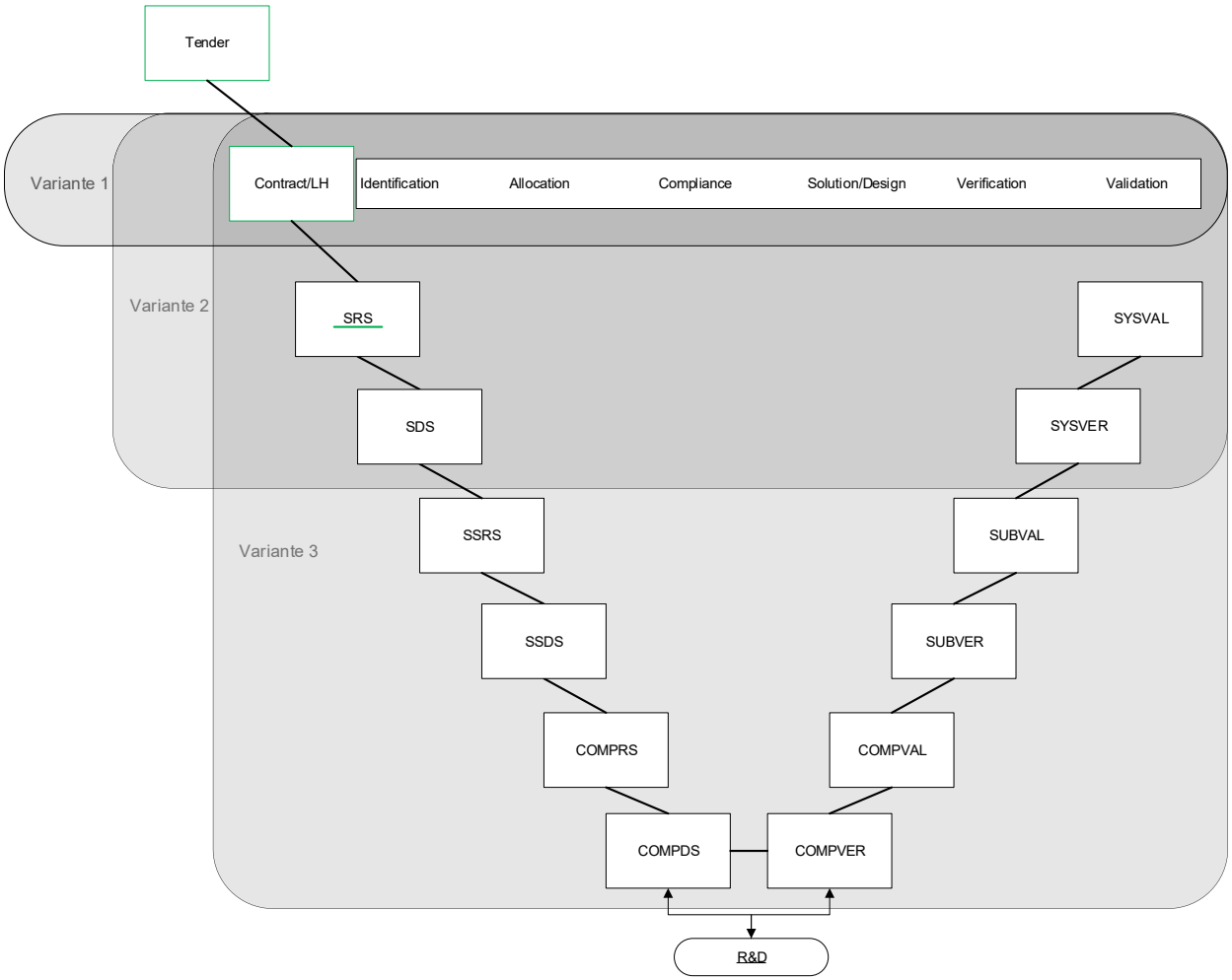

Figure 7 Overview of Variant and Tailoring Areas

In the following, the three possible variants are presented in detail. The most comprehensive variant - variant 3 (full) - will be used, as it represents the full level structure as described in Section 3.1 and shown in Figure 3.

3.2.1 Variant 3 (full) - Complete Tracing in the V-model

In principle, this variant comprises the main levels listed in Figure 3 as well as their sublevels RS, DS, Test (incl. integration and verification) and Validation. Based on the contract, requirements are specified in the requirements level (RS) and linked with solutions at the design level (DS). This can lead to more concrete requirements at the subordinate subsystem level. In requirements engineering, this breaking down is also called the Twin Peaks model (see Figure 7), in which a high level of abstraction is refined into a more detailed level.

The tests created for each requirement on the basis of the verification criteria check the architecture defined in the design and validation checks whether the correct system has been implemented. In addition to the design solutions linked to the requirements, the validation is

based on the underlying validation results and the test, integration and verification statements.

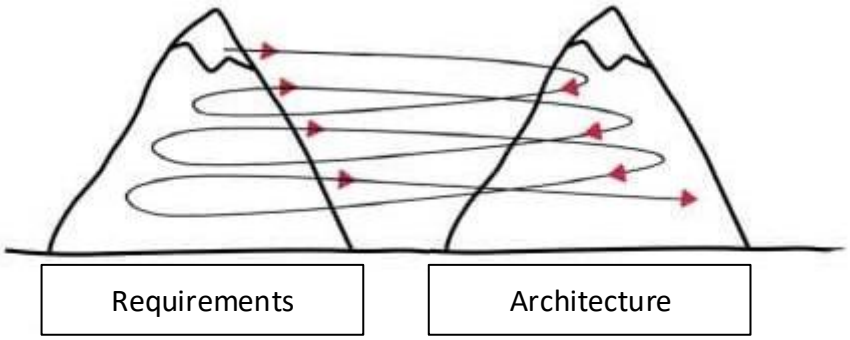

Figure 8 Twin Peaks Model

3.2.2 Variant 2 (basic) - Tracing Down to System Level

As shown in Figure 6, Variant 2 includes only the system level with requirements level (RS), design level (DS), test level and validation level in addition to the contract level. This variant is primarily intended for projects that require a lower level of detail at subsystem and component level. As a rule, standard products are used in these projects. In addition, project requirements generally do not lead to adjustments to products or even to the development of new components.

The solutions are fully documented at the design level of the system and the necessary integration tests of the components used are also performed at the system level. The system will be then validated based on this information.

Variant 2 is mainly used for certain category C projects. The focus here is on being able to distinguish oneself from the customer requirements in the contract by means of a separate system requirements specification.

3.2.3 Option 1 (small) - RM at Contract Level

Variant 1 is only used in projects of category C or S and according to the decision tree for variant selection [MO_MM_Decision_Variants.pdf] only with low risk regarding the technology and process specifications used. As a rule, there are predecessor projects for this type of project that use the same technology and for which the customer and the country are known.

In variant 1, all customer requirements are also taken into account, but are not specified again in a separate requirements specification (SRS). Thus, the mandatory process steps (see chapter 2.1) for identification, consolidation, review, solution definition and implementation as well as validation take place on the contract level. The information is documented in parallel as properties of the requirements (attributes).

3.3 Selection of Tailoring Measures

The tracing structure defined in Chapter 3.1 is the general structure for the structure of requirements management in a project, see also Figure 3. The main levels for the system, the subsystem and the components consist of:

- Requirement Specification (RS) Level
- Design Specification (DS) Level
- Integration and Requirement Verification Level (VER)
- Validation Level (VAL)

The process can be tailored to the following options by the person responsible for the RM in the project as part of the project start according to the following Figure 9:

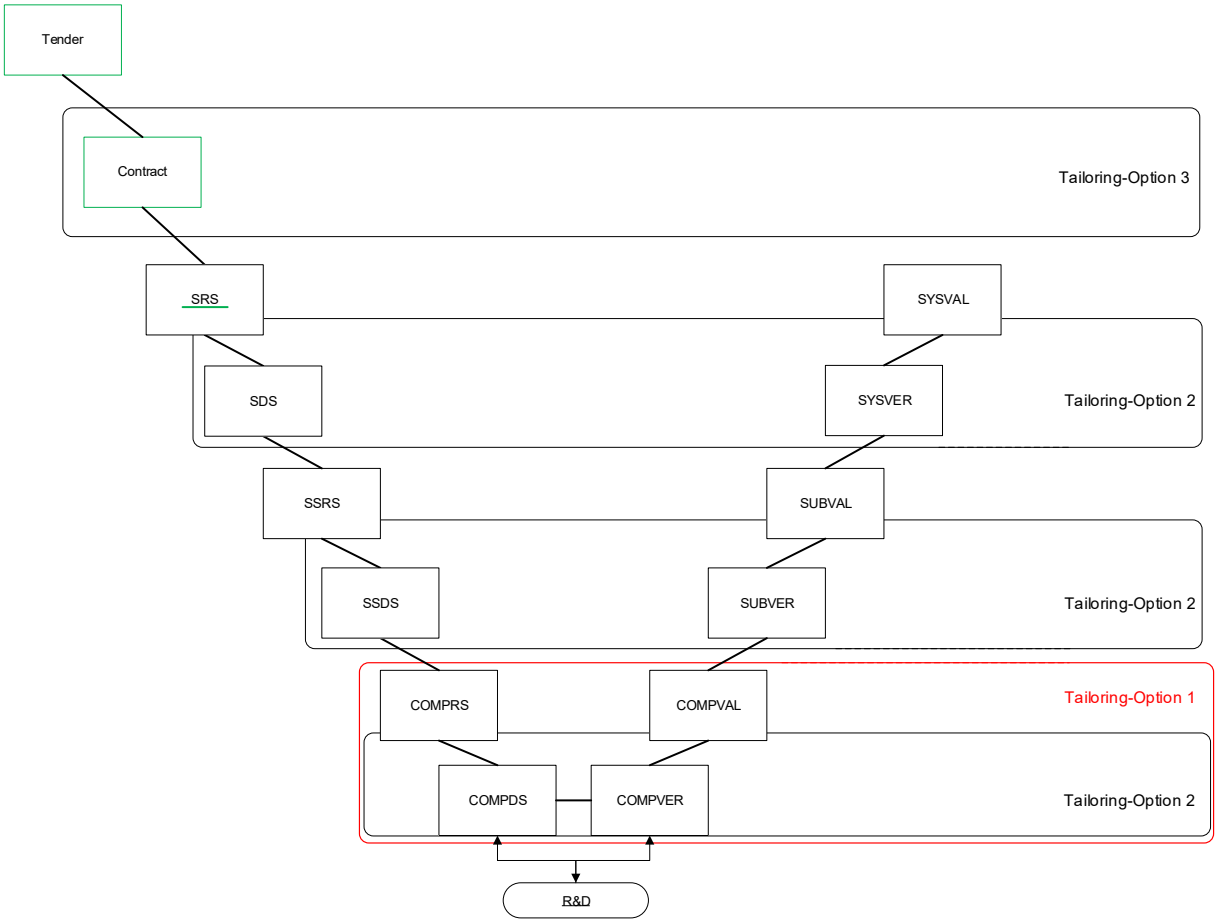

Figure 9 Tailoring Option 1: All Component Levels

Tailoring Option 1: All component levels (e.g. COMPRS, COMPDS)
For example, the complete component level can be dispensed with if no more requirements at subsystem level have to be refined within the framework of the project. Then the validation level for the components is also obsolete. Forwarding to R&D is unaffected by this tailoring.

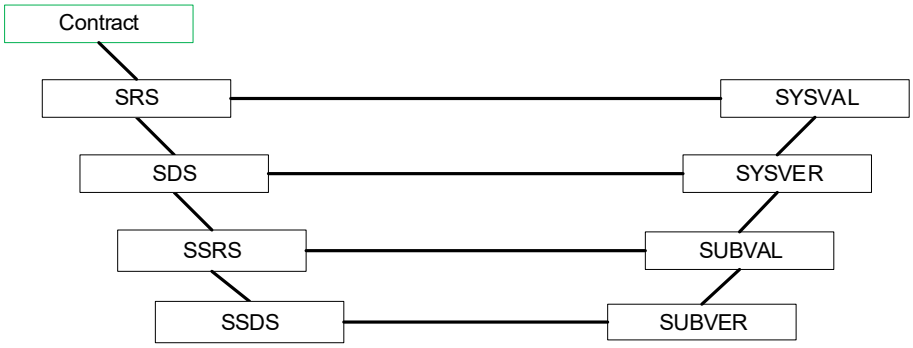

Figure 10 Tailoring Option 1: Without Component Levels

Tailoring Option 2: Design levels (e.g. SDS, SSDS)
All design statements must be defined as attributes on the respective requirement specification level (e.g. SRS, SSRS, COMPRS) and the test results must be documented via an attribute on the validation level (e.g. SUBVAL).

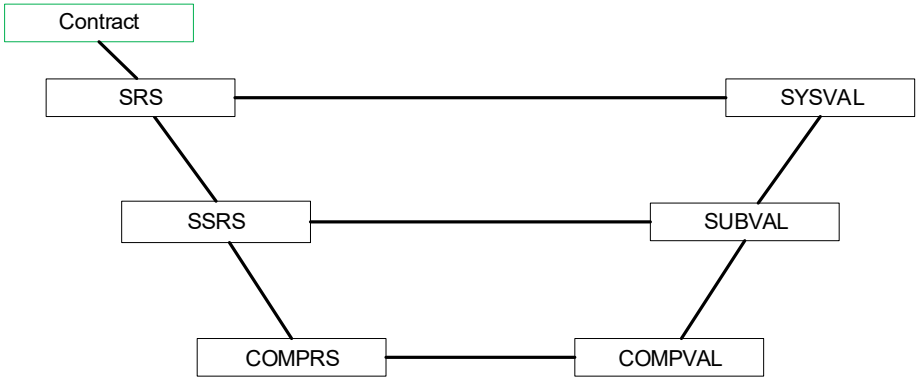

Figure 11 Tailoring Option 2: Without Design Levels

Tailoring Option 3: Contract level
All contract-relevant requirements must be integrated at the System Requirements Specification Level (SRS) due to missing or undocumented input requirements. The contract or tender documentation is not imported into the RM system and the SRS is created without a direct link to the requirements of the customer/stakeholder. The verification of the requirements must take place via a review.

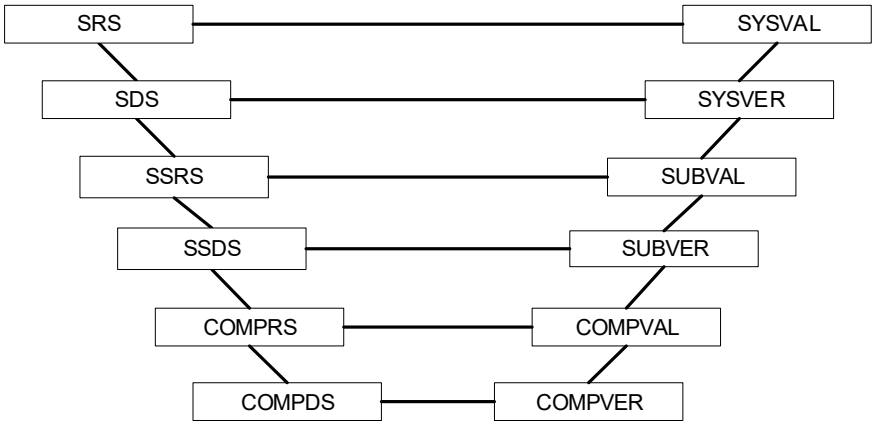

Figure 12 Tailoring Option 3: Without Contract Level

All other levels are necessary for the tracing structure according to its definition in the respective RM variant (see section 3.2) - as far as they are available in the system architecture of the project - and must be implemented during setup.

In accordance with section 3.2, the following overview results when selecting a variant:

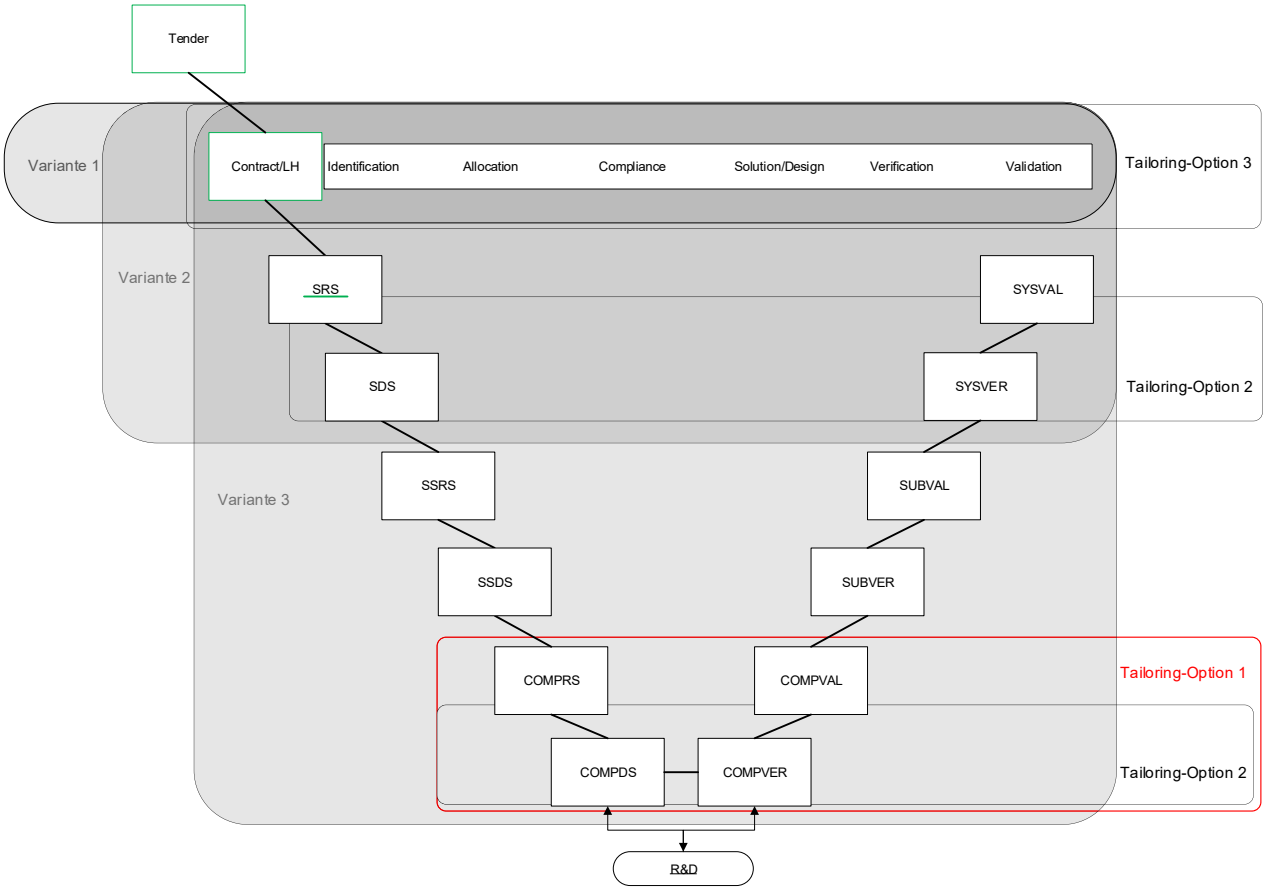

Figure 13 Overlapping Variant and Tailoring Areas

The tracing structure tailored to these options is also displayed in [MO_MM_RM_Checklist.xls].

3.4 Further Process Adaptation

This section describes further customization options that can be applied depending on specific project characteristics. These project-dependent adjustments must be agreed together by project management, requirements management and system management.

3.4.1 Customer-specific Regulations

For projects in which customer-specific regulations or common conventions for requirements management apply, these must be adhered to and the process described in this document is not applicable or must be adapted accordingly.

3.4.2 Hardware/Software Development

If a product or base system is used in a project without functional changes and without the need to demonstrate additional properties or capabilities, i.e. if only HW and/or SW engineering is required, subordinate design and subsystem levels may not be required.

The technical (functional and non-functional) customer requirements can be answered directly with the documented and validated product and system properties and characteristics. In such cases, the need for verification and validation against customer requirements depends e.g. on the safety integrity level and project requirements (e.g. these tasks may not be required if the generic application applied or a product has already been evaluated by a customer or the relevant railway authority).

If the respective engineering process is defined and demonstrably leads to the required engineering data and hardware plans with corresponding quality (e.g. suitable for use in a SIL4 environment), the corresponding input documentation (geodata, site plans, position data of the signaling systems etc.) should be processed directly by the responsible engineering departments.

Verification and validation of the engineering services is only required for the positions for which the process requires it.

3.4.3 Independent Assessment Based on Test/Verification

Some projects already use independently assessed or even approved products, platforms or base systems where the main task is to adapt, configure and design these products without making any changes to the products (see also section 3.4.2 above). These projects using an

independent safety assessment can also be carried out directly based on engineering results, data test results and factory and site acceptance protocols, without the need for a full audit and subsequent validation (which in this case is implicitly covered by the assessment).

This approach differs from the procedures normally required to demonstrate that a certain level of safety integrity (SIL) greater than zero is achieved (according to [EN50128] and [EN50129]),

- it must be agreed with the intended independent safety assessor at the beginning of the project (or already during the bidding phase).
- The required inputs for the safety assessor must be defined in common.
- It must be checked whether the customer requirements with regard to safety integrity can be fulfilled.

4 Preparing the RM Environment

Before beginning to prepare the RM environment, all available information about the project must be thoroughly evaluated so that the RM environment can be prepared according to the project-specific needs. The project-specific RM setup comprises the RM plan, the allocation of the RM tool as well as training and RM documentation.

4.1 Project-specific RM Setup

The RM setup is based on the project-specific parameters and the system configuration including interfaces, e.g. to external suppliers or in consortium formation.

Besides technical requirements there might be requirements from the client, which define specific needs to the Requirement Management. Specific requirements may concern

- the general RM process
- the RM tool
- the RM plan (tasks, roles, milestones, etc.)
- RM reports and metrics

These requirements need to be carefully evaluated with respect to the project-specific tailoring of the RM process. The results and definitions will be incorporated into the RM plan, finally. The template for the RM plan in German and English is available in [RMP Template].

As part of the project configuration, the assignment to the project number must be made in the path of the project according to the EPIQ system, e.g. 2108_61758_DE_Ulm_ESTW.

4.1.1 Contract-relevant Documentation

The basis for RM in project management is the contract and its related documents (e.g. standards, contract amendments, etc.) as well as the respective tender documentation. The contractual documentation usually contains technical, non-technical and normative documents describing the system (scope), the project implementation and the contractual conditions.

The bid documents - ideally the commented requirements - can serve as the initial basis for the RM setup, but any changes that occur during the negotiation phase between bid submission and contract signing must be carefully evaluated. In case of doubt, the contract documents and their amendments shall be decisive.

4.1.2 Object and Level Identifiers

After the definition of the applicable V-model and the level structure according to the characteristics of the project according to chapter 3, the definition of unique requirement identifiers

is mandatory in order to identify and track all objects along the RM life cycle. The RM tool automatically provides and manages unique identifiers. For better recognition, however, naming identifiers can be used, additionally (to be decided project specifically).

4.2 RM Tool Setup

According to chapter 6.1.8 of the [Guideline PM@Mobility], DOORS is the mandatory mainline RM-tool for RM in project execution (i.e. if a RM tool must be used, it must be DOORS). A set of templates for quick and easy setup are stored in [Templates Manuals]. Moreover, the RM Toolbox contains add-ons for efficient and user-friendly processing of requirements.

In some cases (e.g. for extensions/changes of existing projects) the use of other tools is permitted. However, the use of such tools should be carefully balanced and restricted to a minimum.

The project-specific properties of the tool environment, such as

- access paths
- Terminal Server setup (if applicable)
- tool-based interaction with customers and suppliers
- applicable export options to e.g. Word and/or Excel
- selection of metrics and reports

must be defined in the project-specific RM plan.

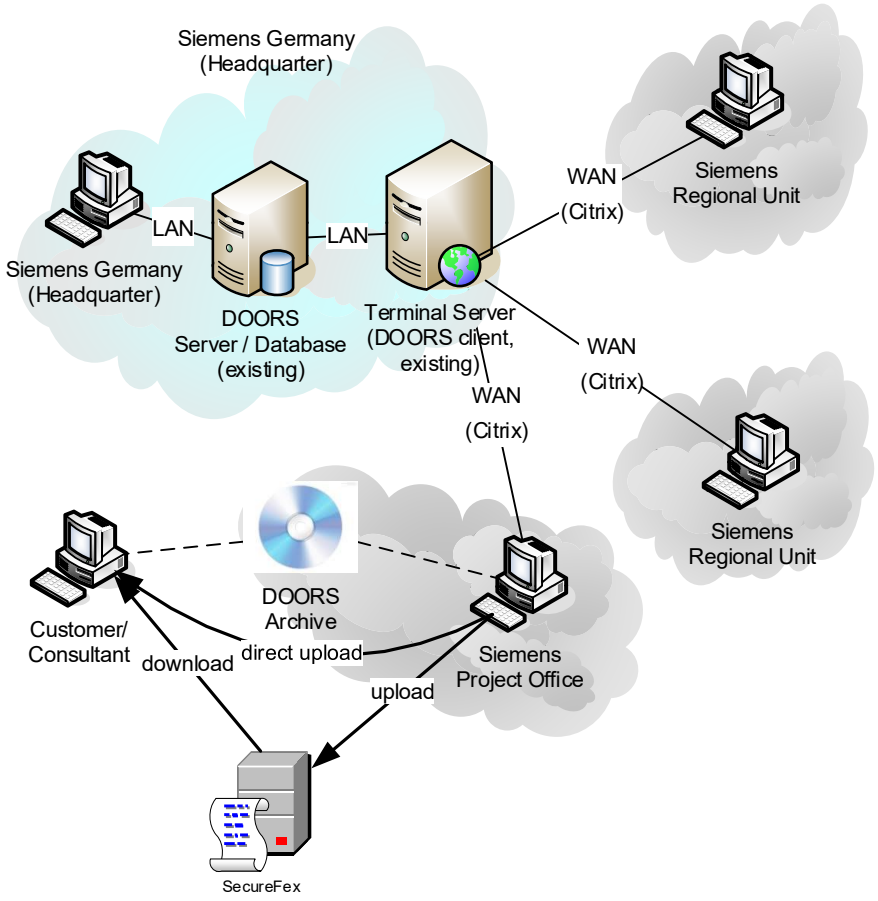

Figure 14 Example of a Project-specific RM-Tool Infrastructure Setup

4.2.1 Modules and Folders

For quick start, a set of preconfigured folders and modules is available which serve as the basis for the project specific tool setup. The folders and modules represent the selected V-Model and level hierarchy required for the specific project execution. Additionally, the traces between objects in the folders are stored in specific link modules. These link modules are predefined according to the structure for processing the V-Modell.

4.2.2 Attributes

The definition of attributes - and their value ranges - is necessary for a fast and consistent requirements evaluation. If required, additional attributes can be added. The list of standard attributes can be found in the Appendix Documents [MO_MM_RM_Checklist.xls]) in Chapter 11.

4.2.3 User Access Rights

The Requirements Manager (RMiP) defines the corresponding user access rights for all project members and domain experts involved. The Project Manager (PM) is responsible for providing the RMiP with the list of all team members involved for the setup.

4.3 Roles and Responsibilities

The following roles are crucial to the execution of the RM process and must therefore be named at the beginning of the project execution.

Abbreviation	Role Name	Description
PM	Project Manager [Role PM]	Overall project manager, responsible for adherence to timeframe and budget, interface to customer
RMiP	Requirements Manager in Project [Role RmiP]	Requirements Manager, responsible for setting up the RM environment and managing requirements throughout the project lifecycle.
SMiP	Systems Manager [Role SMiP]	Systems Manager, responsible for design and implementation of system architectures
PLM	Product Lifecycle Manager [Role_PLM]	PLM for checking and releasing the product or basic system related SSRS (specification of a URS for product/basic system development, extensions or changes).
PSSE	Product and Solution Security Engineer	Systems Engineer, responsible for the verification of requirements and design regarding security
R&D	Research and Development	Recipient of a product or base system related SSRS (URS), reviewer of the document
RAMS	RAMS-Manager	Manager, responsible for checking requirements and design regarding RAM and Safety
SEiP	Systems Engineer [Role SEiP]	Systems Engineer, responsible for (sub)system / component RS /DS and attribute evaluation
VAL	Validator [Role_Val]	Validator, responsible for the validation of the (sub)system
Test	Tester [Role_Test]	Tester, responsible for testing (sub)systems
VER	Verifier [Role_Ver]	Verifizierer, responsible for the audit of the (sub)system

Table 4 Roles and Responsibilities

The project management is responsible for the organisation of the necessary resources to fulfil the RM tasks.

4.4 RM Plan

For each project a specific RM plan is required (created by RMiP, first version at PM080), which at least explains and defines the following points:

- required RM-related results for milestones
- roles and responsibilities
- RM-specific representation of the system structure
- tracing rules
- Attributes
- description of the tool setup

The RM plan can be created on the basis of a template (see [RMP Template] and [RM Sharepoint]).

4.5 Documentation and training

The RMiP supports the project organization both in the provision of specific documentation and in the training of all project team members involved.

4.5.1 Documentation

The RMiP creates and archives project-specific RM documentation, such as RM Plan, status and status and requirements verification reports, and baselines, during the entire duration of the project.

Archiving takes place via the document management system used (e.g. SAP PLM). This includes baselines, e.g. for the release of requirements/design specifications, for the start and end of verification or validation tasks, for Q-gates, before new requirements or requirement changes are included in a requirement specification or before extracts are exported to external suppliers.

The specifications for the baseline creation and archiving of the requirements and the respective processing results are described in Chapter 9.

4.5.2 Training

To ensure efficient requirements handling - from capturing to validation - all roles and system engineers involved must be trained to perform their tasks in the selected environment.

A range of role-specific training documents will be available for requirements' processing and tool handling. The RMiP organizes and plans the necessary (project-specific) training units.

The general training material and references to web-based training courses are also available on the Sharepoint in the latest version, see [RM Sharepoint].

5 RM Process in Project Management

The following table describes the activities and tasks of Requirements Management with reference to the PM milestones.

Milestone	Phase	Tasks of the Requirements Manager
PM 080	Project Handover	Identification of contract relevant documents and definition of RM approach: V-model, hierarchy of levels incl. interfaces
		Present preliminary RM approach at project Kick-Off
		▪ Transformation of an existing bid project RM into project execution (delta analysis) or ▪ Setup of a new project RM including tool environment, import of contract documentation, and capturing of requirements
PM 100	Project Opening and Clarification	Support for ▪ Identification and apportionment of requirements ▪ Definition of system, subsystem and components
		Progress controlling and reporting e.g. of coverage of stakeholder requirements
		Present detailed RM approach at project planning/PACT workshop and train the project team
		Release of RM Plan
PM 200	Detailed Planning	Progress controlling and reporting e.g. of coverage of requirements by design statements
		Provision of requirements to be tested
PM 260	Adaptive Development	Progress controlling and reporting e.g. of assignments to specific subsystem for application development
PM 265	Engineering and Procurement	Progress controlling and reporting e.g. of coverage of requirements by test cases
PM 300	Integration and Test	Incorporation, controlling and reporting of test results (e.g. factory tests) and traces to requirements (for fulfillment proof)
		Support for compilation of checklists for installation and commissioning
PM 600	Commissioning	Incorporation, controlling and reporting of test results from onsite tests (e.g. from checklist and test documentation)
		Support for validation, assessment and site acceptance
PM 650	Acceptance	Reporting of acceptance-relevant requirements
		Support in reporting of requirements and application rules
PM 670	Execution Closure	None / support with enquiries on requirements related information
PM 700	End of Project	None / support with enquiries on requirements related information

Table 5 PM Milestones and Tasks of the Requirements Manager

5.1 Processing Contract Requirements

If the bid documentation is not available or cannot be transferred from the bid phase, the contract documentation with all requirements (e.g. technical specifications, operational scenarios) must be imported completely and transferred to the RM tool (e.g. due to disproportionate changes in content). In other cases, it is sufficient to compare the contractual documentation with the offer documentation and process the identified changes.

After importing new / changed requirements whose correct transfer must be checked according to section 5.1.3, they must be identified, analyzed and recorded in the RM tool. The following sections 5.1.1 and 5.1.2 deal with this in more detail.

5.1.1 Processing of Captured Contract Requirements

After importing new / changed requirements, these must be identified, analyzed and captured in the RM tool in accordance with 2.2.4 "Criteria for the Identification of Stakeholder Requirements".

Attributes to be set according to object type and roles:

- REQ Type (DEF, Prose)
- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (automatically set when REQ Forwarding is set), not applicable, terminated)
- REQ Statement (to be set if REQ Progress=not applicable or terminated)

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

All technical, system relevant requirements (functional and non-functional) including standards and regulations have to be considered within the context of technical traceability by the System Requirements Specification (SRS).

Contract requirements with higher granularity can be forwarded to the corresponding documentation/system level via the SRS (and possibly even lower documentation levels) without changes.

Deviations from these specifications shall be described in the project-specific RM plan.

5.1.2 Transfer of Processed Tender Documents from the Tender Phase

The documents processed during the bid phase with the derived and evaluated requirements are transferred to the contract folder as a copy. The classification REQ Type is reviewed for all requirements according to the criteria in section 2.2.4 and corrected if necessary. In addition, the following attributes shall be set as described in Section 5.1.1:

- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (automatically set when REQ Forwarding is set), not applicable, terminated)
- REQ Statement (to be set if REQ Progress=not applicable or terminated)

The processing status (also may depend on the project milestone) is calculated in the attribute

- DXL Status (processed, not processed)

5.1.3 Review of Requirements Documents Imported into the RM System

An important step after each import of external data into the RM system is to check the correctness using a review. This task step is the responsibility of the Requirements Manager in the project [Role RmiP]. The procedure for this review may vary depending on the type and scope of the project; the result of the review should always be documented.

The following approaches are recommended:

- Visual comparison of imported data in the RM system with the source
- Export the imported data from the RM system and perform a tool-supported comparison with the source.
- Re-importing the data into the RM system (by a second performer)

5.1.4 Process-relevant Activities for PM100

The following activities are the responsibility of the system manager responsible for the system [Role SMiP].

1. a requirement classification is made for each object: REQ Type
2. for each requirement (object with REQ Type = DEF) the future processing is determined by REQ Forwarding
3. For each requirement to be forwarded (object with REQ Type = DEF and REQ Forwarding set) a link of type "realizes" from one or more requirements of the System Requirements Specification (see following section 5.2) shall be set.
4. For each requirement that is not forwarded and not applicable (object with REQ Type = DEF and REQ Progress = not applicable or terminated), a comment must be documented in the REQ Statement attribute as a reason.

5.2 Preparation of the System Requirements Specification

The System Requirements Specification (SRS) - even if it is documented separately in generic and specific parts - is the basis for the design and development of the planned system. It shall contain all explicitly mentioned technical customer requirements as well as all implicit requirements (e.g. relating to environmental conditions, specific standards and norms, etc.) applicable to the system under consideration. In addition, a proof criterion, the so-called PassFailCriteria, must be set for each requirement.

The purpose is to interpret the following texts in the system context

- technical aspects of the customer contract and
- other applicable information / documents / assumptions

and into precise, unambiguous technical specifications to enable them to design a complete, self-conforming system that fully meets the customer's order.

Important:

The SRS describes which system functions and properties are expected and required, but not how the system implements them. Each technical (system-relevant) contract requirement must be traceable to at least one system requirement.

The following flowchart shows the steps required to create a System Requirements Specification.

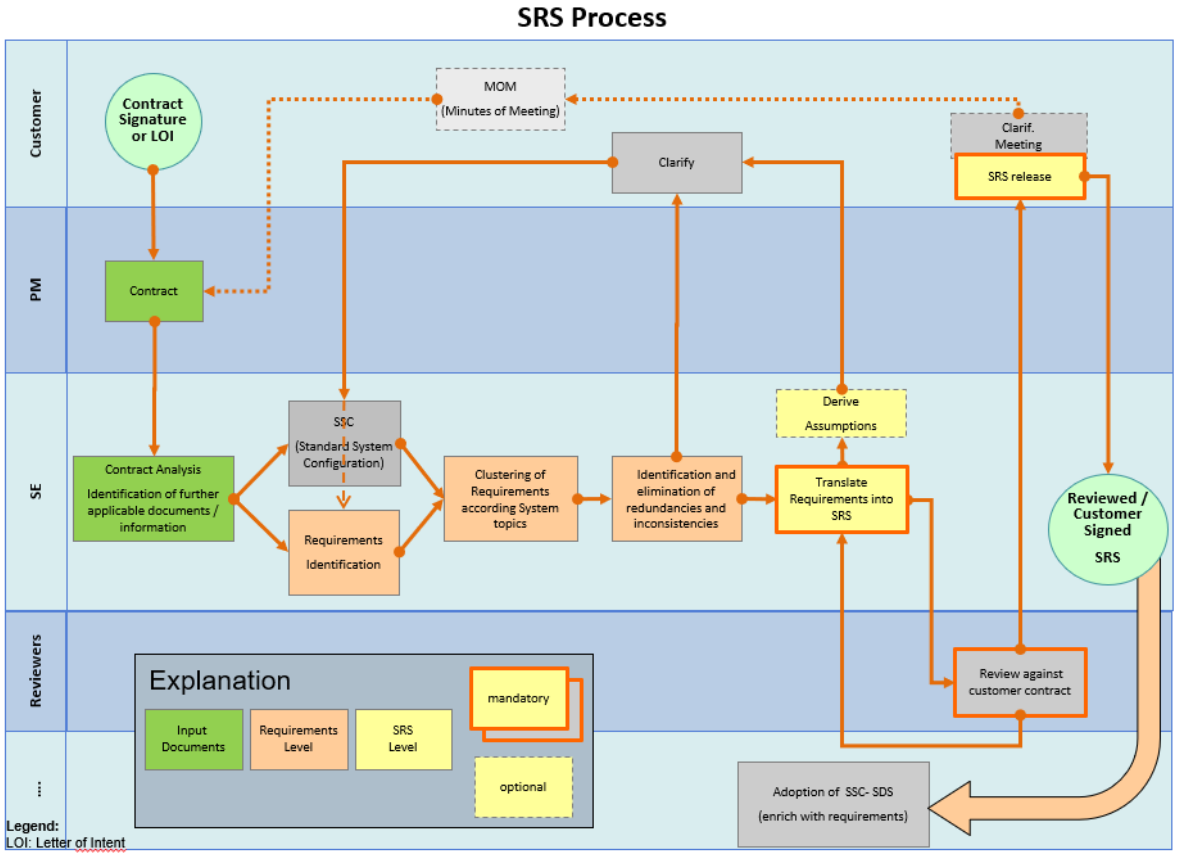

Figure 15 SRS Creation Process

The SRS ensures a common understanding between the customer and the project regarding the system, subsystem or component to be implemented.

It is the basis for the work of the system architect and the designers to enable an optimal technical solution that completely considers the needs of the product's users (functional and non-functional) requirements and the specific safety requirements usually applicable for MM products. It allows architects and designers to consider (technical) boundary conditions that exceed the original task within their approach for a solution from the beginning of the design.

Furthermore, the SRS forms the foundation of the safety demonstration (usually a safety case) that states the fulfillment of all safety related requirements and arguments that the system does not impose systematic or randomly occurring hazards at higher frequencies than demanded by the system specific safety target

The system validation uses the SRS as the main input in order to be able to independently check the fulfilment of the system requirements and the completion of all related tasks.

The author of the SRS must clearly formulate the requirements of the customer from a technical point of view (cf. Chapter 2.2.2), highlighting the requirements aimed at the intended realisation if they deviate from the literal contract requirements. He must also formulate explicit exclusions.

5.2.1 Processing the System Requirements

Mandatory attributes for objects of the System Requirements Specification are:

- REQ Type (DEF, Prose)
- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (set automatically when REQ Forwarding is set), not applicable)
- REQ Statement (to be set if REQ Progress=not applicable)
- REQ Safety_related (yes, no)
- REQ Security_related (yes, no)
- REQ PassFailCriteria

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

5.2.2 Process-relevant Activities for PM200

The following activities are the responsibility of the system manager responsible for the system [Role SMiP].

1. a requirement classification is made for each object: REQ Type
2. For each requirement (object with REQ Type = DEF), a classification is made using REQ Safety_related.
3. for each requirement (object with REQ Type = DEF) a classification is made using REQ Security_related
4. For each requirement to be forwarded (object set with REQ Type = DEF and REQ Forwarding), a link of type "realizes" from one or more solution descriptions of the System Design Specification (see section 5.3 below) shall be set.
5. for each closed requirement that cannot be forwarded (object with REQ Type = DEF and REQ Progress = not applicable), a comment must be documented in the attribute REQ Statement as a reason.

5.3 Preparation of the System Design Specification

A design specification (SDS) describes how the requirements of the user are met by an architecture (e.g. from subsystems at SDS level or from a combination of hardware and software at SSDS level). It divides the design solution into individual platform components or subsystems and describes the interactions and interfaces between these modules. As such,

it includes the architecture and provides a framework for the development of the detail design.

The main tasks of requirements engineering are the assignment of requirements to subsystems and/or elements defined within the system architecture and the identification of the contribution of the subsystems/components to the realisation of the requirement. This makes it possible to derive the relevant requirements for the development of the subordinate subsystem or components.

Furthermore, the SDS is the basis for the definition of the required integration tests.

As a rule, there are system requirements that do not have to be assigned to the next RS level because they can only be implemented or demonstrated at the current level (for example, a requirement that can only be tested through the functional interaction of at least two subsystems or components).

In addition, not every single requirement needs to be refined according to its assignment to a subsystem or component (e.g. a requirement that requires compliance with a particular standard). It can be forwarded to a subsystem without changes if the current level is not affected or if it is specifically applicable to the next lower subsystem.

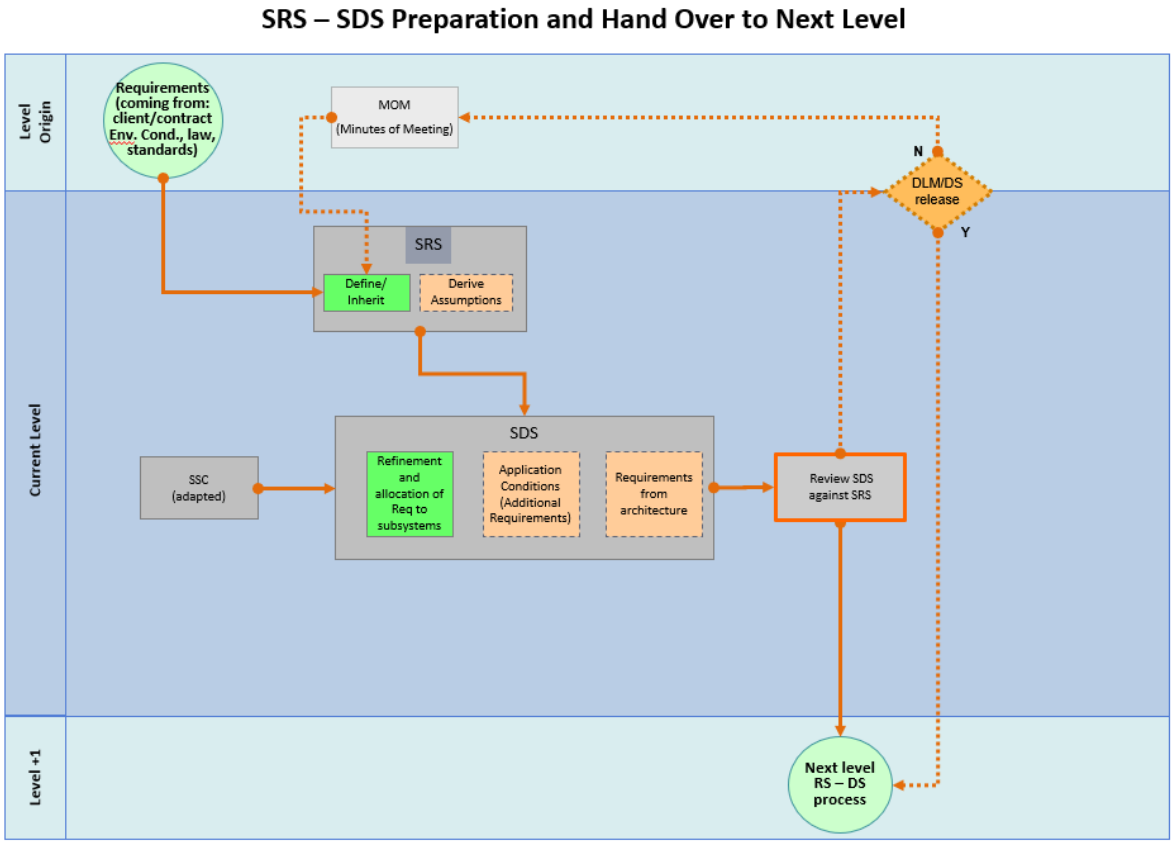

Figure 16 SDS Creation Process

Based on the assignment of the subsystem and the identification of the contribution of the subsystem to the realisation of the requirement, the system manager or system engineer responsible for the unit shall prepare the appropriate specification of the subsystem (SSRS) requirements.

Existing statements in design documents can be linked to cover requirements for these. The implementation of such a tool can provide statements in the statement attribute of the requirements or a link after the transfer of the document into the RM system.

5.3.1 Implementation of the System Requirements by Solutions

Mandatory attributes for objects of the System Design Specification are:

- REQ Type (DEF, Prose)
- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (automatically set when REQ Forwarding is set), terminated, open)
- REQ Statement (to be set for REQ Progress=terminated or open)

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

5.3.2 Process-relevant Activities for PM265 (Part 1)

The following activities are the responsibility of the system manager responsible for the design system [Role SMiP].

1. a solution/design statement classification is made for each object: REQ Type
2. for each solution to be implemented by subsystem (object set with REQ Type = DEF and REQ Forwarded) a link of type "realizes" from one or more requirements of the respective subsystem Requirements Specification (see section 5.4 below) shall be set.
3. For each solution (description) at system level (object with REQ Type = DEF and REQ Forwarding = empty) the attribute REQ Progress = terminated must be set.

5.4 Requirements Specifications on Levels Below the System

The principles for defining a requirements specification at the next levels of the V-Modell are the same as for SRS. Input for a requirement specification are the design decisions from the design specification of the higher level (see previous chapter 5.3).

5.4.1 Preparation of Subsystem Requirements Specifications

Mandatory attributes for objects of the subsystem Requirements Specification are:

- REQ Type (DEF, Prose)
- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (automatically set when REQ Forwarding is set), not applicable, terminated)
- REQ Statement (to be set if REQ Progress=not applicable)

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

5.4.2 Process-relevant activities for PM265 (Part 2)

The activities listed below are the responsibility of the system engineer [Role SEiP] responsible for the subsystem in question and/or the product manager [Role_PLM] if applicable.

1. a requirement classification is made for each object: REQ Type
2. For each requirement to be forwarded (object set with REQ Type = DEF and REQ Forwarding), a link of the type "realizes" from one or more solution descriptions of the associated subsystem Design Specification (see previous section 5.3) shall be set.
3. for each requirement not to be forwarded (object with REQ Type = DEF and REQ Progress=terminated or not applicable) a comment must be documented in the attribute REQ Statement as a reason.

5.5 Creating Design Specifications on Levels Below the System

The principles for defining design specifications at the next levels of the V-model are the same as for SDS. Input for this is the respective requirement specification (see previous chapter 5.4) on the same level, since a design specification is always created for the requirements that are exactly defined for the respective level in the overall system.

5.5.1 Implementation of the Subystem Requirements by Solutions

Mandatory attributes for objects of the subsystem Requirements Specification are:

- REQ Type (DEF, Prose)
- REQ Forwarding (enumeration type of the assignment target)
- REQ Progress (forwarded (automatically set when REQ Forwarding is set), terminated, open)
- REQ Statement (to be set for REQ Progress=terminated or open)

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

5.5.2 Process-relevant Activities for PM265 (Part 3)

The activities listed below are the responsibility of the system engineer [Role SEiP] responsible for the design of the relevant subsystem and/or the product manager [Role_PLM].

1. a solution/design statement classification is made for each object: REQ Type
2. For each solution that is to be implemented by a subordinate subsystem (e.g. a component) (object set with REQ Type = DEF and REQ Forwarded), a link of the type "realizes" of one or more requirements of the respective subsystem Requirements Specification underlying the V-Modell must be set.
3. For each solution (description) on the current level (object with REQ Type = DEF and REQ Forwarding = empty) the attribute REQ Progress = terminated must be set.

5.6 Assignment of the Results of the Test and Integration Phase

System integration constitutes the demonstration of the correct interaction between different subsystems (respectively components) forming the super ordinate system (respectively subsystem).

The task of requirements verification is to demonstrate the fulfillment of all requirements applicable to the (sub-) system under consideration according to the pass-fail criteria. Requirements verification can be done by logical argument, inspection, modeling, simulation, analysis, expert review, (integration) test or operational demonstration. The results of the verification (e.g. test report, analysis, review, etc.) are imported or referenced in the respective integration level statement. One or more requirements verification results can demonstrate the fulfillment of one or more requirements.

Since the test management process is not part of the RM@MM process, the interface is limited to the transfer of the requirements to be tested and the assignment of the test results to these requirements. When using the RM system to manage test cases, the following attributes must be used:

- TEST Type (DEF, Prose)
- TEST Result (passed, failed)
- TEST Comment (to be set if TEST Result=failed)

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

5.7 Validation

The task of validation is to check independently on the basis of evidence planning (based on the results of the requirement review, e.g. audit or analysis, see Section 5.6 above) whether the fulfilment of all stakeholder requirements applicable to the (sub)system under consideration has been correctly demonstrated in accordance with the pass fail criteria. If the degree of compliance is not 100%, a corresponding condition is added to the result - which is a separate requirement (see Chapter 6.3, Application Rules).

The validation of a system, subsystem or component must base on a defined status of answered/fulfilled requirements (baseline).

The set of affected requirements, their status and the verifiers' arguments for their solution must be frozen in a certain status to allow continuing work of designers and verifiers (as long as the considered entity is not finalized regarding the processing of requirements)

The validator needs a facility to comment and work on requirements independently without consequences for the frozen requirements verification status.

The validation result may differ from the result of the requirements verification; consequently, both must be documented. Figure 16 shows the processing of verification and validation at a specific level with the inputs of the previous level and the outputs for the next level.

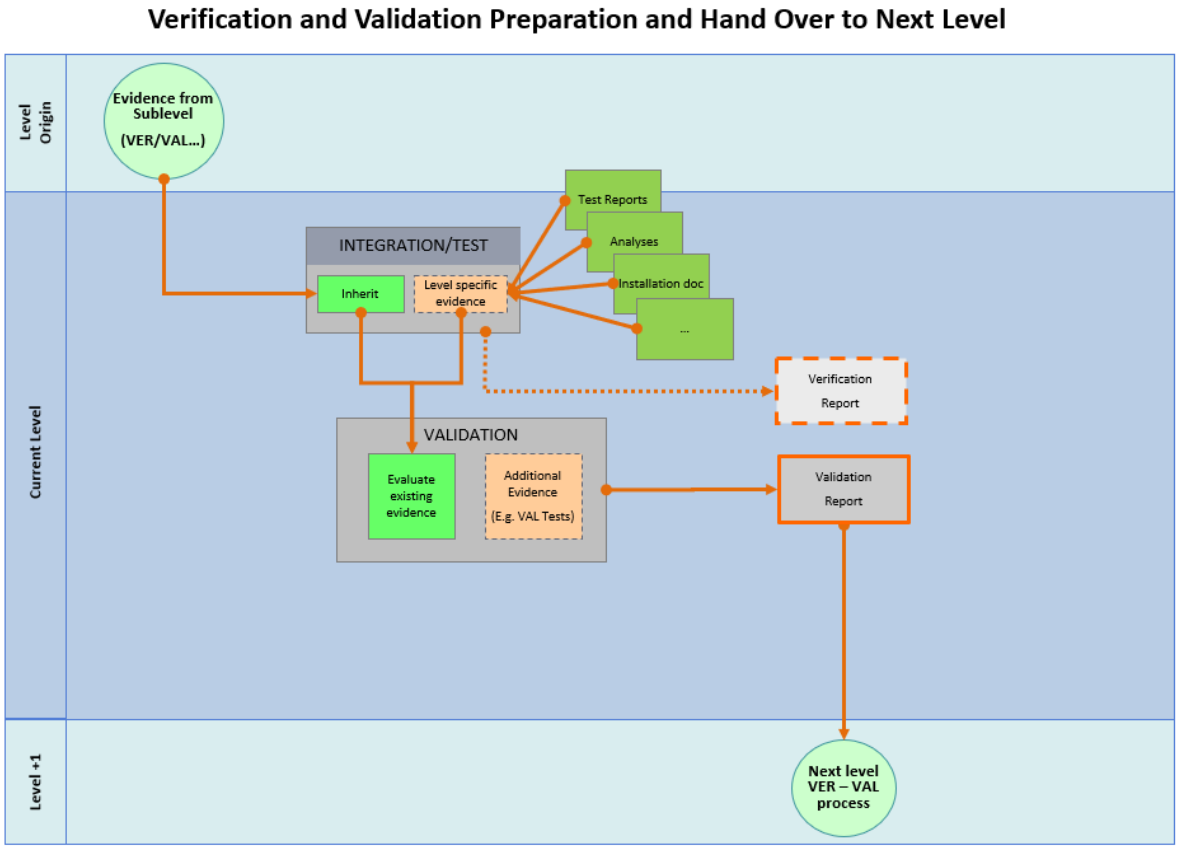

Figure 17 Verification and Validation for All Levels

For SIL 1-4 systems/subsystems/components an independent validation is mandatory. For SIL 0 requirements the requirements verification result can be sufficient (see [EN50129]) but must be linked to the validation level as evidence for the requirements' fulfillment.

The validation level will be used for declaring the fulfillment of the requirements of the respective RS level based on the requirements verification results.

The following attributes must be used in the RM system to validate the requirements:

- VAL Type (DEF, Prose)
- VAL Result (fulfilled, partly fulfilled, not fulfilled, closed, open, not evaluated)
- VAL Evidence
- VAL V&V Method
- VAL Condition

The processing status is calculated in the attribute

- DXL Status (processed, not processed)

Deviations from these specifications shall be described in the project-specific RM plan.

6 Special Handling Rules

Some topics during the implementation of the process require special rules for the concrete procedure in requirements management in order to be processed correctly and consistently.

6.1 RAMSS related Requirements

Due to the importance of RAMSS-related requirements (RAMSS = RAM, Safety and Security), the processing of these requirements must follow certain rules - from identification to validation.

6.1.1 RAM related Requirements

The attribute REQ RAM_related marks a requirement as relevant for reliability, availability and maintainability. This means that the non-fulfilment or omission of such a requirement can lead to, for example, the contractual MTBF or availability targets not being met and to an unreasonable accumulation of train delays during operation.

The proof of its compliance may require an analysis, a statement or a specific proof by the RAMSS management.

- RAM Demonstration
- Safety- und RAM-Pläne

6.1.2 Safety related Requirements

The attribute REQ safety_related identifies a requirement as safety-relevant. This means that non-compliance with or failure to comply with such a requirement may endanger the system.

According to the CENELEC standard [EN50129], a distinction can be made between safety and non-safety requirements. The safety requirements can then be further subdivided into safety integrity and safety function requirements. For further explanations see Appendix A.2 of [EN50129].

This differentiation (in line with and according to the subsequent sections) is also recommended for the correct designation and assignment of the requirements within a requirements management tool environment.

However, if no differentiation is made in the project with regard to this differentiation, an evaluation in the attribute REQ safety_related with regard to yes or no must be carried out.

6.1.2.1 Safety Functional Requirements

The attribute value safety_functional identifies a requirement as relevant for the safety of the system/subsystem/components. A requirement is marked as safety functional if its non-fulfilment or omission can lead to a hazard.

Safety functional requirements must not be mixed up with requirements that must be met or verified by RAMSS experts within a project.

Safety functional requirements according to the above definitions are functional requirements or requirements for a specific design that is to be implemented. These must be verified (by analysis, reasoning, testing) and validated like any other requirement, in some cases by a safety analysis, explanation or evidence to be provided by the RAMSS manager in the project and the corresponding documentation (e.g. a safety demonstration).

6.1.2.2 Safety Integrity Requirements

In addition to the requirements for safety functionality, there are usually a large number of requirements that require RAMSS experts to take measures that are not safety functional in the sense of the above definitions, e.g. requirements for the creation of certain documents:

- hazard analysis
- safety plan
- safety verification

are often defined to verify the safety performance but must not be set to "safety functional". In any case, they are the responsibility of the RAMSS expert.

If such documents provide the solution for requirements, either their content must be linked to the respective requirements (if the documents are to be imported into the RM tool or created within the RM tool) or an unambiguous reference (identifier from SAP or similar archiving instruments) must be documented as evidence of their fulfillment.

6.1.3 Security Related Requirements

The attribute Security-related marks a requirement as relevant for security aspects. This means that the non-fulfillment or omission of such a requirement can result in a non-acceptable threat (from outside) to the system.

The demonstration of its fulfillment can require an analysis, a statement or certain evidence to be provided by PSSE.

6.1.4 Sources

RAMSS-related requirements can be

- derived directly from the customer documentation (contract documentation), such as

  - Requirement to the operating module:
    The track vacancy information must be read in safely.
    (Mikrocomputer-Stellwerk NS, Teilheft 2, Stellwerkselemente)
- a result of a hazard analysis (FMEA, Operational Analysis, Human Factors Study etc.), e.g:
  - OHA.006 The communication between driver and signaler regarding route release requests must be regulated in a way that reduces communication errors to a minimum.
    (Operational Hazard Analysis JJ-DPL; SIG HSL)
- are derived from product, subsystem or component-related documents (application rules, safety-related application rules, validation conditions, security cases, etc., see also Section 7.3), e.g.
- #REQ ECC PROZ INOM2 Leitungslaenge, Leitungsfuehrung#REF#
  The maximum allowed cable length for indications- and command cable is 100m…
  (Conditions of Use Element Control Computer Input-/Output Module 2)

RAMSS-related requirements derived from the contract are input to the RM structure via the SRS anyway.

RAMS-related requirements emerging from analysis must enter the RM structure on the level they are derived respectively on the design level above the requirements specification of the subsystems or components they need to be assigned to be able to correctly assign and detail them considering the properties of the affected subsystem or component.

The handling of (safety related) application rules from products, subsystems or components is described in section 6.3.

6.1.5 Handling

In order to enable a distinction to be made between requirements that directly affect the (functional) safety of the system and requirements that require a particular safety-related activity or type of analytical evidence during the implementation of the system, requirements may be identified as "non_safety" (no), "safety_functional" (SF) or "safety_integrity" (SI) requirements in accordance with section 6.1.2, resulting in the recommendation of a safety_related attribute with three selectable values:

- no
- safety_functional or SF
- safety_integrity or SI

If the differentiation in a project is not necessary, the value " yes " can be used instead of SF and SI.

For RAM-related requirements it is sufficient to identify them with a single value ("REQ RAM-related" - "yes" or "no"), since no "integrity" has to be demonstrated for the RAM demonstration. Normally, all RAM-related requirements require an action from the RAMSS Manager.

Safety and RAM related requirements derived by hazard or RAM analyses must be incorporated into the RM structure on the design level above the (sub-)system requirements level of the (sub-)systems that are affected by those to allow their correct assignment.

Open RAM- and especially safety-relevant requirements must be evaluated by validation or in the respective safety case regarding their impact on safety-relevant operation and operational availability. Rules and conditions for operation will result if an open requirement indicates missing safety functionality.

6.2 Generic vs. Specific Requirements

Requirements that are generally valid, application-specific, station-specific and/or related to a specific project phase must follow certain handling rules.

6.2.1 Generic Requirements

A generic requirement

- extends a system platform (e.g. new base system release) or
- refers to the customer-specific logic application (e.g. extension of an existing interlocking logic) or to programming rules, or
- defines a solid/constant basis for the future stations and projects of the customers.

Thus, generic requirements usually aim at the functions and characteristics of a certain product or system base and are processed and realized by a research and development department (R&D). The requirements are provided to the R&D department by means of a product/base system specific URS or SSRS.

From the point of view of the projects, all relevant input forming the for the station specific customization is generic. However, a not insignificant proportion of generic requirements also have a project-specific aspect, which must also be proven in a project-specific manner. The multiselect attribute "REQ Approach" with the values "product_generic" and "project_specific" should be used for unique assignment.

Examples of "cross-project" requirements for the further development of a basic system or a platform:

1. the project-specific system contains some additional interfaces to a given base, so it requires only a few adaptations.

   → A delta requirement specification is to be generated. The requirements derived from the interface specifications must be assigned to the affected subsystems.

2. a complete logic/software development as a generic application of a basic system must be initiated by a specific project.
   → Logic/software development should be treated as a subsystem during project execution.
3. more than one project uses and adapts a logic/software.
   → The logic/software development should be triggered and addressed by all projects concerned using one set of common generic application requirements. Depending on the applied base system and the amount of development effort, it must be decided whether the development is to be carried out within the project according to item 2 or whether it is subject to an SSRS (URS) to be realized by the responsible research and development (R&D) as an internal supplier (see also Chapter 3.1 and Figure 5).

For details on extending existing products and basic systems, please refer to the PPM/PLM process [PLM/PPM-Process] defining the required tasks and evaluation criteria to be applied for the submission of R&D orders and budgeting.

6.2.2 Specific Requirements

All requirements related to the configuration and HW/SW engineering of a system are considered as specific requirements. Depending on the applied products, platforms and defined subsystems used and the available processes for hardware and software engineering, either a separate (sub)subsystem for the engineering should be defined that allows the assignment of specific requirements (e.g. via SSRS BTTC for ETCS engineering data), or the specific requirements must be covered by the engineering guidelines/instructions to be observed during hardware and software development.

Identified specific requirements (also including e.g. relevant layout plans, geographical information, route tables etc.) must be checked regarding possible contradictions to a generic solution. If any contradiction is identified, the generic solution may not be suitable for the specific application and must be modified (unless an alternative, deviating solution based on the original generic solution can be agreed upon with the customer). The respective “generic part” of the requirement must be directed to the affected system or subsystem to enable the fulfillment of the specific requirement.

6.2.3 Verification and Validation of Specific Requirements

Many of the customer requirements can be validated completely based on the actual installation only, but the actual installations themselves are based on a generic application to be customized for each of them. This dependency can lead to repeated requirements verification and validation when several specific installations are carried out applying the same generic application although the major part of the specific single customer requirement can be answered generically (i.e. it can largely be fulfilled by the generic application), leaving only a small portion to be proven within the actual installation.

All requirements should be considered and evaluated project-wide for all installations of the realized system, product or component. The goal must be to guide the requirements only once through the V-model.

If there are several stations or installations to be customized, station specific requirements can be transformed into engineering, test, validation or construction specifications (see also sections 5.6 and 5.7) to ensure easy handling within the actual installation. During requirements verification all those requirements must be checked for their assignments to the respective checklists and reports for engineering, tests, installation etc. The subsequent validation then only needs to examine the completeness of the filled-in checklists and reports.

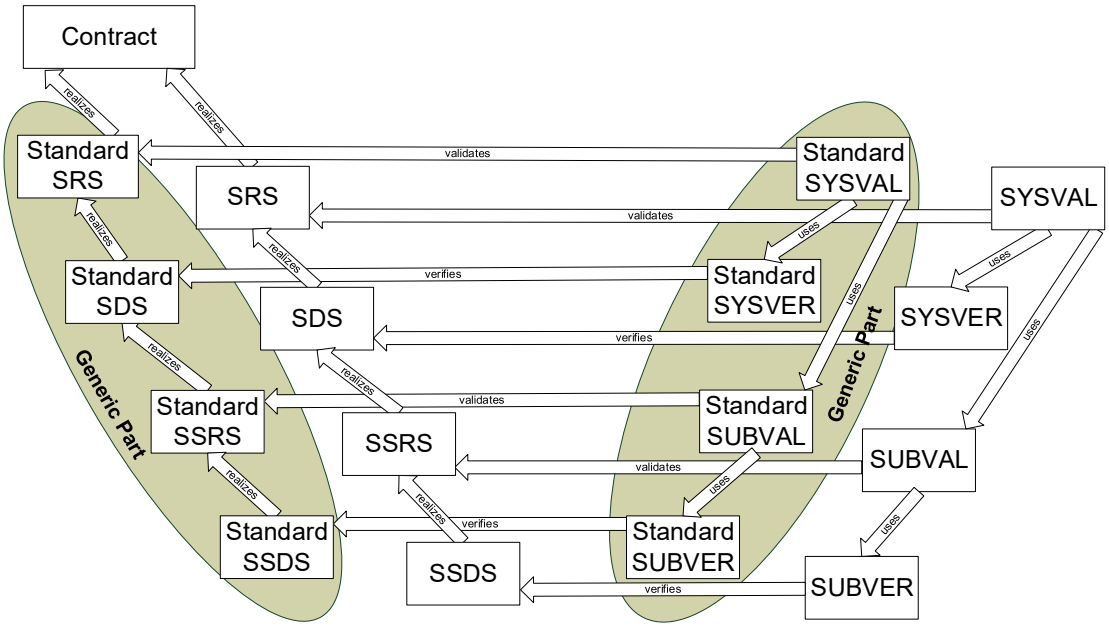

Figure 18 Handling of Generic Requirements

6.3 Handling of Versions and Validity of Requirements

To handle requirements that are only valid in a certain phase of the project, it must be ensured that the system described is fully documented for each release of the documented requirements. If the functions are to be implemented gradually in the system, this can be done using values of the control attribute. However, if requirements are only valid for certain versions, a separate attribute must be used. All relevant requirements must be documented for release.

6.3.1 Postponed Requirements

Requirements that are not yet to be implemented in the next version of the system must also be documented in the corresponding requirement specification. The status of these requirements is to be set to the value "postponed" using the attribute REQ Progress until they are used in a version. These requirements are not considered in the following, i.e. in the design specification as well as in the test and validation of the current version. The System Manager in the project [Role SMiP] has the technical responsibility that the system specified by all requirements not set to "postponed" is completely described. If postponed requirements are to be implemented in a later version of the system, the value of the REQ Progress attribute shall be set for the SRS in accordance with section 5.2.2 The same applies to the requirements of subordinate subsystems.

6.3.2 Assignment of Requirements to Versions

In opposite to the postponed requirements, which add functions to the system during project processing, requirements that are only valid for certain versions of the project must be marked with a separate attribute. This not only ensures that requirements can only become relevant for later versions, but also that requirements of earlier versions are no longer valid for a current version of the system. The REQ Release attribute must be used to identify the requirements relevant for versions, whereby the attribute values are adapted to the concrete version names for each project.

6.4 Application Rules

Application Rules are requirements which arise from a system, subsystem or component as such. They need to be obeyed if it was decided to use a specific system, subsystem or component. An application rule might be fulfilled by (an)other component(s) or by the integration of (sub-)systems. There are

- Product/System Application Rules (AR) - already known rules
- Safety application rules (SAR) - they are drawn up during the project planning phase.
- Validation conditions (VC) - they are generated during the validation phase.

Together with all customer requirements derived from the contractual documents all normative requirements like the application rules must be handled in the requirements management system. This does not include all internal regulations and guidelines.

The import of application rules into the project and their definition including existing solutions are described in [RM Manual Application Rules].

6.4.1 Handling within the RM structure

According to the [RM Manual Application Rules], application rules within the RM structure must be handled as any other type of requirement. To ensure that they are applied to the subsystems and/or constituents concerned, the correct entry level is the system level. The following Figure 18 shows the source and entry point of

- ARs and SARs resulting from the use of a particular component at the subsystem or component level.
- VCs defined during validation

The application rules should enter the requirements hierarchy at the level at which they arise, for example, due to design decisions or at the level above the subsystem/component level to which they are assigned.

The verification of application rules checks the correct apportionment to the subsystem(s) and the applied solution.

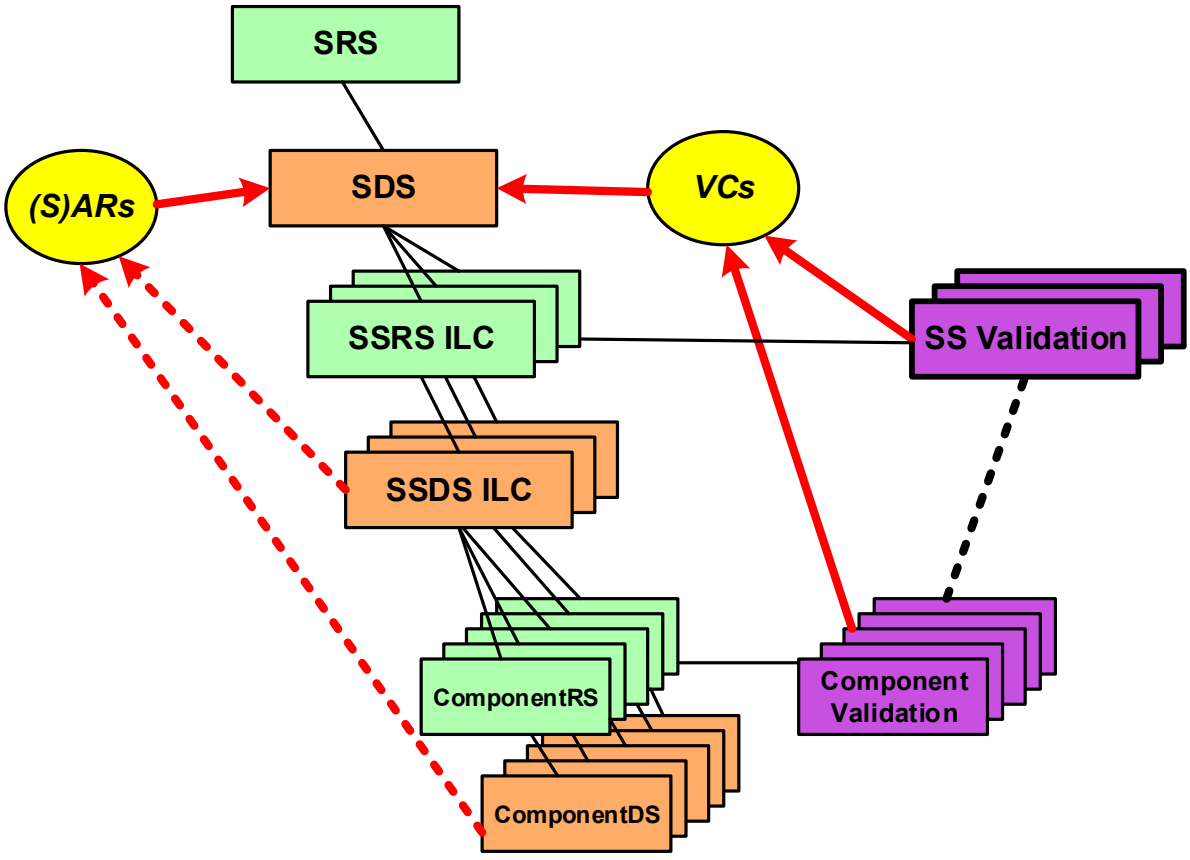

Figure 19 Handling of (S)ARs and Validation Conditions in the RM Structure

The validation of application rules follows the tracing tree. Apportioned application rules usually need to be validated based on integration/test results (functional) or design review and, if applicable, installation reports or as-built documentation (non-functional).

Special care should be taken when changing or updating subsystems/components. In this case, it is important to check whether application rules are affected and need to be changed or even re-apportioned.

If design or requirement specifications need to be changed due to emerging conditions, it is strongly recommended to analyze the impact of the changes before releasing them (especially in late project phases, e.g. during integration or validation). The analysis results should be included in the amended specification, supplemented by a statement on the impact on sub-specifications and associated documents, in order to keep the documentation consistent without having to change all documents related to the amended specifications.

6.5 Handling of Standards and Norms

As a rule, customer contracts require compliance with a number of standards, norms and/or customer-specific rules and guidelines. It is reasonable to include the standards as requirements in the SRS and thus import them into the applied requirements management tool. On the other hand, it should be avoided under all circumstances to create a requirement from every clause of the applicable standards and to import the content of those standards into the RM tool clause by clause.

The need for adherence to a certain standard should become a single requirement to be fulfilled by appropriate evidence (e.g. by a product certificate for the adherence to standards regarding environmental conditions or e.g. by a safety case for the demonstration of fulfillment of [EN50129]).

Even if compliance with a standard for which there is no evidence should be required, it should not be split up into separate requirements but fulfilled by a reference to comprehensive evidence covering the applicable aspects of that standard.

7 Tool-supported Tracing

Regardless of the RM tool used, the tracing rules and restrictions defined in the RM process must be adhered to. This can be done by monitoring the traces or, if available, using a configuration for

- Defined trace types
- Defined trace directions
- Prohibition of non-process conformable traces

Figure 19 shows the defined trace directions and trace identifiers for traces in an RM realization project.

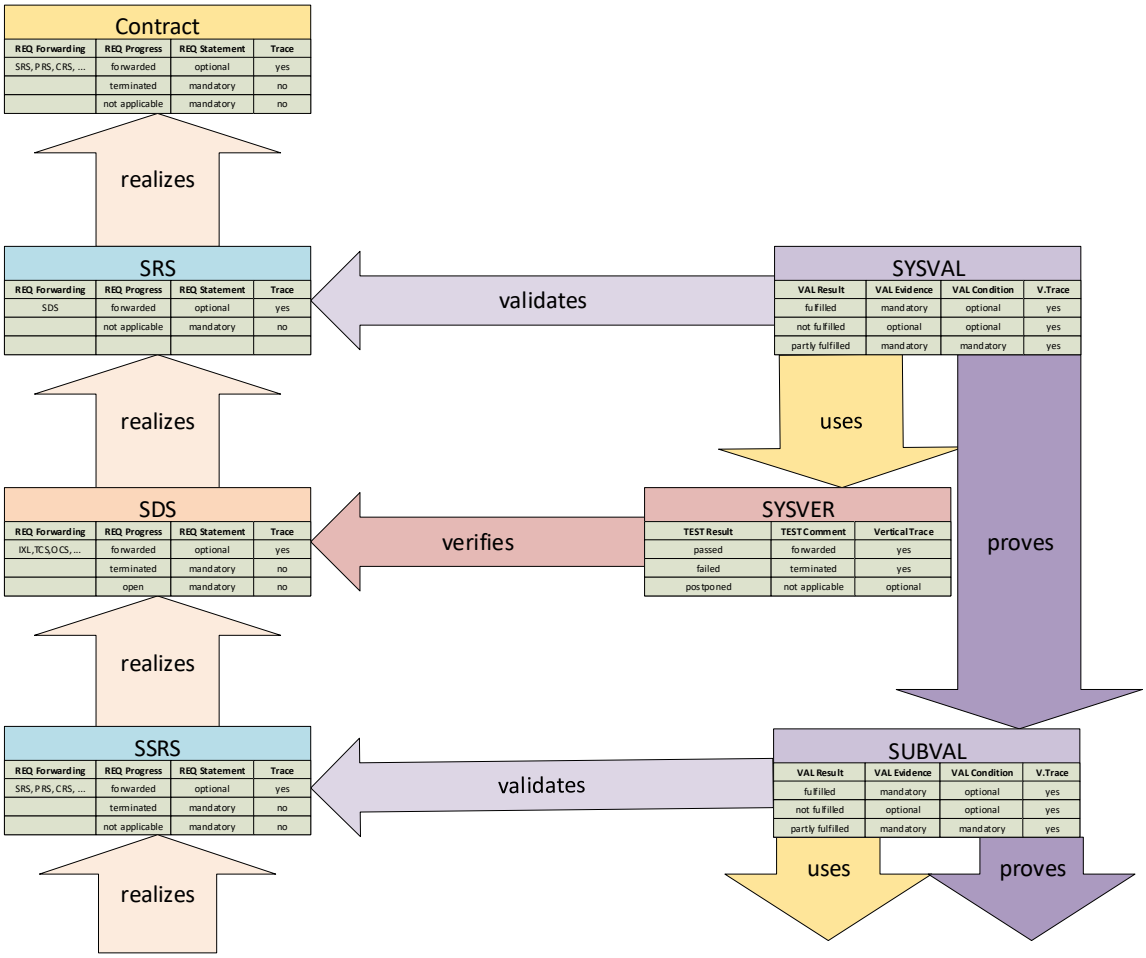

Figure 20 Traces between the Levels of the V-Model

Trace Identifier	Trace Direction	Relations	Description
realizes	RS → Contract	n:m	Coverage of customer requirements by system requirements (from SRS level)

Trace Identifier	Trace Direction	Relations	Description
realizes	DS → RS	n:m	Assignment of design statements to requirements - valid for all existing levels (SDS → SRS, SSDS → SSRS, COMPDS → COMPRS etc.)
realizes	RS → DS	n:m	Assignment of requirements from a lower level to the previous design level - valid for all existing main levels (SSRS → SDS, COMPRS → SSDS etc.)
verifies	VER → DS	n:m	Coverage of design statements by verification statements and/or test cases - valid for all existing levels (SYSVER → SDS, SUBVER → SSDS, COMPVER → COMPDS etc.)
validates	VAL → RS	1:1	Coverage of requirements by validation results - valid for all existing level combinations (SYSVAL → SRS, SUB-VAL → SSRS, COMPVAL → COMPRS etc.)
uses	VAL → VER	n:m	Evidence relation from a validation statement to verification statements and/or test cases - valid for all existing levels (SYSVAL → SYSVER, SUB-VAL → SUBVER, COMPVAL → COMPVER etc.)
proves	VAL → VAL	n:m	Evidence relation from a validation result to validation results of the subordinated level - valid for all existing main levels (SYSVAL → SUBVAL, SUBVAL → COMPVAL etc.)
42_reference_of	DS → AR	1:1	Reference to a source module with the application rules for the product version used

Table 6 Predefined Trace Identifier in RM@MM Projects

In addition to customer requirements, all application rules (safety-related and non safety-related) have to be processed in the project execution phase according to section 6.3. The proceeding of elicitation and managing of application rules is described in [RM Manual Application Rules]. The trace definition 42_reference_of is a cross-project link to the central storage containing the defined application rules.

8 RM Controlling and Metrics

Due to the duration and complexity of a project, it is necessary to closely monitor the progress of RM activities. In order to document the current RM status of a project, it is necessary to pass the Q-gates along the project execution. The customer may also request the current RM status of projects.

8.1 RM Controlling

The RMiP is responsible for monitoring RM progress during project execution. This also ensures the timely detection of delays or incorrect RM processing. The PM is overall responsible for the accomplishment of all RM and RE tasks (which can of course be delegated to project team members) during the project.

The information to be monitored shall include at least:

- number of objects and requirements captured (total / per assigned subsystem)
- levels and traces
- unprocessed/open requirements (missing test results, requirements verification statements)
- validation status
- status of the safety-related requirements

8.2 RM Status Report

A standard RM report is available (see [RM Report Template], Figure 20) that provides an overview of the entire RM status of the project. If necessary, this report can be extended with project specific metrics required to manage the project properly.

The RMiP is responsible for providing this report to the project and the corresponding recipients.

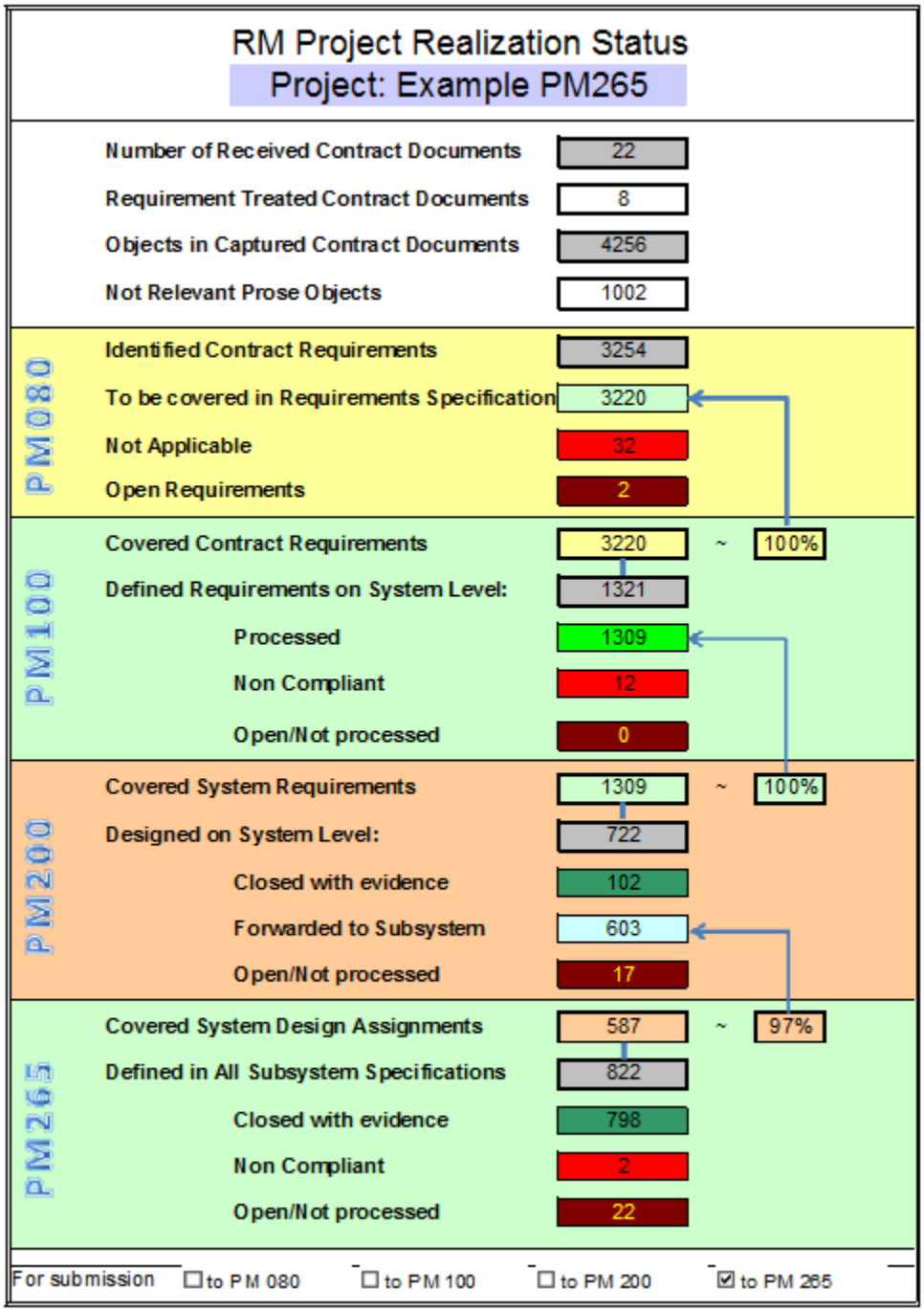

Figure 21 Standard Project RM Report

8.3 Q-Gates Reporting

As an additional controlling instrument for the appropriate processing of requirements and to check the quality of their management, a set of PM-milestone specific results with a focus on requirements management must be available and approved. These results are listed in the appendix [MM_Milestone_Results] and linked from the main QM milestone question lists.

8.4 Monitoring the Tracing Relations

Given the complexity of a typical project, it is necessary to use an RM tool to manage and monitor requirements and their tracing relationships.

The surveillance of the tracing relations (see Section 2.3) depends on how the requirements are handled, e.g. changing requirement information. Because the base documents can be changed outside the requirements management tool, the management tool must reflect these changes when a requirement text (like any other attribute) is changed. At the latest before the first processing of the requirement within the tool (e.g. for reporting) after the change, this change must be communicated to the RMiP. Especially before starting an analysis for the project, a baseline must be defined and all documents with requirements must be under control of the requirements management tool. With regard to the project milestones, a consistent status of the documents can be defined as the basis for the requirements tracking process. With regard to these baselines, snapshots of the tracing status are possible.

The surveillance applies only to the requirement-related information. Changes to other parts of the document do not need to be reported through the requirements management tool. However, if there are changes to a requirement text, those changes affect all related relationships to and from the requirement because the information in the requirement may no longer match the existing related relationships. Therefore, these relations must be checked and, if necessary, marked as suspect before they can be considered valid and used in reports.

The requirements management tool must support the user in recognizing all changes and clearly displaying the links of all requirements. The links can be displayed using matrices or trees. The status (suspect, not suspect) of each link shall be recognizable in an easy way. Further states of the requirements should be visible and editable in lists. In these lists all attributes should be visible at a glance and an attribute of all or a group of requirements should be adjustable in one step.

A view definition within the requirements management tool must enable user-specific views of requirements and their tracing relations. Especially for validation using the aggregation of requirement results must be possible to summarize the information and export it to defined documents (ideally using the project document template).

Advanced surveillance can be performed by an automatic query tool that collects all query results and documents the results in a report. Depending on the functionality of the requirements management system used, such a query tool must be adapted to the project environment. The reported data could be prepared as shown in following example:

Level	Category	Quantity	thereof **not applicable/ in discussion**	thereof **not compliant/ not available/closed/ open/forwarded**	thereof **Non-Functional**	Trace-To	No Trace-To	Trace-From	No Trace-From	**open Trace without open/closed**
CONTRACT	Belgian Border	11	./.	./.	./.	11	0	./.	./.	./.
	Entrance HSLZ	98	./.	./.	./.	92	6	./.	./.	./.
	ETCS L1	5	./.	./.	./.	4	1	./.	./.	./.
	ETCS L2	27	./.	./.	./.	2	25	./.	./.	./.
	Exit HSLZ	35	./.	./.	./.	34	1	./.	./.	./.
	Failure Scenarios	12	./.	./.	./.	8	4	./.	./.	./.
	Maintenance Yard	28	./.	./.	./.	28	0	./.	./.	./.
	Power Control	12	./.	./.	./.	11	1	./.	./.	./.
	Sign.Principles	20	./.	./.	./.	20	0	./.	./.	./.
	Staff Protection	78	./.	./.	./.	77	1	./.	./.	./.
	Suitability Check	9	./.	./.	./.	9	0	./.	./.	./.
	TSR	28	./.	./.	./.	0	28	./.	./.	./.
	Tunnel Operation	51	./.	./.	./.	50	1	./.	./.	./.
Total	**414**	**414**	0	0	0	346	68	0	0	0
SRS	RCM	299	0	13	./.	286	13	./.	./.	0
	IRS	277	0	0	./.	277	0	./.	./.	0
	FRS	1020	364	0	./.	656	364	282	738	0
	EPC (MR,SN,SR)	34	0	7	./.	34	0	./.	./.	0
	Additional	37	0	0	./.	37	0	./.	./.	0
Total	**1667**	**1667**	364	20	0	1290	377	282	738	0
SDS	RCM	286	4	43	32	239	47	286	0	0
	IRS	277	14	52	33	211	66	277	0	0
	FRS	656	0	193	201	463	193	656	0	0
	EPC (MR,SN,SR)	34	0	15	8	19	15	34	0	0
	Additional	37	0	2	0	35	2	37	0	0
	SIMIS-W	817	325	19	0	473	344	./.	./.	0
	SAC	423	5	323	0	95	328	./.	./.	0
Total	**2530**	**2530**	348	647	274	1535	995	1290	0	0
SSRS	RP	1324	0	0	./.	1324	0	1324	0	0
	TP L1	202	0	0	./.	201	1	202	0	1
	PS	87	0	0	./.	87	0	87	0	0
	TP L2	337	0	337	./.	0	337	337	0	0
Total	**1950**	**1950**	0	337	0	1612	338	1950	0	1
SSDS	RP	1324	43	354	0	927	397	1324	0	0
	TP L1	201	0	34	0	167	34	201	0	0
	PS	91	0	91	91	0	91	91	0	0
	IF IL AEM	30	0	1	1	29	1	30	0	0
	IF Barendrecht	35	0	6	6	29	6	35	0	0
	TDD RAS	99	0	46	46	53	46	99	0	0
	IDD NMBS	36	0	14	14	22	14	36	0	0
Total	**1816**	**1816**	43	546	158	1227	589	1816	0	0
SWRS	HW	1191	0	23	./.	1168	23	1191	0	0
	SW	1147	0	108	./.	1031	116	1147	0	8
Total	**2338**	**2338**	0	131	0	2199	139	2338	0	8
KOMPRS	RS Logik	193	1	4	./.	0	193	161	32	188
	RS Logik System	58	0	0	./.	0	58	0	58	58
	RS ETCS L1	124	0	124	./.	0	124	77	47	0
	RS SuD / MMI	61	0	61	./.	0	61	58	3	0
	RS PIA	86	0	86	./.	0	86	86	0	0
	RS IL System Basis	149	1	148	./.	0	149	149	0	0
	RS Proj. RP	81	11	70	./.	0	81	81	0	0
	RS Axle Counter	85	0	85	./.	0	85	85	0	0
	RS Block IF	67	0	67	./.	0	67	67	0	0
	RS Cables	23	1	22	./.	0	23	23	0	0
	RS El. Housing	23	0	23	./.	0	23	23	0	0
	RS HW L1/L2	60	0	60	./.	0	60	60	0	0
	RS HW Route Prot.	150	0	150	./.	0	150	150	0	0
	RS Point Equipment	83	1	82	./.	0	83	83	0	0
	RS Signal	159	0	159	./.	0	159	159	0	0
	RS SMB	33	0	33	./.	0	33	33	0	0
	RS TTI	10	0	10	./.	0	10	10	0	0
	RS WZ KEY	29	0	29	./.	0	29	29	0	0
Total	**1474**	**1474**	15	1213	0	0	1474	1334	140	246

Figure 22 Example of a Tracing Report

The reports address the following issues:

- How many requirements are there at which level and for which section?
- What is the number of forwarded requirements?
- What is the status of the defined requirements?
- Where are wrong traces set in the tracing structure?
- Are the apportionments correct?
- How many requirements are defined in total?

- Where are not processed requirements?
- What has changed since the last query?

9 Specifications for Baselines

A project or release baseline freezes the current status of the requirements of a project with their respective attributes and contains the defined status of all RM-relevant documents, which are stored in their own module baselines and then officially released as documents after an export. Project baselines are usually created or assigned depending on the respective system or subsystem releases, which includes viewing the links between different documents. In addition, the baseline allows you to retrieve the complete RM status including all document versions (requirement sources) of the respective baseline.

Each baseline relevant to the project must be archived as an (exported) document in the Document Management System (e.g. SAP) in accordance with the standard archiving rules for contract-relevant/legally relevant documents.

There are two cases where a baseline is mandatory:

- In the context of a document export (from the RM tool) e.g. SRS, DS, RS Statement, excerpts for external suppliers, etc.
- Before content changes (see Change Management, section 10) are made to released documents, e.g. input documents (new versions), system changes, (S)RS or (S)DS changes, etc., the RM data (within the RM tool) is taken into account.

For example, a baseline must be created for PM100 or when the SRS of the project is released for the first time. Also with the PM200, after the release of the SSDSs, a baseline of requirements, design statements and all associated attributes is mandatory. When using an RM system, a uniform procedure for baseline creation must be defined.

10 Change Management

Change management affects changes to released documents. The RM process deals with the results of change management. Change management as such is described in the CM process (see [CM Process]). The RMiP must be informed of the released changes by the Change Manager/Project Management if requirements are affected.

The tasks of RM (performed by RMiP) in connection with changes are:

- Identification of all affected requirements at all levels
- Drawing a baseline before updating (mandatory)
- Update all affected requirements with the new content
- Notification of the responsible SMiP/SEiP of the changes that have occurred

The SMiP/SEiP must re-evaluate and re-elaborate the new/changed requirements according to the RM process described in this document. The detailed RM-related procedures shall be described in the project-specific RM plan.

11 Appendix Documents

The documents listed below are available as attachments (see [Manual Appendices]) to this manual.

Document / Reference	Content
[MO_MM_RM_Checklist.xls]	Workflow and Checklist
[MO_MM_Decision_Variants.pdf]	Decision tree for selecting an RM variant

Table 7 Attached Documents

SIEMENS

12 Lists

12.1 List of figures

12.2 List of tables