




ERJU SYSTEM PILLAR

System Requirements Specification_TCCS - Part 2 Configuration Repository (SERA Version)



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Abstract	This document defines the system requirements for the Configuration Repository used in the management and distribution of BuildingBlockConfiguration (BBC) artifacts within a safety-critical railway system context. It provides the specification of services, structure, and expectations required to support secure, traceable, and consistent handling of configuration data across multiple levels of responsibility — including suppliers, integrators, and operators. Intended Audience: System Engineers involved in architecture, implementation, and maintenance of the repository Developers of Service Function Controllers (SFC) Engineers responsible for data preparation and configuration authoring Certification and safety engineers responsible for validation of configuration handling Integrators and operators deploying configuration updates to rail infrastructure and rolling stock Developers of Safe Configuration Authority (SCA) components This document complements the System Interface Specification REPO, and serves as the foundation for interface, validation, and testing activities related to the configuration management infrastructure. Open
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1 Preamble

1.1 Scope and intended audience

This document defines the system requirements for the Configuration Repository used in the management and distribution of BuildingBlockConfiguration (BBC) artifacts within a safety-critical railway system context. It provides the specification of services, structure, and expectations required to support secure, traceable, and consistent handling of configuration data across multiple levels of responsibility — including suppliers, integrators, and operators.

Intended Audience:

- System Engineers involved in architecture, implementation, and maintenance of the repository
- Developers of Service Function Controllers (SFC)
- Engineers responsible for data preparation and configuration authoring
- RAMS engineers responsible for validation of configuration handling
- Integrators and operators deploying configuration updates to rail infrastructure and rolling stock
- Developers of Safe Configuration Authority (SCA) components

This document complements the System Interface Specification REPO, and serves as the foundation for interface, validation, and testing activities related to the configuration management infrastructure.
[SPT2TS-130460]

1.2 Purpose

This specification defines the system-level functional and non-functional requirements for the Configuration Repository, covering its capabilities to store, retrieve, and structure safety-relevant and non-safety-relevant configuration artifacts. The repository is part of a distributed configuration management solution, aligned with EN 50126-1:2017 (CLC/TC 9X WI 50126-1) — Railway applications — The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) — Part 1: Generic RAMS process — system lifecycle phase 4 (System Requirements).

It is an authoritative source of configuration data for:

- The Data Preparation phase (suppliers and integrators)
- The Service Function Configuration (SFC) process
- The Safe Configuration Authority (SCA) through protected artifact access

This specification outlines the core system characteristics required to ensure integrity, traceability, cryptographic validation, and seamless integration into hierarchical dependency-based configuration workflows.

[SPT2TS-131252]

1.3 Glossary

1.3.1 General abbreviations

Abbreviation	Definition
REST	Representational State Transfer
BBC	BuildingBlockConfiguration
JWT	JSON Web Token
JSON	JavaScript Object Notation
SFC	Service Function Configuration
SCA	Safe Configuration Authority
MCSC	Manufacturer Config Signer Certificate
OCSC	Operator Config Signer Certificate
PKI	Public Key Infrastructure

1.3.2 Document-specific abbreviations

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1.3.3 Term definition

Term	Definition
Configuration Repository	A REST-based system for immutable storage and structured retrieval of BBC artifacts.
Dependency Tree	A directed acyclic graph formed by nested references to dependent BuildingBlockConfigurations.
Canonical JSON	Deterministic JSON serialization (e.g., RFC 8785) required for hash reproducibility and signing.

Term	Definition
Payload	Optional binary file associated with a configuration (e.g., firmware, parameter package).
Public Key Reference	kid and x5u JWT fields referencing the certificate containing the public key used for signature validation. The certificate chain is managed and published via the Shared Security Services PKI. Signature validation itself is performed locally on each device using the public key from the supplied certificate, after verifying the chain up to a known and trusted root CA.

2 Assumptions and dependencies

The Configuration Repository is not responsible for validating payload contents beyond hash consistency. Signing, versioning, and dependency correctness are the responsibility of the data preparation entity (supplier/integrator).

The Service Function Configuration (SFC) reads configurations and verifies signatures before use.

The Public Key Infrastructure (PKI) is managed externally via the Shared Security Services platform. [SPT2TS-131253]

3 Constraints

SPT2TS-131254 - Immutability: Once written, configurations cannot be changed or deleted (WRITE-ONCE, READ-MANY).

Hierarchical Structuring: The repository shall follow a dot-separated path logic derived from bbld, bbld, and bbcVersion.

No Runtime Configuration: The repository does not support partial updates or state transitions — only full artifact submissions.

No Signing or Validation at Storage: Validation is performed externally. The repository only persists artifacts.

HTTPS-only Access: All operations must occur via secure transport (TLS).

4 System overview

The Shared Service Repository is a REST-based system designed to manage and expose BBC artifacts to authenticated users and systems across the railway configuration ecosystem.

It enables:

- Suppliers and integrators to publish configurations as structured, signed, immutable artifacts
- SFCs and SCAs to discover and retrieve verified and cryptographically signed configuration sets
- Trust enforcement by referencing public key material hosted in a centralized Shared PK


[SPT2TS-131255]

4.1 System context

see  SPT2TS-129006 - System context [SPT2TS-130256]

4.2 System interfaces

4.2.1 REPO

see  SPT2TS-129685 - System Interface Description_TCCS-System Interface REPO (SERA Version) [SPT2TS-130257]

4.3 System modes and states

The configuration repository has a simplified operational model:

Mode	Description
BOOT	System starts and initializes base services
IDLE	Awaiting storage or retrieval requests
WRITE	Artifacts for one BBC are being written (atomic transaction)
READ	Artifact is being retrieved or validated
ERROR	System has encountered a blocking fault

State transitions are linear and deterministic, e.g., BOOT → IDLE → WRITE/READ → IDLE. There is no operational runtime logic; validation, signing, and activation occur externally.

5 System requirements

Define functional and non-functional requirements applicable to system following SPPROCESS/SEMP Annex R Requirements/SEMP Annex R3 - Rules for writing textual requirements : 723841.

5.1 Non-functional requirements

5.1.1 Performance and Scalability

SPT2TS-129523 - High Availability: The System shall remain available with minimal downtime.

ToDo: add SMART requirements

SPT2TS-130251 - Low Latency: BBC retrieval and dependency resolution should be fast, even for large projects.

ToDo: add SMART requirements

SPT2TS-130252 - Horizontal & Vertical Scalability: Must support increasing numbers of BBCs and concurrent requests.

ToDo: add SMART requirements

5.1.2 Security and Access Control

SPT2TS-131434 - System Pillar Cybersecurity: Secure Component Specification V1.0 (SPPRAMSS-1473)

SPT2TS-131435 - System Pillar Cybersecurity: Secure Communication Specification V1.0 (SPPRAMSS-1482)

SPT2TS-131436 - System Pillar Cybersecurity: Secure Shared Service Specification V1.0 (SPPRAMSS-1495)

ToDo: Align and complete the security requirements with the System Pillar Cybersecurity Specifications V1.0. The following topics shall be considered:

- Authentication & Authorization: Role-based access control (RBAC) in combination with the IAM shared service is used to restrict who can upload, modify, or delete artifacts.
- Encryption & Secure Communication: Data in transit (e.g., HTTPS, TLS) and at rest is encrypted.
- Integrity & Trust Management: The BBC artifacts (payload, configuration.json and configurationSafe.json) are signed and verified to prevent tampering.
- Audit Logging: The REPO maintains logs of repository access, uploads, and downloads for compliance tracking.

[SPT2TS-130245]

5.1.3 RAMS

SPT2TS-131256 - *ToDo: SMART RAMS requirements*

5.2 Functional requirements

5.2.1 Storage and Retrieval Functions

The Configuration Repository provides a versioned, immutable, and structured storage and access system for all artifacts related to a **BuildingBlockConfiguration (BBC)**. It supports authorized PUT and POST operations over HTTPS via a REST API. This interface is used by the **Data Preparation** processes for uploading content, and by the **Service Function Configuration (SFC)** for retrieving BBCs and their dependencies during configuration orchestration.

SPT2TS-129521 - BBC Artifacts Storage

Each **BBC version** is stored in its own uniquely addressable directory or repository path based on its identifiers (bbld.bbclid.bbcVersion). The repository must contain the following files for each configuration version:

file	description	isMandatory
configuration.json	The primary configuration descriptor. Contains metadata, dependencies, and optional payload references. Used by the non-safe SFC to orchestrate distribution trees. See [SPT2TS-125852].	yes
configurationSafe.jwt	The signed and encrypted version of the configurationSafe.json. Used only for SAFE (safety related and SIL1-4) configurations and consumed exclusively by the Safe Configuration Authority (SCA). Shall not be sent to the Diagnosable BuildingBlock.	for safe BBC only
<payload filename>	The transparent or non transparent payload file (e.g., firmware, parameter set). The filename is explicitly specified in configuration.json → configurationFile → configurationFileName.	Optional

The public keys references in the JWT are retrieved from the PKI of the Shared Security Services Infrastructure.

SPT2TS-130243 - BBC Retrieval (GET Operation)

The Configuration Repository shall support **GET** operations via HTTPS REST endpoints. A client (e.g., the SFC) must be able to retrieve all artifacts (configuration.json, configurationSafe.jwt, payload, signature) associated with a BBC version.

Access Pattern:

GET /<bblId path>/<bbcId path>/<bbcVersion>/...

Example:

GET /de.db.io.signalgear/firmware.maincontroller/1.2.3/configuration.json

Structure Mapping:

All dots (.) in bblId, bbcId, and bbcVersion are translated into subdirectories as a hierarchical level.

SPT2TS-130244 - BBC Storage (UPLOAD)

The Configuration Repository shall support **POST** operations for uploading BBC artifacts.

Access Pattern:

POST /<bblId path>/<bbcId path>/<bbcVersion>/

Clients upload:

- configuration.json
- configurationSafe.jwt (if applicable)
- Payload(s) and .sig
- Referenced public key (e.g., ocsc-operator2025.pub.pem)

Immutability Rule: Once a BBC version is created, it is immutable. Updates or deletions of any file or folder are not allowed. New versions must be created by incrementing the bbcVersion according to Semantic Versioning (e.g., from 1.0.0 to 1.0.1).

SPT2TS-130242 - BBC Hierarcharchical Structure

The Configuration Repository organizes BBC artifacts in a hierarchical structure based on the values of bblId, bbcId, and bbcVersion. Each "." (dot) in these identifiers is replaced by a directory level to create a structured file path. The bbcVersion is always the final level.

SPT2TS-130459 - Security and Trust Anchoring

- The Configuration Repository TLS endpoint shall implement the requirements from SP-SEC-CommSpec Chapter 5 - Secure Communication for HTTP (**SPPRAMSS-8269**)
- Access authorization shall be based on roles with the either permission "eu.rail.config-repo.datapreparation" or "eu.rail.config-repo.configuration"
- Integrity and authenticity of signatures shall be checked using the corresponding trusted signing key

SPT2TS-131257 - *ToDo: Depreciation of a Configuration*

Deprecation of configurations can be handled in multiple ways (subject to ongoing discussion):

1. Centralized blacklist — Maintain a centralized blacklist containing all Building Block Configurations (BBCs) identified as having safety issues.
 - a. The blacklist shall be checked before applying any configuration updates.
 - b. For offline operation, a lease time for the locally cached blacklist may be used to ensure timely re-validation once connectivity is restored.
2. Certificate revocation — Revoke the certificate(s) associated with unsafe configurations via the Shared Security Services PKI to prevent further trust in those configurations.

5.2.2 Logging, Monitoring and Auditing

SPT2TS-129533 - Access Auditing

All access to BBC artifacts (uploads and downloads) shall be logged. Each action must include the following metadata:

- User identity or system identifier
- Timestamp (UTC, date and time)

- Type of action (READ, UPLOAD, VERIFY, etc.)
- Affected BBC (bbld.bbcld.bbcVersion)
- IP address or technical origin

SPT2TS-129534 - Configuration Repository Monitoring

The configuration repository system shall provide real-time metrics to monitor operational health and performance, including:

- Number of accesses (per time unit, categorized by API endpoint)
- Response times of the REST API (average, median, outliers)
- Storage usage (per BBC, per directory)
- System availability (uptime/downtime)
- Error rates (e.g., HTTP 5xx responses, timeouts, validation failures)

All metrics shall be exposed via standardized interfaces (**Prometheus exporter?**) for integration into central monitoring dashboards.




5.2.3 API and Interface Functions




SPT2TS-129538 - Expose REST API for BBC Management




- Upload, retrieve, delete, and query BBCs via API.
- Resolve dependencies programmatically.




5.3 Application Conditions on Data Preparation System



5.3.1 Configuration Data Package conditions



SPT2TS-130991 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5062 - European Trackside Protection System as per the structure defined in  SPT2TS-130318 - ETPSConfigurationData.



SPT2TS-130992 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5058 - Automatic Train Operation Trackside as per the structure defined in  SPT2TS-130997 - {



SPT2TS-130999 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5060 - Plan Execution System as per the structure defined in  SPT2TS-131186 - PlanExecutionConfigurationData



SPT2TS-131000 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5111 - Traffic Management System as per the structure defined in  SPT2TS-131188 - TrafficManagementSystemConfigurationData .

SPT2TS-131041 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5068 - Subsystem - Point as per the structure defined in (Placeholder) .



SPT2TS-131042 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5066 - Subsystem - Level Crossing as per the structure defined in (Placeholder) .

SPT2TS-131037 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5070 - Subsystem - Train Detection System as per the structure defined in (Placeholder) .

SPT2TS-131039 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5057 - Automatic Train Operation On-board as per the structure defined in (Placeholder) .

SPT2TS-131040 - The  SPMS-7069 - Data Preparation shall create the configuration data for  SPMS-5063 - European Train Control System On-board as per the structure defined in (Placeholder) .




5.3.2 Dependency tree conditions

SPT2TS-131105 - The  SPMS-7069 - Data Preparation shall create the dependency tree for the  SPMS-5101 - CCS System as per the structure defined in (Placeholder) .




5.3.3 Data quality conditions

5.3.3.1 INFRA

SPT2TS-130924 - TrainDetectors associated with a TvpSection shall be positioned on LinearElements that are fully covered by the TvpSection's linkedArea NetAreaReference.




Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define all</p> <ul style="list-style-type: none">  SPT2TS-125470 - TrainDetectors associated with a  SPT2TS-12698 - TvpSection on LinearElements that are fully covered by the TvpSection's linkedArea NetAreaReference. 	<p>Let :</p> <p>tvps - TvpSection td - TrainDetector ar - NetAreaReference lr - NetLinearReference le - LinearElement tc - TopologicalCoordinate</p> <p>$\forall tvps:$ $(\forall td \Rightarrow (\exists tc.tc \wedge$ $tc.onLinearElement(le) \wedge$ $\exists linkedArea(ar) \wedge ar.includes(lr)$ $isCoveredBy (le, lr)))$</p> <p>where the auxiliary predicate isCoveredBy(le, lr) ensures le is part of the lr's linear references:</p> <p>isCoveredBy(le, lr) = $(\exists lr.startsAt.onLinearElement v$ $\exists lr.endsAt.onLinearElement v$ $\exists lr.hasSequence)$</p>

SPT2TS-130928 - The hasSequence of a NetLinearReference shall be empty if its startsAt and endsAt topological coordinates reference the same LinearElement.




Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall ensure that if a  SPT2TS-125513 - NetLinearReference (LinkedPath)s startsAt and endsAt topological coordinates reference the same  SPT2TS-49005 - LinearElement , then its hasSequence must be empty/undefined (no intermediate LinearElements).</p>	<p>Let :</p> <p>le - LinearElement lr - NetLinearReference tc - TopologicalCoordinate</p>

Application Condition	Rule Formalisation
	$\forall lr:$ $(\exists(\text{startsAt}(tc_1) \wedge \text{endsAt}(tc_2)) \wedge tc_1.le \wedge tc_2.le \Rightarrow \neg \exists \text{hasSequence}(le_n))$

SPT2TS-130930 - The LinearElements referenced by a NetLinearReference's startsAt and endsAt topological coordinates shall not appear in its hasSequence list.




Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall ensure that</p> <p> SPT2TS-49005 - LinearElements referenced by a</p> <p> SPT2TS-125513 - NetLinearReference (LinkedPath)s startsAt and endsAt topological coordinates does not appear in its hasSequence list.</p>	<p>Let :</p> <p>le - LinearElement</p> <p>lr - NetLinearReference</p> <p>tc - TopologicalCoordinate</p> <p>startsAt(lr,tc_s): lr starts at tc_s.</p> <p>endsAt(lr,tc_e): lr ends at tc_e.</p> <p>onLinearElement(tc,le): tc lies on le.</p> <p>hasSequence(lr le): le is in sequence of lr.</p> <p>$\forall lr:$</p> <p>$(\exists tc_s, tc_e, le_s, le_e \text{ startsAt}(lr, tc_s) \wedge \text{endsAt}(lr, tc_e) \wedge \text{onLinearElement}(tc_s, le_s) \wedge \text{onLinearElement}(tc_e, le_e) \Rightarrow (\neg \text{hasSequence}(lr, le_s) \wedge \neg \text{hasSequence}(lr, le_e)))$</p>

SPT2TS-130927 - For every NetRelation, the referenced elementA and elementB shall be distinct LinearElements.



Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall ensure that referenced</p> <p> SPT2TS-49005 - LinearElement in a  SPT2TS-125424 - NetRelations</p>	<p>Let :</p> <p>le - LinearElement</p> <p>nr - NetRelation</p>

Application Condition	Rule Formalisation
elementA and elementB are distinct. (That is, NetRelation cannot connect a LinearElement to itself)	$\forall nr:$ $(\exists le1, le2 \text{ (elementA}(le1) \wedge \text{elementB}(le2) \wedge (le1 \neq le2)))$



SPT2TS-130926 - Every LinearElement shall exist in at least one NetRelation, either as elementA or elementB.

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall ensure that every defined  SPT2TS-49005 - LinearElement exists in at least one  SPT2TS-125424 - NetRelation (either as elementA or elementB).	<p>Let :</p> <p>le - LinearElement nr - NetRelation</p> <p>$\forall le:$ $(\exists nr(\text{elementA}(le) \vee \text{elementB}(le)))$</p>



SPT2TS-130925 - All StopLocations associated with a PlatformEdge shall be positioned on LinearElements that are fully covered by the PlatformEdge's linearReference.

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define the stopLocations associated with  SPT2TS-49092 - PlatformEdge on corresponding linear element that are fully covered by the PlatformEdge's linearReference.	<p>Let :</p> <p>pe - PlatformEdge sl - StopLocation lr - NetLinearReference le - LinearElement npr - NetPointReference tc - TopologicalCoordinate</p> <p>$\forall pe:$ $\forall pe.sl \Rightarrow$ $(\exists sl.npr(\text{NetPointReference}) \wedge$ $npr.tc \wedge$ $tc.le \wedge \exists pe.lr \wedge \text{isCoveredBy}(le, lr))$</p> <p>where the auxiliary predicate isCoveredBy(le, lr) ensures le is part of the lr's linear references:</p> <p>isCoveredBy(le, lr) = $(\exists lr.startsAt.onLinearElement \vee$ $\exists lr.endsAt.onLinearElement \vee$ $\exists lr.hasSequence)$</p>


SPT2TS-125777 - No two distinct derailleurs may be declared at the exact same position in the network, regardless of their orientation.

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define only a single instance of  SPT2TS-125451 - Derailler at a specific position on a linear element.	<p>Let:</p> <p>d - Derailler, npr - NetPointReference, tc - TopologicalCoordinate, le - LinearElement</p> <p>$\forall d_1, d_2 :$ $($ $(d_1 \neq d_2) \wedge$ $(d_1.netPointReference =$ $npr_1) \wedge$ $(d_2.netPointReference =$ $npr_2) \wedge$ $(npr_1.hasTopoCoordinate =$ $tc_1) \wedge$ $(npr_2.hasTopoCoordinate =$ $tc_2) \wedge$ $(tc_1.onLinearElement = le)$ \wedge $(tc_2.onLinearElement = le)$ $)$ \Rightarrow $($ $tc_1.offsetFromOrigin \neq$ $tc_2.offsetFromOrigin$ $)$</p>


SPT2TS-125797 - No two distinct buffer stops may be declared at the exact same position in the network



Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define only a single instance of  SPT2TS-100570 - BufferStop at a specific position on a linear element.	<p>$\forall bs_1, bs_2 \in \text{BufferStop}:$ $(bs_1 \neq bs_2) \Rightarrow$ $(bs_1.netPointReference.hasTopo$ $Coordinate.onLinearElement \neq$ $bs_2.netPointReference.hasTopoC$ $oordinate.onLinearElement \vee$ $bs_1.netPointReference.hasTopoC$ $oordinate.offsetFromOrigin \neq$ $bs_2.netPointReference.hasTopoC$ $oordinate.offsetFromOrigin)$</p>



SPT2TS-125800 - At a specific position on a linear element, only a single instance of balise shall be present.




Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define only a single instance of balise at a specific position on a linear element.	<p>$\forall bg \in \text{BaliseGroup}:$ $\forall b_1, b_2 \in bg.balises:$ $(b_1 \neq b_2) \Rightarrow$ $(b_1.topologicalCoordinate.onLi$ $nearElement \neq$</p>

Application Condition	Rule Formalisation
	$b_2.topologicalCoordinate.onLinearElement \vee$ $b_1.topologicalCoordinate.offsetFromOrigin \neq$ $b_2.topologicalCoordinate.offsetFromOrigin)$



SPT2TS-125788 - The  SPT2TS-125471 - BaliseGroup shall have unique Balise Group NIDs (NID_C + NID_BG) within a ETCS Country ID.


Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define the  SPT2TS-125471 - BaliseGroup with a unique Balise Group NIDs (NID_C + NID_BG) within a ETCS Country ID.	$\forall bg1: BaliseGroup:$ $\forall bg2: BaliseGroup:$ $(bg1 \neq bg2 \wedge bg1.nid_c = bg2.nid_c) \Rightarrow$ $(bg1.nid_bg \neq bg2.nid_bg)$



SPT2TS-125789 - A  SPT2TS-125450 - SlipCrossing shall not contain 3 instances of  SPT2TS-49048 - Switch (SimplePoint) .


Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall NOT define a  SPT2TS-125450 - SlipCrossing containing 3 instances of  SPT2TS-49048 - Switch (SimplePoint).	$\forall slipCrossing:$ $ $ $slipCrossing.Switches \neq 3$



SPT2TS-127316 - The extent of  SPT2TS-125449 - CantSamplePoint definition shall be congruent to the definition of horizontal arc and transition segments.

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define the extent of  SPT2TS-125449 - CantSamplePoint to be congruent to the definition of horizontal arc and transition segments.	<p>Let:</p> <p>$CantSamplePoint(c)$: c is a cant (superelevation) sample point</p> <p>$pos(x)$: Position of X along the linear element</p> <p>$slope(x)$: Gradient of X (permill, \pm for rise/fall)</p> <p> $\forall s(HorizontalArc(s) \vee HorizontalTransition(s)) \Rightarrow$ $(\exists c \wedge pos(c) = elementGeometryPos(s)) \wedge$ $(\exists c \wedge pos(c) = elementGeometryPos(s) + length(s))$ </p>

SPT2TS-127315 - The extent of  SPT2TS-125448 - SlopeSamplePoint definition shall be congruent to the definition of vertical line and vertical arc segments.




Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the extent of  SPT2TS-125448 - SlopeSamplePoint to be congruent to the definition of vertical line and vertical arc segments.</p> <p>(a) The sign of the slope at the samplePoint must be the same as that of the underlying segment at that position.</p> <p>(b) Positional Continuity: Sampled points must cover segment boundaries.</p>	<p>Let:</p> <p>SlopeSamplePoint(ssp): ssp is a slope sample point</p> <p>pos(x): Position of X along the linear element</p> <p>slope(x): Gradient of X (permill, ± for rise/fall)</p> <p>(a)</p> <p>$\forall ssp:$ $(\exists s(\text{VerticalLine}(s) \vee \text{VerticalArc}(s)) \wedge$ $(\text{pos}(ssp) \in$ $[\text{elementGeometryPos}(s),$ $\text{elementGeometryPos}(s) +$ $\text{length}(s)]) \Rightarrow$ $(\text{sign} \text{slope}(ssp) = \text{sign} \text{slope}(s,$ $\text{pos}(ssp)))$</p> <p>(b)</p> <p>$\forall s(\text{VerticalLine}(s) \vee \text{VerticalArc}(s)) \Rightarrow$ $(\exists ssp \wedge \text{pos}(ssp) =$ $\text{elementGeometryPos}(s)) \wedge$ $(\exists ssp \wedge$ $\text{pos}(ssp) = \text{elementGeometryPos}(s)$ $+ \text{length}(s))$</p>

SPT2TS-125791 - The extent of  SPT2TS-125446 - CurveSamplePoint definition shall be congruent to the definition of horizontal arc and transition segments.




Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the extent of  SPT2TS-125446 - CurveSamplePoint to be congruent to the definition of horizontal arc and transition segments.</p> <p>a. The sign of radius at the samplePoint must be the same as that of the underlying segment at that position</p> <p>b. Positional Continuity: Sampled points must not skip segment boundaries; that is, every segment start/end must have a corresponding sampled point.</p>	<p>Let</p> <p>CurveSamplePoint(c): c is a curve sample point</p> <p>pos(x): Position of entity X along the linear element</p> <p>sign(radius(x)): Sign of the Radius of curvature of X</p> <p>(a)</p> <p>$\forall c:$ $(\exists s(\text{HorizontalArc}(s) \vee \text{HorizontalTransitio}(s)) \wedge$</p>

Application Condition	Rule Formalisation
	$(\text{pos}(c) \in [\text{elementGeometryPos}(s), \text{elementGeometryPos}(s) + \text{length}(s)]) \Rightarrow (\text{sign} \text{radius}(c) = \text{sign} \text{radius}(s, \text{pos}(c)))$ <p>(b)</p> $\forall s(\text{HorizontalArc}(s) \vee \text{HorizontalTransition}(s)) \Rightarrow (\exists c \wedge \text{pos}(c) = \text{elementGeometryPos}(s)) \wedge (\exists c \wedge \text{pos}(c) = \text{elementGeometryPos}(s) + \text{length}(s))$

SPT2TS-130846 - The position (pos) of the speed limit for every StaticSpeedLimit defined in a LinearElementSpeedProfile shall not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement




Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define the position (pos) of the speed limit for every  SPT2TS-125464 - StaticSpeedLimit defined in a  SPT2TS-49086 - LinearElementSpeedProfile (TrackEdgeSpeedProfile) such that it does not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement (linked via shared id)	<p>Let :</p> <p>le - LinearElement lesp - LinearElementSpeedProfile sp - SpeedProfile ssl - StaticSpeedLimit</p> <p>$\forall \text{lesp}, \forall \text{sp}, \forall \text{ssl}:$ $(\text{lesp.id} = \text{le.id} \wedge (\text{sp} = \text{lesp.sameDirProfile} \vee \text{sp} = \text{lesp.oppositeDirProfile}) \wedge \text{ssl} \in \text{sp.staticSpeedProfile}) \Rightarrow \text{ssl.pos} \leq \text{le.lengthOfNetLinearElement}$</p>

SPT2TS-130851 - For every defined horizontal segment (line, arc, or transition curve) in a LinearElementGeometry, the position of the segment shall not exceed the length of the corresponding LinearElement

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall define the  SPT2TS-125444 - HorizontalSegment (line, arc, or transition curve) in a  SPT2TS-125443 - LinearElementGeometry such that the position of the defined segment does not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement	<p>Let :</p> <p>le - LinearElement leg - LinearElementGeometry hs - HorizontalSegment hl - HorizontalLine</p>




Application Condition	Rule Formalisation
	<p>ha - HorizontalArc ht - HorizontalTransition</p> <p>$\forall leg, \forall hs:$ $(leg.id=le.id \wedge hs \in leg.horizontalAlignments) \Rightarrow$ $((\exists hl \in hs.horizontalSegmentLine \wedge$ $hl.elementGeometryPos \leq$ $le.lengthOfNetLinearElement) \vee (\exists ha \in$ $hs.horizontalSegmentArc \wedge$ $ha.elementGeometryPos \leq le.lengthOfNetLinearElement))$</p> <p>$\vee (\exists ht \in hs.horizontalSegmentTransition \wedge$ $ht.elementGeometryPos \leq le.lengthOfNetLinearElement))$</p>

SPT2TS-130874 - For every defined vertical segment (line or arc) in a LinearElementGeometry, the position of the segment shall not exceed the length of the corresponding LinearElement






Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the  SPT2TS-125439 - VerticalSegment (line or arc) in a  SPT2TS-125443 - LinearElementGeometry such that the position of the defined segment does not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement</p>	<p>Let : le - LinearElement leg - LinearElementGeometry vs - VerticalSegment vl - VerticalLine va - VerticalArc</p> <p>$\forall leg, \forall vs:$ $(leg.id=le.id \wedge vs \in leg.verticalAlignments)$</p>

Application Condition	Rule Formalisation
	\Rightarrow $((\exists vl \in$ $vs.verticalSegmentLin$ $e \wedge$ $vl.elementGeometryPo$ $s \leq$ $le.lengthOfNetLinearEl$ $ement)$ $\vee (\exists va \in$ $vs.verticalSegmentArc$ \wedge $va.elementGeometryP$ $os \leq$ $le.lengthOfNetLinearEl$ $ement)$

SPT2TS-130875 - The position (elementGeometryPos) of every cant point defined in a LinearElementGeometry shall not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement



Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the position (elementGeometryPos) of the  SPT2TS-125442 - CantPoint in a  SPT2TS-125443 - LinearElementGeometry such that it does not exceed the length (lengthOfNetLinearElement) of the corresponding LinearElement</p>	<p>Let :</p> <p>le - LinearElement leg - LinearElementGeometry cp - CantPoint</p> <p>$\forall leg, \forall cp:$ $(leg.id=le.id \wedge cp \in leg.cantPoints) \Rightarrow$ $cp.elementGeometryPos \leq$ $le.lengthOfNetLinearEl$ $ement$</p>

SPT2TS-125785 - The position 'pos' of the CantSamplePoint, SlopeSamplePoint, and CurveSamplePoint for the defined SampleLinearElementGeometry object shall not exceed the length of the underlying linear element.



Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the 'pos' values of the  SPT2TS-125449 - CantSamplePoint ,  SPT2TS-125448 - SlopeSamplePoint , and  SPT2TS-125446 - CurveSamplePoint for the defined  SPT2TS-125447 -</p>	<p>\forall object: {LinearElement}: $object.pos \leq$ $object.linearElement.lengthOfNetLinearElement$</p>

Application Condition	Rule Formalisation
SampledLinearElementGeometry object not exceeding the length of the underlying linear element.	<p>\forall CantSamplePoint: exists SampleLinearElementGeometry: CantSamplePoint \in SampleLinearElementGeometry.cants \wedge CantSamplePoint.pos \leq LinearElement[SampleLinearElementGeometry.id].lengthOfNetLinearElement</p> <p>\forall SlopeSamplePoint: exists SampleLinearElementGeometry: SlopeSamplePoint \in SampleLinearElementGeometry.slopes \wedge SlopeSamplePoint.pos \leq LinearElement[SampleLinearElementGeometry.id].lengthOfNetLinearElement</p> <p>\forall CurveSamplePoint: exists SampleLinearElementGeometry: CurveSamplePoint \in SampleLinearElementGeometry.curves \wedge CurveSamplePoint.pos \leq LinearElement[SampleLinearElementGeometry.id].lengthOfNetLinearElement</p>



SPT2TS-125869 - For each LinearElementSection, the 'startOffsetFromOrigin' value shall not be greater than 'endOffsetFromOrigin' value.

Application Condition	Rule Formalisation
The  SPMS-7069 - Data Preparation shall NOT define the  SPT2TS-131398 - LinearElementSections such that 'startOffsetFromOrigin' value greater than 'endOffsetFromOrigin' value.	<p>\forall linearElementSection LES: LES.endOffsetFromOrigin \geq LES.startOffsetFromOrigin</p>



SPT2TS-125783 - A LinearElementSection shall always be limited within a LinearElement. i.e., LinearElementSection do not span over multiple linearElements.

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall always define</p> <p> SPT2TS-131398 - LinearElementSection to be limited within a linear element i.e., linear element sections do not span over multiple linear elements.</p>	$\forall \text{ linearElementSection LES:}$ $\text{LES.startOffsetFromOrigin} \geq 0$ \wedge $\text{LES.endOffsetFromOrigin} \geq 0$ \wedge $\text{LES.endOffsetFromOrigin} \leq \text{LinearElement.length}$



SPT2TS-130788 - There shall be no netRelations defined between linear elements marked by a Switch as leftBranch and rightBranch .

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define NO NetRelation between LinearElement marked by a</p> <p> SPT2TS-49048 - Switch (SimplePoint) as leftBranch and rightBranch.</p> <p>Note: LinearElement are not explicitly marked as leftBranch, rightBranch. They have to be derived based on the NetRelation marked as leftBranch and rightBranch in a Switch (Simple Point).</p>	<p>Let :</p> <ul style="list-style-type: none"> • Switch(s) — s is a Switch • NetRelation(n) — n is a NetRelation • leftBranch(s, n₁) and rightBranch(s, n₂) — n₁ and n₂ are NetRelations connected to s • Pairs(n) = { (a, oa), (b, ob) } where: <ul style="list-style-type: none"> a = elementA(n), b = elementB(n) oa = isOnOriginOfElementA(n), ob = isOnOriginOfElementB(n) <p>Then:</p> <p>If</p> $\text{Switch}(s) \wedge \text{leftBranch}(s, n_1) \wedge \text{rightBranch}(s, n_2) \wedge n_1 \neq n_2$ <p>And let:</p> $P_1 = \text{Pairs}(n_1); P_2 = \text{Pairs}(n_2)$ $\text{Shared} = P_1 \cap P_2$ $\text{Exclusive} = (P_1 \cup P_2) \setminus \text{Shared}$ $\forall n \in \text{NetRelation}, \forall p_1, p_2 \in \text{Exclusive:}$ $p_1 \neq p_2 \Rightarrow \neg(p_1 \in \text{Pairs}(n) \wedge p_2 \in \text{Pairs}(n))$

SPT2TS-130787 - There shall be exactly 3 unique (LinearElement, isOnOrigin) flag pairs for every Switch

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define each  SPT2TS-49048 - Switch (SimplePoint) such that the combined set of (element, isOnOrigin) pairs from its associated leftBranch and rightBranch objects contains exactly three unique pairs.</p> <p>NT: LinearElement are not explicitly indicated on Switch object: Therefore, for every Switch, retrieve all associated leftBranch (pointLeft) and rightBranch (pointRight) objects. Each of these links to two elements: elementA and elementB, each associated with a boolean flag (isOnOriginOfElementA, isOnOriginOfElementB). Combine these four (element, flag) pairs. A Switch is valid if and only if the number of unique (element, flag) pairs is exactly 3.</p>	<p>Let:</p> <ul style="list-style-type: none"> • S be the set of all Switch instances. • For each switch $s \in S$, define: $LB(s)$ = set of leftBranch objects of s. $RB(s)$ = set of rightBranch objects of s. For each netRelation $nr \in LB(s) \cup RB(s)$: $elementA(nr) \in ElementID$ $isOnOriginOfElementA(nr) \in Bool$ $elementB(nr) \in ElementID$ $isOnOriginOfElementB(nr) \in Bool$ <p>Then, combined element-flag set for switch s is defined as: $EF(s) = \{ (elementA(nr), isOnOriginOfA(nr)) \mid nr \in LB(s) \cup RB(s) \} \cup \{ (elementB(nr), isOnOriginOfB(nr)) \mid nr \in LB(s) \cup RB(s) \}$</p> <p>A switch s is valid iff $EF(s) = 3$</p> <p>$\forall s \in S,$ $ValidSwitch(s) \Leftrightarrow EF(s) = 3$</p>



SPT2TS-130995 - Every axle load speed profile defined in either direction of a track section shall be congruent with the corresponding linear element.

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall ensure that for every  SPT2TS-125462 - AxleLoadSpeedProfile defined in either direction</p>	<p>Let:</p> <p>lesp - LinearElementSpeedProfile le - LinearElement sp - SpeedProfile</p>



Application Condition	Rule Formalisation
<p>of a track section:</p> <ul style="list-style-type: none"> The profile's start and end positions must not exceed the track length The start position must come before the end position" 	<p>alsp - AxleLoadSpeedProfile</p> <p>$\forall \text{lesp}:$</p> <p>((lesp.id = le.id) \wedge (sp = lesp.sameDirProfile) \vee (sp = lesp.oppositeDirProfile)) \wedge (alsp \in sp.axleLoadSpeedProfiles)) \Rightarrow ((alsp.startPos \leq le.lengthOfNetLinearElement) \wedge (alsp.endPos \leq le.lengthOfNetLinearElement) \wedge (alsp.startPos \leq alsp.endPos))</p>

5.3.4 ENG



SPT2TS-125958 - The position (pos) of every kilometric post in a LinearElementKm shall not exceed the length of the corresponding LinearElement.

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the position (pos) of every  SPT2TS-125615 - KilometricPost in a LinearElementKm such that it does not exceed the length of the corresponding LinearElement</p>	<p>Let :</p> <p>le - LinearElement lek - LinearElementKm kp - KilometricPost</p> <p>$\forall \text{lek}, \forall \text{kp} (\text{lek.linearElement} = \text{le} \wedge$ $\text{kp} \in \text{lek.kilometricPosts}) \Rightarrow \text{kp.pos}$ $\leq \text{le.lengthOfNetLinearElement}$</p>

SPT2TS-130878 - For every Level Crossings, the danger points shall be congruent with the corresponding areaReference



Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define the extent of  SPT2TS-122277 - DangerPoint that correspond to the level crossing's area reference(s)</p>	<p>Let :</p> <p>lc - LevelCrossing dp - DangerPoint ar - NetAreaReference lr - NetLinearReference le - LinearElement tc - TopologicalCoordinate</p> <p>$\forall lc:$ $(\forall dp \Rightarrow (\exists dp.tc \wedge tc.onLinearElement \wedge \exists ar \wedge \exists lr.includes \wedge (isCoveredBy(le, lr))))$</p> <p>where the auxiliary predicate isCoveredBy(le, lr) ensures le is part of the lr's linear references:</p> <p>isCoveredBy(le, lr) = $(\exists lr.startsAt.onLinearElement \vee \exists lr.endsAt.onLinearElement \vee \exists lr.hasSequence)$</p>

SPT2TS-130910 - All FoulingPoints associated with a Switch shall be positioned on LinearElements that are directly connected via the Switch's leftBranch or rightBranch NetRelations.

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define all  SPT2TS-124160 - FoulingPoints associated with a Switch on LinearElements that are directly connected via the Switch's leftBranch or rightBranch NetRelations.</p>	<p>Let :</p> <p>sw - Switch fp - FoulingPoint nr - NetRelation le - LinearElement tc - TopologicalCoordinate</p> <p>$\forall sw:$ $(\forall fp \Rightarrow (\exists tc \wedge tc.onLinearElement(le) \wedge ((leftBranch(sw, nr_1) \wedge connects(nr_1, le)) \vee (rightBranch(sw, nr_2) \wedge connects(nr_2, le))))))$</p> <p>leftBranch(sw, nr₁) and</p>


Application Condition	Rule Formalisation
	<p>$\text{rightBranch}(\text{sw}, \text{nr}_2) \text{ — } \text{nr}_1 \text{ and } \text{nr}_2$ are NetRelations connected to sw</p> <p>$\text{connects}(\text{nr}, \text{le})$: True if nr's elementA or elementB is le: $\text{connects}(\text{nr}, \text{le}) \equiv \text{elementA}(\text{nr}, \text{le})$ $\vee \text{elementB}(\text{nr}, \text{le})$</p>

SPT2TS-130923 - All FoulingPoints associated with a Crossing must be positioned on the same LinearElements referenced in the Crossing's topologicalCoordinates.

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparation shall define all  SPT2TS-124160 - FoulingPoints associated with a Crossing on the same LinearElements referenced in the Crossing's topologicalCoordinates.</p>	<p>Let :</p> <p>cr - Crossing fp - FoulingPoint le - LinearElement tc - TopologicalCoordinate</p> <p>$\forall \text{cr} :$ $(\forall \text{fp} \Rightarrow (\exists \text{fp.tc}_1 \wedge$ $\text{tc}_1.\text{onLinearElement}(\text{le})$ \wedge $(\exists \text{cr.tc}_2 \wedge$ $\text{tc}_2.\text{onLinearElement}(\text{le})$ $))$</p>

5.3.5 MAP

SPT2TS-130994 - The defined EPSG code value in MAP shall be valid

Application Condition	Rule Formalisation
<p>The  SPMS-7069 - Data Preparationshall define epsg value for every instance of MAP such that it is either exactly 1 (reserved monitor value) or be an integer that EXIST in the EPSG registry</p>	<p>Let :</p> <p>map - MAP $\text{epsg}(\text{map}, v)$ - the value of the epsg attribute of map is v. $\text{InEPSGRegistry}(v)$ - true when the value v exists in the official EPSG registry.</p> <p>$\forall \text{map} :$</p>

Application Condition	Rule Formalisation
	$(\text{epsg}(\text{map}, v) \Rightarrow (v = 1 \vee \text{InEPSGRegistry}(v)))$

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