RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

MAP Object Catalogue

Preliminary Issue

Document id: RCA.Doc.69

Revision history

0.1	04.02.2022	Peter Eimann, Harish Narayanan	Initial release
0.2	16.03.2022	Peter Eimann, Harish Narayanan	First stable version after cross cluster A.P.M. review

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1 Introduction

1.1 Release information

Basic document information:

RCA-Document Number: RCA.Doc.69

Document Name: MAP Object Catalogue

Cenelec Phase: 4

Version: 0.2

RCA Baseline set: BL0R4

Approval date: 16.03.2022

1.2 Imprint

Publisher:

RCA (an initiative of the ERTMS Users Group and EULYNX Consortium)

Support and Feedback: For feedback, or if you have trouble accessing the material, please contact rca@eulynx.eu.

1.3 Purpose of the document

This document defines and describes the Object Model that will be used by MAP cluster to provide reliable and validated topology and topography data in the form of Map Data for all operational RCA / OCORA subsystems and the Planning System.

Note: The document is being created in an iterative process and therefore does not yet contain a complete definition of all necessary objects. In particular, the following aspects will be covered in the next iterations:

- The list of domain objects in Tier 3 will be supplemented and completed by including the still missing requirements of the different subsystems.
- Versioning and Release-Management (including a bi-temporal historicization and construction states for physical objects)
- Accuracy requirements to meet safety targets

1.4 Scope

The MAP Object catalogue for the current iteration defines the data models used to derive data structure for the following different types of data as shown in the figure below:

- Trackside Map Data (APS, TMS, ATO, PE, …)
- Onboard Map Data (only localisation specific aspects)

Note: See [3] for the detailed definition of the types of data

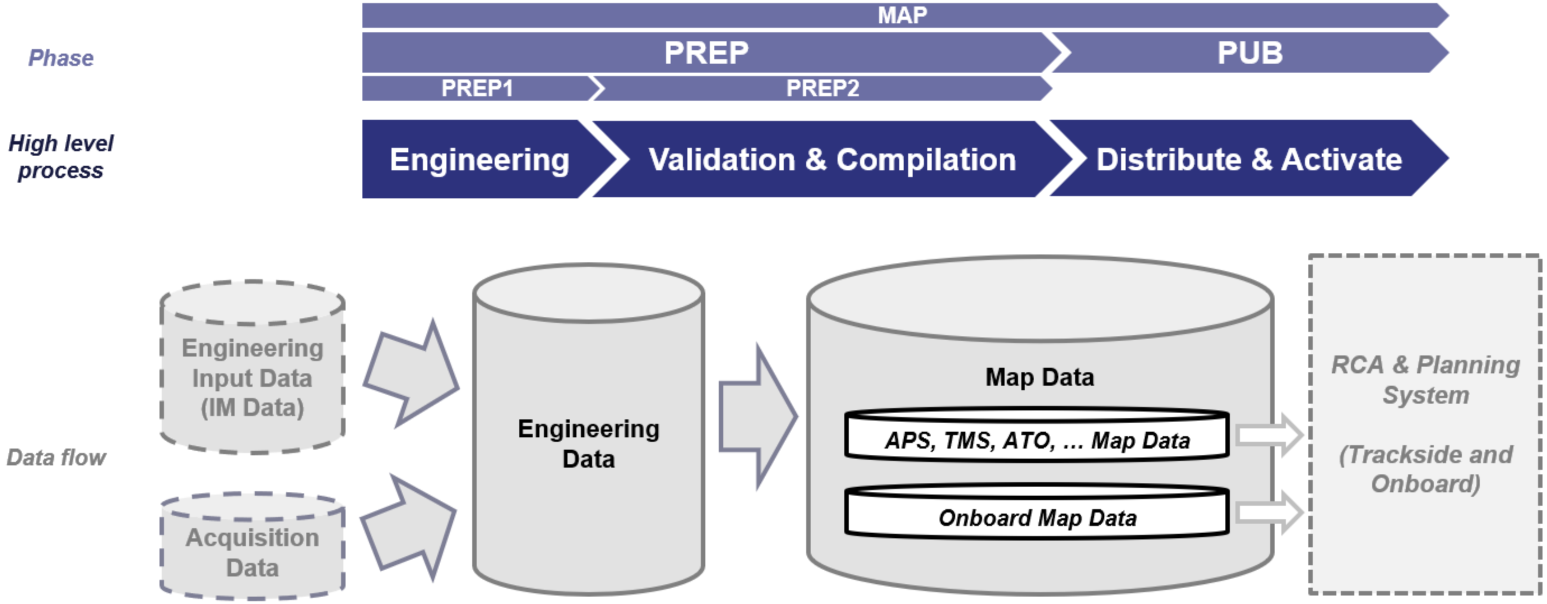


Figure 1 High level process of MAP

As shown in the figure above, the object model that is defined in this document focuses only on Map Data. The Map Data are created in the preparation phase and remain unchanged during operation phase until the next provisioning of Map Data.

Any Operational Data that will be transmitted between production systems and therefore changes if an operational state changes, has to be defined by the relevant subsystems. Operational Data may be overlaid on the Map Data and objects and attributes that are already available in the Map Data should not be redefined to model the Operational Data.

1.5 Target audience

The target group consists of members of the RCA/OCORA.

1.6 Terms and Abbreviations

For terms and definitions refer to the general RCA Terms and Abstract Concepts document. [2].

1.6.1 Acronyms

AS	Allocation Section
BNT	Base Net element service Topology
CTA	Contiguous Track Area
DPS	Drive Protection Section
LCTA	Linear Contiguous Track Area
TA	Track Area
TE	Track Edge
TEP	Track Edge Point
TES	Track Edge Section
TN	Track Node

1.7. Legend

The following table defines the legend for the definition of the different data objects and their attributes.

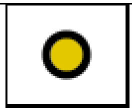
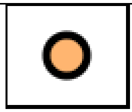
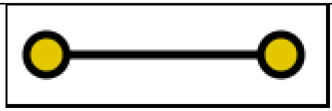
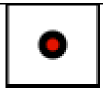
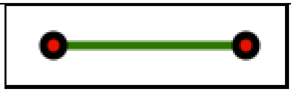
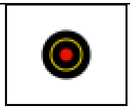
Table 1 Legend for the data object definition

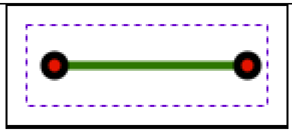
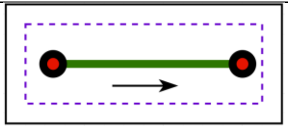
Column Name	Description
ID	Unique ID for each object and attribute. The ID is build using the tier number, an optional object group, an object specific identifier and a sequential number for each attribute in the format: T{0..3}-[{Object-Group ID}]-{Object ID}[-{Number}]
Object	Name of the object / class (in pascal case notation, starting with a capital letter) An object in italic defines an abstract object which is used to define common attributes that are equal in the inherited / specialized objects. An object name in the form {Name1}::{Name2} means, that the object {Name2} is inherited from object {Name1} (object {Name1} is the generalization of object {Name2}). In this case object {Name2} will contain all the attributes defined in object {Name1} plus the attributes defined additionally in object {Name2}. Note: Hyphens in the object names are not part of the name but are caused by hyphenation.
Attribute	Name of the attribute of an object / class (in camel case notation, starting with a small letter) (The attributes belong to the object that is defined in column “Object”) Note: Hyphens in the attribute names are not part of the name but are caused by hyphenation.
Description	Description for either the object (if column object is filled) or the attribute (if column attribute is filled)
Type	Datatype of the attribute An italic datatype refers to an object that is defined within the document (in column object) ENUM defines an enumeration with pre-defined constants
Range	The range of an attribute if it is restricted (e.g. minimum and/or maximum value for numbers, special content for strings, the possible constants of enumerations) For the data type Double (floating point numbers), the range also defines the maximum possible decimal places. UUID defines that the attribute contains an Universally Unique Identifier.
Cardinality	Defines whether the attribute is optional, mandatory or if it might occur multiple times (as an array of the attribute). Commonly used definitions are: 1: Attribute is mandatory and shall only occur one time n: Attribute is mandatory and shall occur exactly ‘n’ times 0..1: Attribute is optional but when it is used, it shall only occur one time

	1..*: Attribute is mandatory and shall occur multiple times (* = no upper limit) 0..*: Attribute is optional but when it is used, it shall occur multiple times (* = no upper limit) 1..n: Attribute is mandatory and shall occur maximum ‘n’ times 0..n: Attribute is optional but when it is used, it shall occur maximum ‘n’ times m..*: Attribute shall occur at minimum ‘m’ times (with m ≥ 1) and at maximum multiple times (* = no upper limit) m..n: Attribute shall occur at minimum ‘m’ times (m ≥ 1) and at maximum ‘n’ times (with n > m)
Unit	The unit of the attribute value (if applicable)

The following colour codes and legends are applicable for the topology objects within the entire document.

Table 2: Legends for topology objects

Colour / Legend	Object
Yellow / 	Track Node of type ‘Point’
Orange / 	Track Node of type ‘System border’ or ‘End of track’
Black / 	Track Edge with Track Nodes (of type ‘Point’)
Red / 	Track Edge Point
Green / 	Track Edge Section with Track Edge Point(s)
Red / 	Track Edge Point at the same location as Track Node of type ‘point’

Purple / 	Area that includes several Track Edge Sections (Track Area, Contiguous Track Area, Linear Contiguous Track Area, Area of Control, Operational Point) Note: The dotted line rectangle is referred here.
Purple / 	Area that includes several Track Edge Sections with a given direction

1.8. Related Documents

The following documents provide related information:

[1] RCA Digital Map Evaluation Reference Model [RCA.Doc.57] - published with BL0R3

[2] RCA Terms and Abstract Concepts [RCA.Doc.14] - published with BL0R4

[3] RCA MAP Concept [RCA.Doc.54] - published with BL0R4

[4] BNT Study of SBB, https://www.smartrail40.ch/download/downloads/20180716_Abschlussbericht_BNT.pdf (22.03.2021)

[5] Guide on the application of the common specifications of the register of Infrastructure (RINF application guide, Version 1.5.2.6, 25.10.2021)

[6] ATO over ETCS Subset 141-0.0.7

[7] ETCS Subset 026-7 v360

[8] ETCS Subset 036 v310

2. Context

The Data Model is based on the RCA Terms and Abstract Concepts [2] for the topology aspects. The model that is used in the Topology-Domain is an abstracted representation of the so called BNT ("Base Net element service Topology"). BNT has been developed by the Swiss Federal Railways (SBB) as common reference model for the railway infrastructure and is described in detail in [5].

2.1. Track network reference model

The track network reference model as the basis for engineering the topology is based on a node-edge model, the Base Net element service Topology (BNT) model with the following basic properties:

- Classic node-edge model
- Nodes represent branches (points), end of tracks, or system borders in the track network
- Edges (rail tracks) represent the connections between the nodes. For each edge it is defined which node is the start node and which is the end node, thus the edges also implicitly get a direction (from the start node to the end node)
- Navigability describes how the nodes can be navigated between the adjacent edges

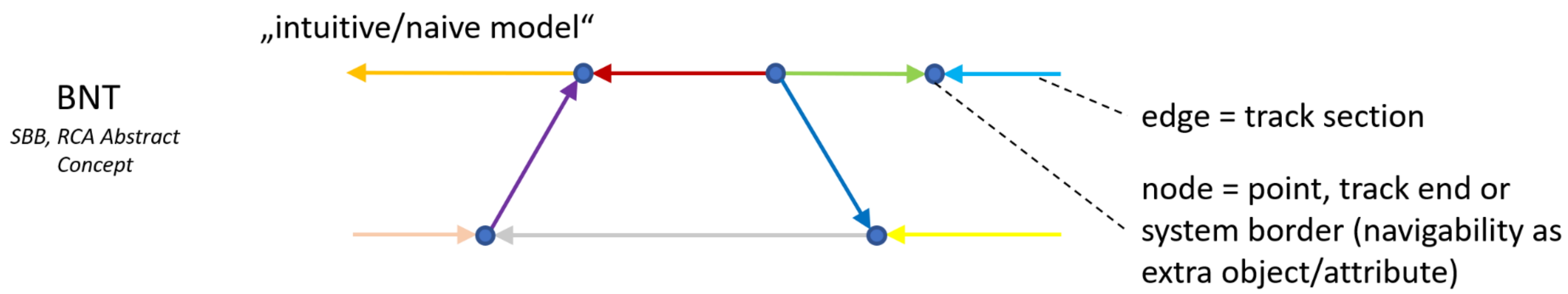


Figure 2 BNT model

Nodes represent:

- Points
- System borders / End of Tracks (e.g. Buffer Stops)

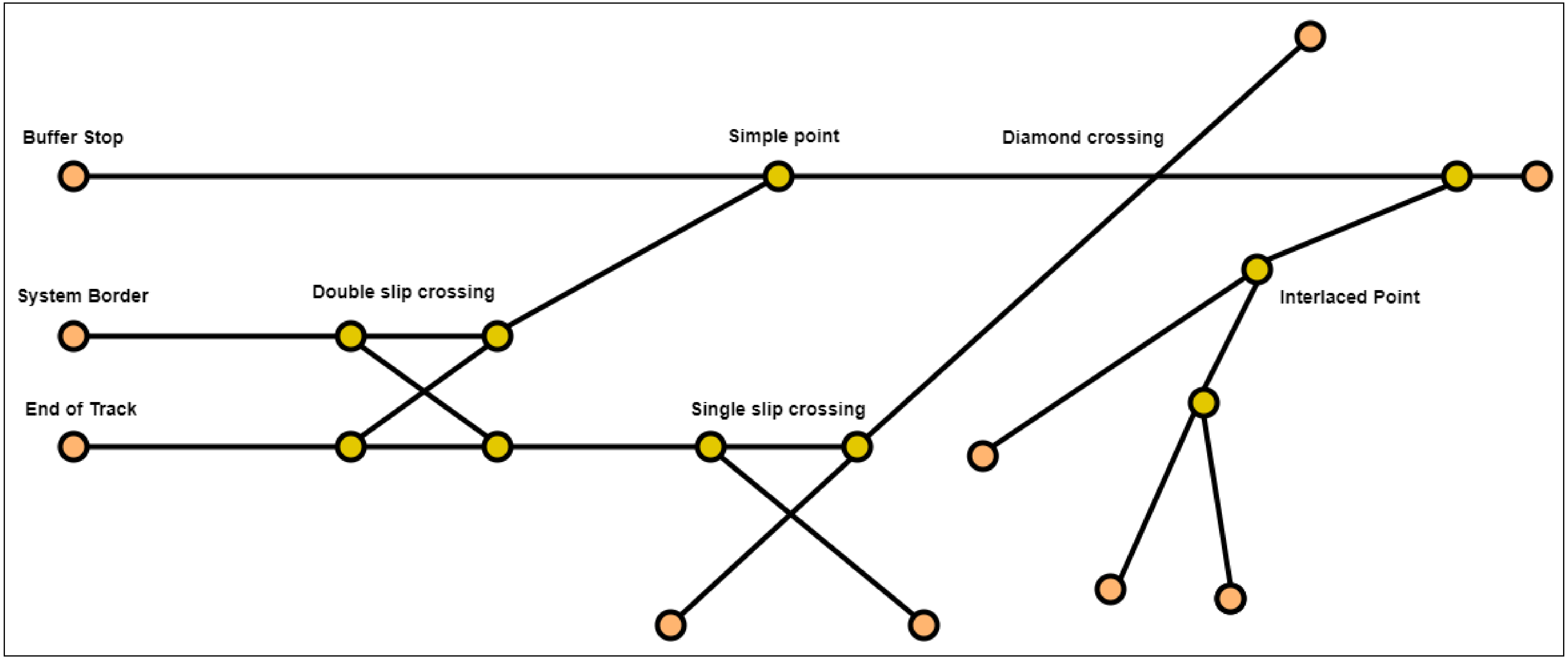


Figure 3 Nodes in BNT

Diamond crossings and derailer devices are not represented by a node, as there are no decision points for navigation at these elements (it is not possible to move from one edge to another).

2.2. Navigability

For all nodes that represent a point, navigability defines the possible movements between the edges that are connected to the node.

The navigability is an ordered pair of edges that have a common node (applies to relation in Figure 4 Relationships between Nodes, Edges and Navigabilities). It defines for each node how a train can pass from one edge to another.

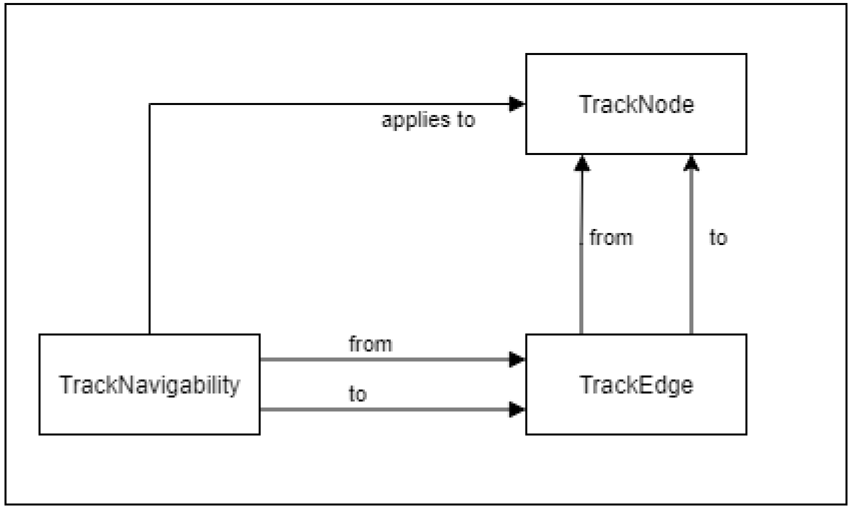


Figure 4 Relationships between Nodes, Edges and Navigabilities

3. Abstract Topology Concept

The topology domain currently defined in RCA Terms and Abstract Concepts [2] defines an abstract representation of how the generic topology elements relate to each other. These generic concepts can be further extended/detailed to reference infrastructure facilities like points, tracks, stations, etc.

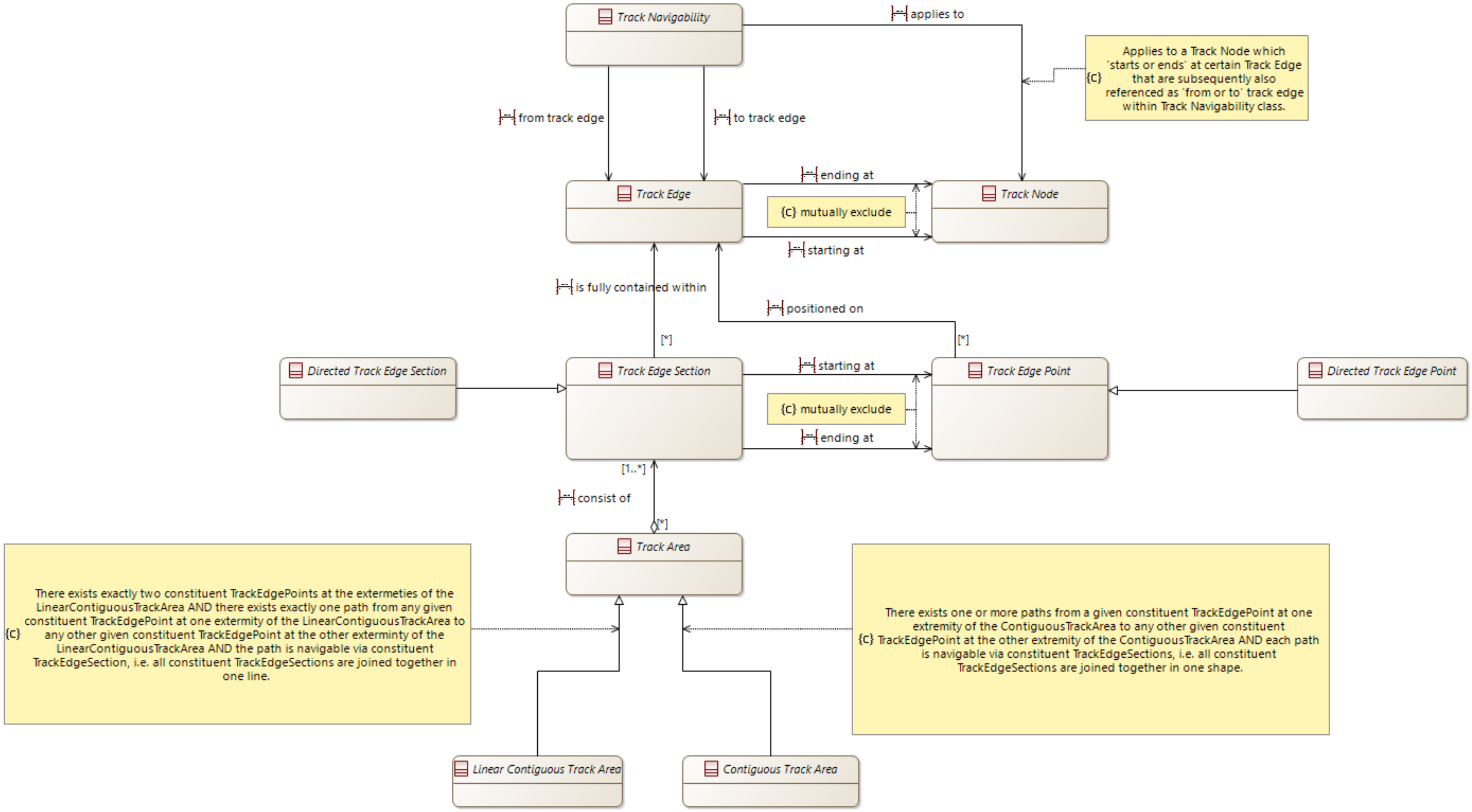


Figure 5 Topology Domain in the RCA Abstract Concepts

This class diagram shows the relationships between the abstract topology objects. Track Edges, Track Nodes and Navigability represent the base network topology of the railway which only changes when the infrastructure is physically changed. Track Edge Section and Track Edge Point, Track Area, Contiguous Track Area and Linear Contiguous Track Area represent the spatial topology of the track.

4. Tiers of the MAP Object Model

The MAP Object Model structures the various topology objects in 4 different tiers. Objects in each tier are referencing the objects either within them or the underlying tier(s).

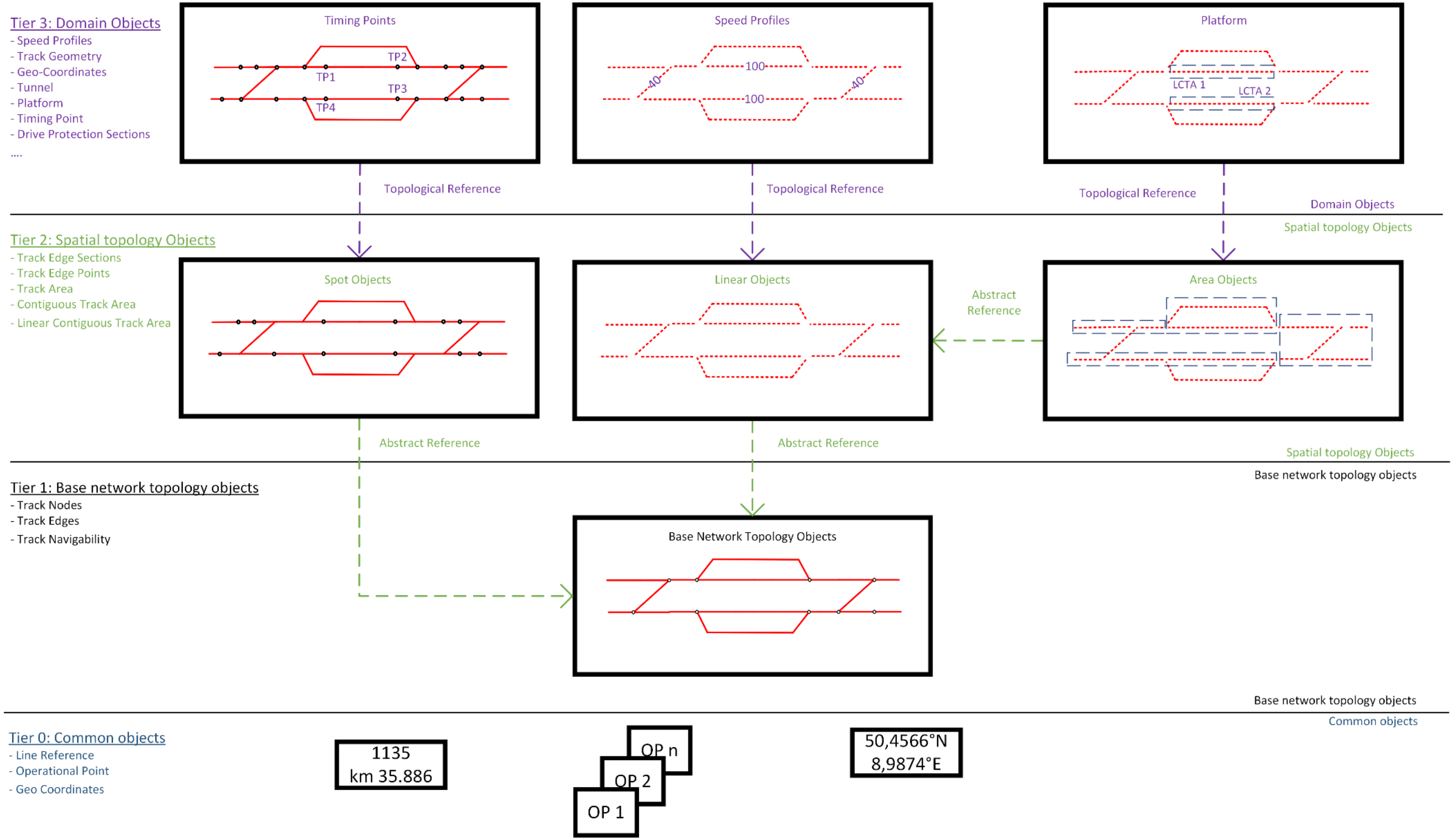


Figure 6 Tiers of the MAP Object Model

5. Tier 0: Common objects

5.1. Line Reference

The line reference is used to link the location of an object to a reference point on the line indicated by a line number and a line kilometre.

5.1.1. Definition

Table 3 Definition Line Reference

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T0-LR	**LineReference**						
T0-LR-1		lineKilometre	Reference to the line kilometrage (with 3 deci-mal places).	Double	-9999.999 - +9999.999	1	Km
T0-LR-2		lineNumber	Reference to the line number	String	-	1	

5.2. Operational Point

The operational point is understood as a point without dimensions, attributed with generic parameters and with objects described by their own parameters. The operational point is the primary element of the network and selection of operational points is the first task for Infrastructure Managers (IMs) in procedure of presenting its network.

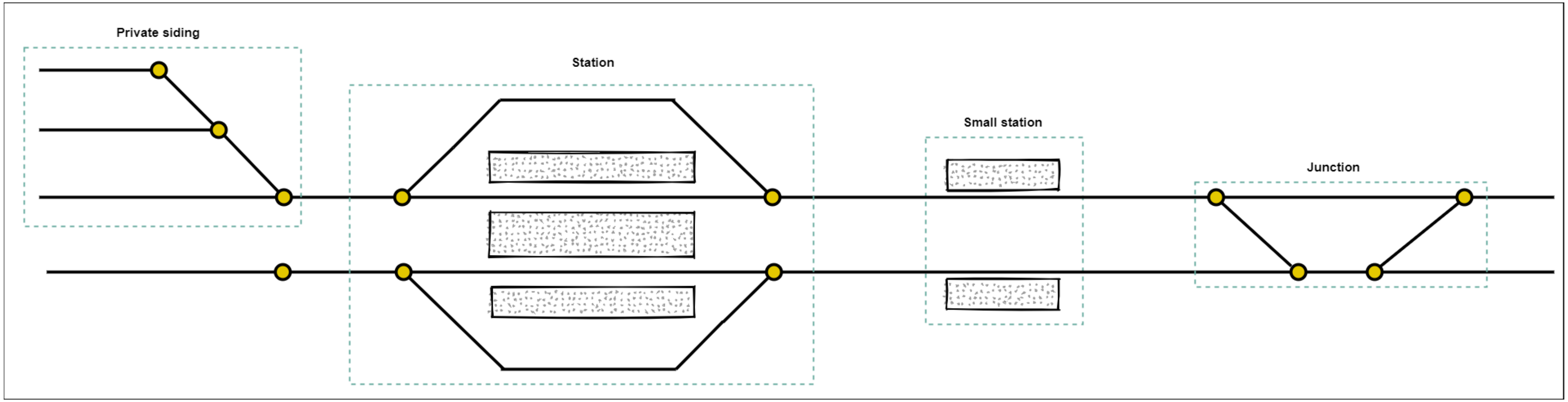


Figure 7: Operational Points illustrating station, junction, small station, and private siding

5.2.1. Definition

Table 4 Definition Operational Point

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T0-OP	**OperationalPoint**						
T0-OP-1		id	Unique generated ID	String	UUID	1	
T0-OP-2		name	Name of the operational point, normally related to the town or village or to traffic control purpose	String	alphanumeric	1	
T0-OP-3		identifier	Identifier of the operational point	String	alphanumeric	1	
T0-OP-4		type	Type of the operational point: • station	ENUM	see Description	1	

			• small station • passenger terminal • passenger stop • freight terminal • depot • train technical services • junction • point • shunting yard • technical change • private siding • border point • domestic border point				
T0-OP-5		lineReference	Reference to the line(s) which are connected to the operational point.	*LineReference*	-	1..*	
T0-OP-6		isLocatedAtGeoCo-ordinates	Geo-Coordinates of this operational point (in a specific coordinate system)	*GeoCoordinates*	-	1	
T0-OP-7		isWithinAreaOfCon-trol	Identification of the Area of Control, by which the operational point is controlled.	*AreaOfControl*	-	1..*	

5.2.2. Basis / rules and regulations

The rules for the definition of operational points are IM specific. The IMs shall provide a list of operational points in the above format based on the definition in [6].

5.2.3. Engineering rules

An operational point will be represented by a so called ‘centre point’ on a global map. This centre point is defined by relevant IM (note that it is not always in the centre of the operational point area) and determines the geographical coordinates (and the kilometrage from the start of the railway line) of operational point to be inserted to generic data about location of the operational point.

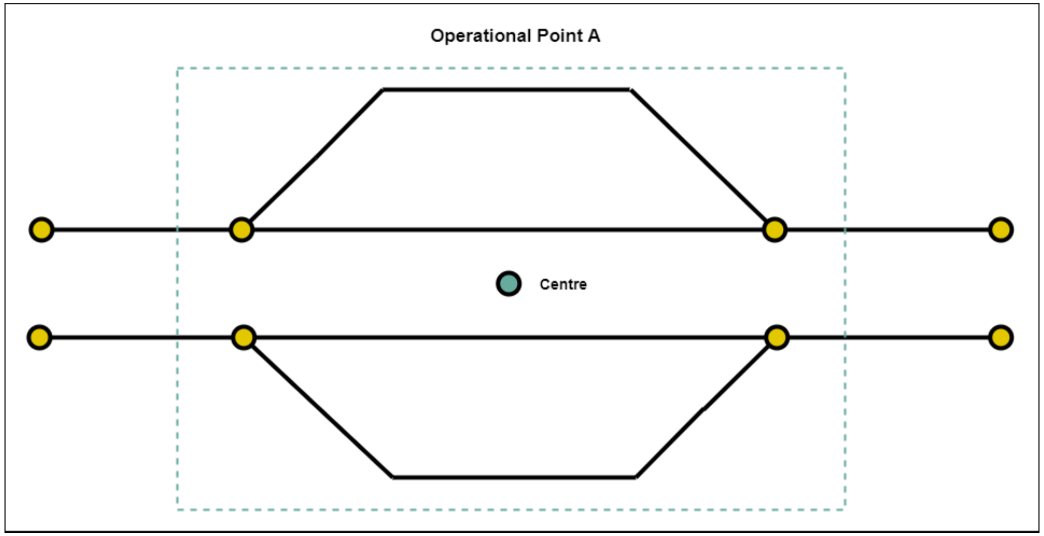


Figure 8: Location of Operational Point

An operational point is allowed to have no track (e.g. border points, technical change or operational point private siding).

The following types of operational points have been defined in [6]:

1. Station – big or huge station with several functions, important for international traffic, basic for national railway system
2. Small station – multifunctional station not so big and not so important like “Station”
3. Passenger terminal – station with dominating function of service for passenger traffic
4. Freight terminal – station dominantly serving for loading and unloading of freight trains
5. Depot – group of tracks used by depot or workshop for RST maintenance
6. Train technical services – group of tracks for servicing trains (parking, washing, etc.)
7. Passenger stop – small operational point consisting of at least one platform, normally serving mostly for local passenger services
8. Junction – operational point consisting of at least one turnout, normally used for changing direction along the route for trains, with reduced or not existing other functions
9. Border point – located in the point where a border between Major States meets a railway line
10. Shunting yard – group of tracks used for shunting trains, mostly related to freight traffic

11. Technical change - to describe a change on CCS or a type of contact line or a Gauge changeover facility – fixed installation allowing a train to travel across a break of gauge where two railway networks with different track gauges meet
12. Point - operational point consisting of only one point. It describes a single point without any extension contrary to a junction that has a real spatial extension and is generally delimited by entry signals
13. Private siding - operational point that describes the embranchment located on the main line that leads to the private siding with the information regarding the embranchment characteristics
14. Domestic border point – located exactly in the point where a border between IMs meets a railway line

5.2.4. Dependencies

Operational Points can be assigned when the following objects are created:

- Track Node
- Track Edge Point

The identifier might be used as a prefix for the attribute "name" of the individual objects in order to establish an unambiguous assignment of an object to an operational point (e.g. for point numbers and other designations of track asset elements).

The Operational Point shall be mapped to a corresponding Area of Control, which is defined in chapter 8.1 later in this document.

5.3. Geo-Coordinates

Geo-Coordinates are used to locate topology objects (like Track Nodes and Track Edge Points) on or alongside track. They provide pure absolute positioning. The topology objects are also relatively positioned within respect to Track Edges and Track Nodes.

5.3.1. Definition

Table 5 Definition Geo-Coordinates

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T0-GC	**GeoCoordinates**						
T0-GC-1		id	Unique generated ID	String	UUID	1	
T0-GC-2		name	Name for the geo-coordinate.	String	alphanumeric	1	
T0-GC-5		xCoordinate	Value of x-coordinate. The semantic meaning is specific to the ETRS89 coordinate system (with 6 decimal places).	Double	-9999999.999999 - +9999999.999999	1	
T0-GC-6		yCoordinate	Value of y-coordinate. The semantic meaning is specific to the ETRS89 coordinate system (with 6 decimal places).	Double	-9999999.999999 - +9999999.999999	1	
T0-GC-7		zCoordinate	Value of z-coordinate. The semantic meaning is specific to the ETRS89 coordinate system (with 6 decimal places).	Double	-9999999.999999 - +9999999.999999	1	

5.3.2. Basis / rules and regulations

MAP uses the European Terrestial Reference System 1989 (ETRS89 – SRID 4258) as the geodetic Cartesian reference frame.

The SRID is a unique value used to unambiguously identify projected, unprojected, and local spatial coordinate system definitions. EPSG Geodetic Parameter Dataset (also EPSG registry) is a public registry of geodetic datums, spatial reference systems, Earth ellipsoids, coordinate transformations and related units of measurement. Most geographic information systems (GIS) and GIS libraries use EPSG codes as Spatial Reference System Identifiers (SRIDs) and EPSG definition data for identifying coordinate reference systems.

5.3.3. Dependencies

Each object, that is mapped to a spot location (e.g. Track Node, Track Edge Point, Operational Point) should contain a reference to a corresponding geo-coordinate to reference the spot location in space.

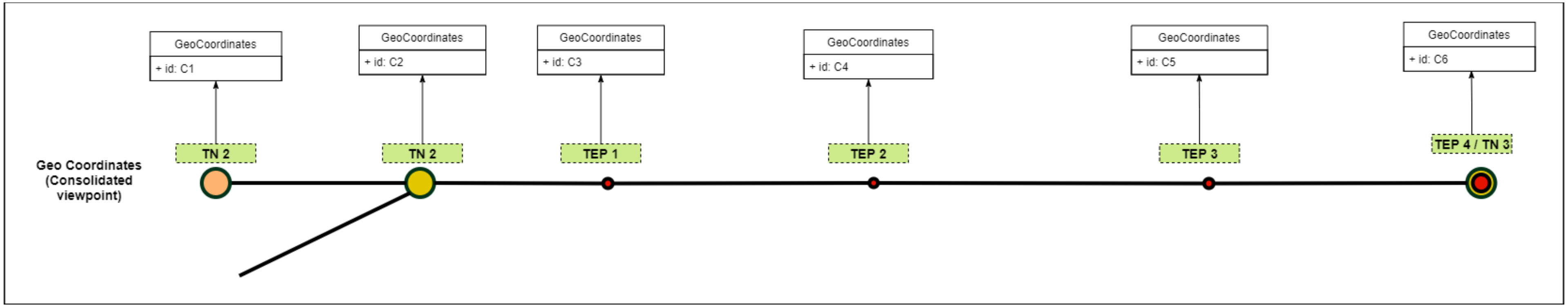


Figure 9: Geo-Coordinates

6. Tier 1: Base network topology objects

This chapter defines and describes the base network topology objects with the following taxonomy:

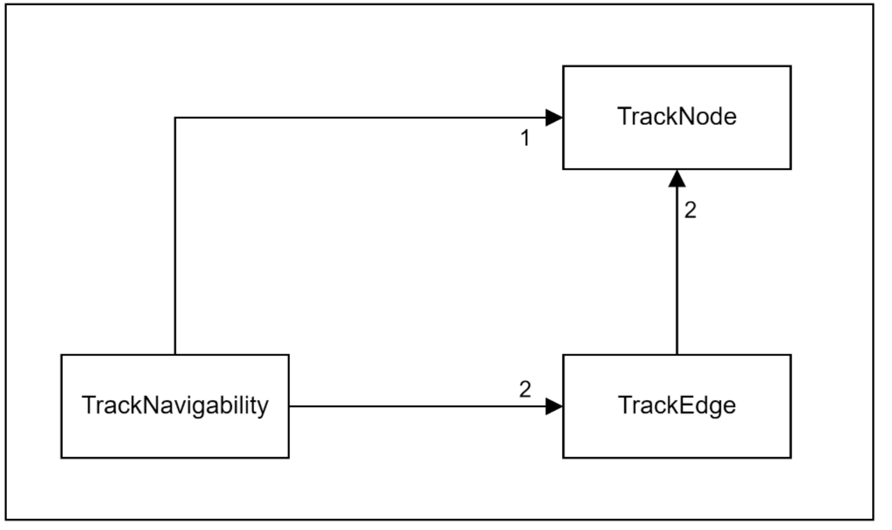


Figure 10 Taxonomy base network topology objects

6.1. Track Node

A Track Node is a position on the topological model of the track network where a Track Edge begins or ends. There are several situations where a Track Edge begins or ends, and all are modelled as Track Node (list is not exhaustive):

- Points – It is a location of the track network where trains coming from one direction and have more than one possible Track Edge to continue driving.

  Note: Even if one Track Edge begins while another passes through the point, the Track Node that represents the point splits the passing track into two Track Edges

- End Of Track – The point on the track network where the physical track ends or a Buffer Stop is located.
- System borders - The point defining a system border (i.e. between two infrastructure operators, between two areas of control or between a controlled and a non-controlled area)

  Note: Even if the physical track continues, on this location one track edge ends and another begins

6.1.1. Definition

Table 6 Definition Track Node

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T1-TN	**TrackNode**						
T1-TN-1		id	Unique generated ID	String	UUID	1	
T1-TN-2		name	Name of the Track Node in the form: {operational point identifier}-{node number}, with {node number}: - Identifier/number of the point for type ‘point’ - Track number for type ‘End of Track’ and type ‘System Borders’ e.g. BAZ-8 or HO-9016	String	alphanumeric	1	
T1-TN-3		nodeType	ENUM value indicating the Track Node type	ENUM	Point System Border End of Track	1	
T1-TN-4		isLocatedAtGeo-Coordinates	Geo-Coordinates of this Track Node (in a specific coordinate system)	*GeoCoordinates*	-	1	

T1-TN-5		hasOperational-Point	The operational point to which this Track Node is related.	*OperationalPoint*	-	0..1	
T1-TN-6		lineReference	Reference to line (with 3 decimal places)	*LineReference*		0..1	

6.1.2. Basis / rules and regulations

- Simple points and high-speed points are represented by one Track Node of the type 'point'.
- Interlaced points and single slip crossings are represented by two Track Nodes of the type 'point'.
- Double slip crossings are represented by four Track Nodes of the type 'point'.
- Track ends and buffer stops are represented by one Track Node of the type 'End of Track' depending on their existence on the physical track.
- Border between two infrastructure operators or between two areas of control or between a controlled and a non-controlled area are represented by one Track Node of type 'System Border'
- Diamond crossings (with or without movable blades) and derailment devices are not represented as Track Nodes (i.e. Points or track ends). These are rather represented by a Track Edge point and thus have a reference to Track Edges and not to Track Nodes.

6.1.3. Engineering rules

The position of the Track Node for points corresponds to the location of the point tip (the start of the point) which normally refers to the tangent or secant intersection point. The location of the point tip is not identical with the location of the point tongues. Depending on the engineering parameters of the point, the point tip can be located 0.5 – 2 m away from the point tongue.

Note: Actually, the point tongue is visible and can be measured much better than the geometrical point tip. In addition, it is the more relevant information from operational / safety / supervision perspective and must be configured anyway for a Drive Protection Section (DPS, see chapter 8.7). However, the point tip is the information that is engineered and used by track alignment / track geometry data. It should be discussed, if it can be configured within RCA to use the point tongue instead of the point tip as general reference point. This is a decision, which must be alligned with the surrounding systems of RCA (i.e. TMS) or at least an impact / safety analysis must be performed in case of accepted deviations of reference points (tip vs. tongue).

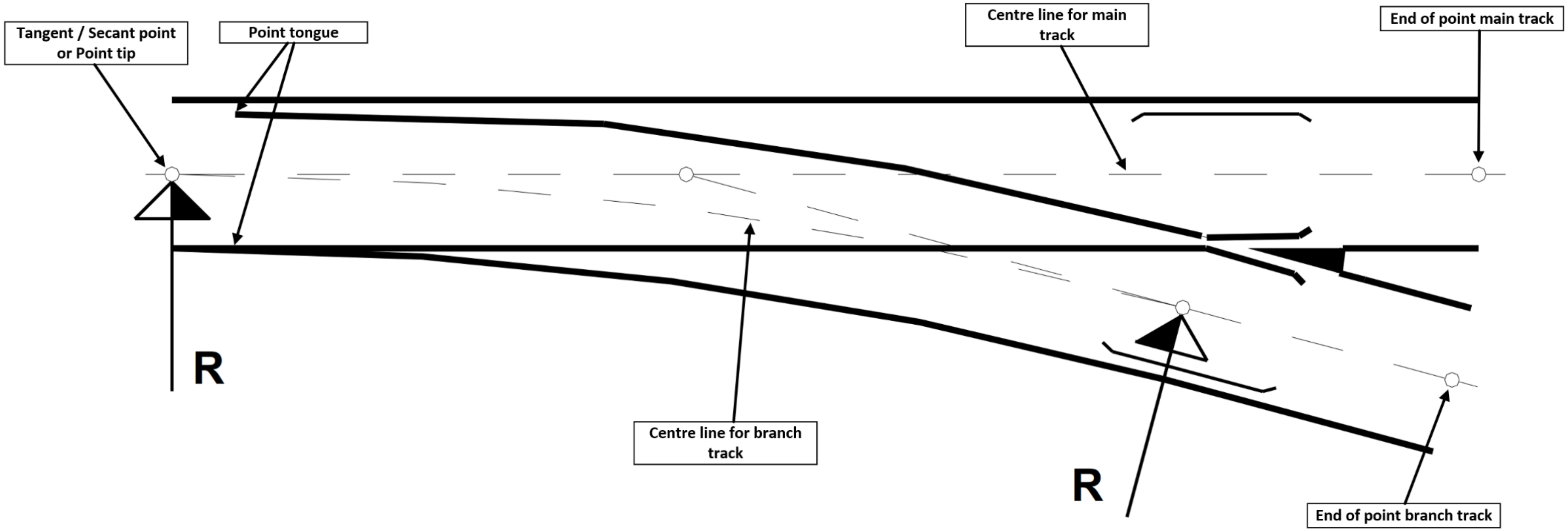


Figure 11 Position of tangent / secant point for simple points

The tangent or secant point refers to the point of intersection between the track centre lines of main and branch tracks.

The position or the location (geo-coordinates) of the nodes at slip crossing corresponds to the respective point tips at each side of the slip crossing:

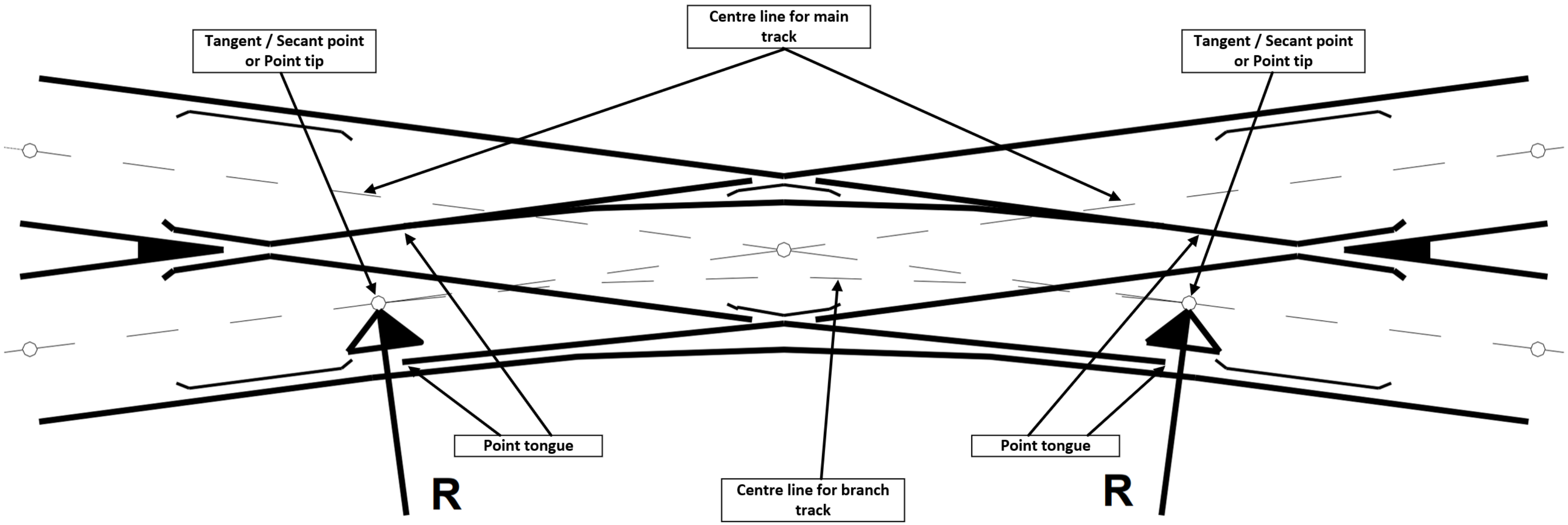
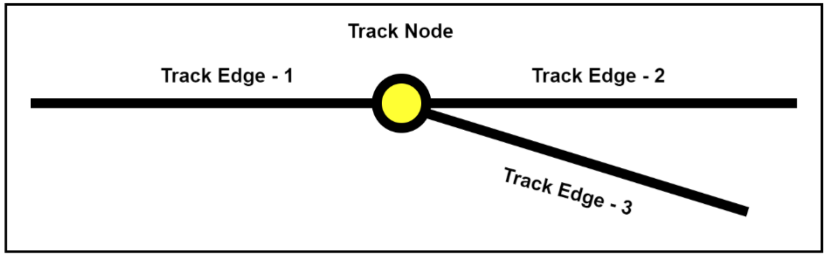


Figure 12 Position of tangent / secant point for a single slip crossing

The single slip crossing therefore has 2, the double slip crossing 4 track positions and geo-coordinates to map the nodes. In addition, the position of the point intersection point should also be engineered when defining the derived point object.

6.1.4. Dependencies

➔ When a Track Node is represented as a Point, then it shall have 3 Track Edges connected to it.



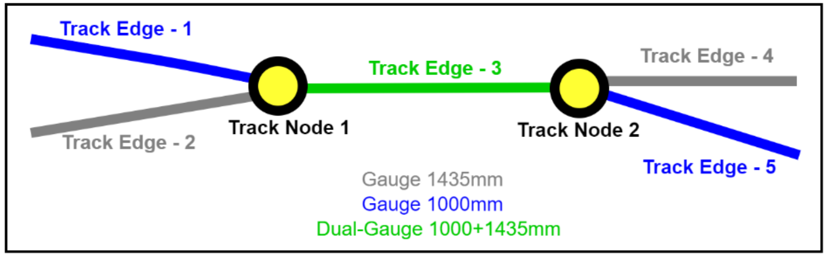


Figure 13 Track Node type Point

➔ When a Track Node is represented as a System Border, then it shall have 2 Track Edges connected to it.

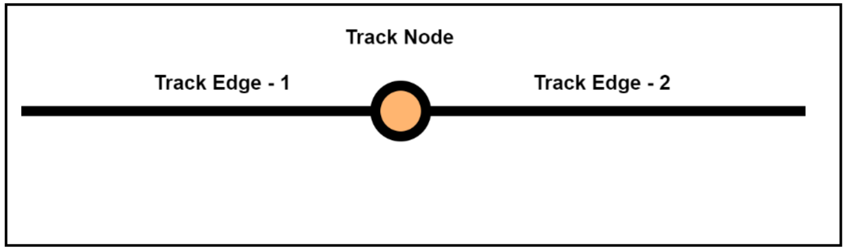


Figure 14 Track Node type System Border

A System border can be realized as the followings,

1. Border between two major Infrastructure Managers
2. Border between two states
3. Border between two Areas of Control

➔ When a Track Node is represented as an End of Track, then it shall have 1 Track Edge connected to.

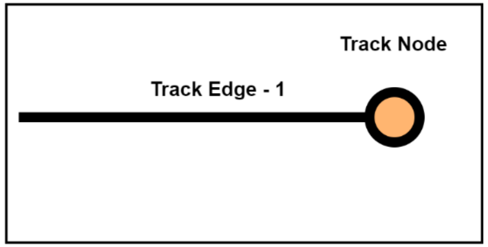


Figure 15 Track Node type End of Track

6.2. Track Edge

A Track Edge is a linear object that connects exactly two Track Nodes. One of these Track Nodes is defined as the Start Track Node, the other is defined as the End Track Node, which gives an implicit direction to the Track Edge. The implicit Track Edge direction does not specify the drivability of a Track Edge.

6.2.1. Definition

Table 7 Definition Track Edge

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T1-TE	**TrackEdge**						
T1-TE-1		id	Unique generated ID	String	UUID	1	
T1-TE-2		name	Name of the Track Edge in the form: {start node}-{branch side}_{end node}-{branch side}, with {branch side}: L → left branch (**L**eft) R → right branch (**R**ight) T → start of point, system border or end of track (**T**op) e.g. AD-2-L_AD-3-R	String	alphanumeric	1	
T1-TE-3		length	Real length of Track Edge in meters (with 3 decimal places)	Double	0.000 - 999999.999	1	m
T1-TE-4		gauge	Gauge(s) of the Track Edge, depending on whether the edge refences a single, dual or even multiple gauge track. Possible gauge values in mm: • 750 • 1000 • 1435 • 1520 • 1524 • 1600 • 1668 • 1676	ENUM	see Descrip-tion	1..*	mm

T1-TE-5		hasStart-TrackNode	Track Node where Track Edge starts	*TrackNode*	-	1	
T1-TE-6		hasEnd-TrackNode	Track Node where Track Edge ends	*TrackNode*	-	1	

6.2.2. Basis / rules and regulations

The Track Edge has no explicit direction, but rather it shall be derived implicitly from the start and end Track Edge Points, i.e.

Start to End **→ from start Track Node to end Track Node**

End to Start **→ from end Track Node to start Track Node**

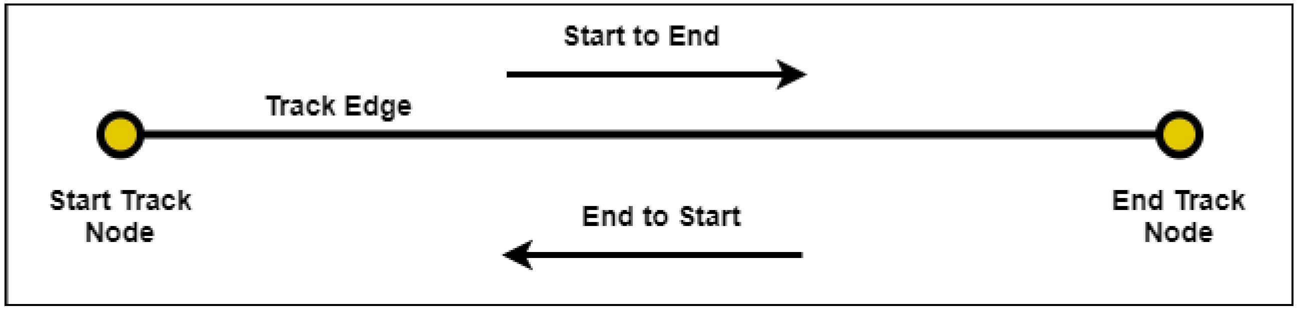


Figure 16 Direction of a Track Edge

6.2.3. Engineering rules

The start and end Track Node must not refer to the same Track Node.

A node is set as start Track Node such that it lies on the lower route kilometrage and vice-versa for the end Track Node.

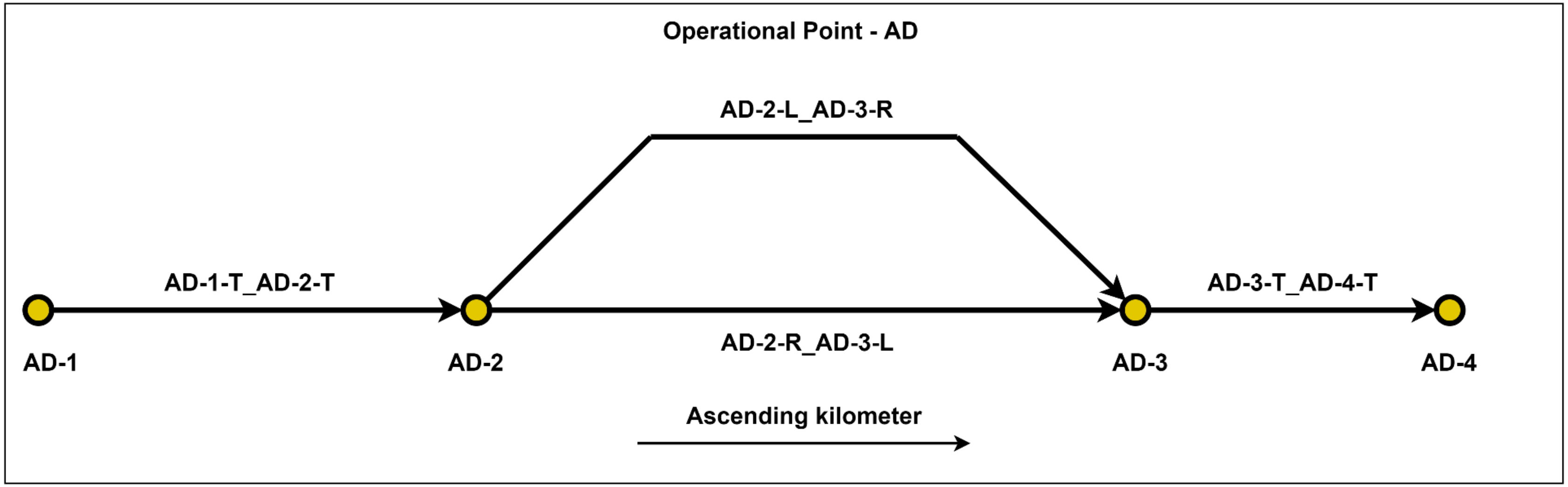


Figure 17 Definition of the start and end track node for Track Edge direction

- Track Edge AD-1-T_AD-2-T:
  - Start Track Node is the end of track (T) AD-1 and end Track Node is the top of point (T) AD-2.
- Track Edge AD-2-R_AD-3-L:
  - Start Track Node is the right branch of track (R) AD-2 and end Track Node is the left branch of track (L) AD-3
- Track Edge AD-2-L_AD-3-R:
  - Start Track Node is the left branch of track (L) AD-2 and end Track Node is the right branch of track (R) AD-3
- Track Edge AD-3-T_AD-4-T:
  - Start Track Node is the top of point (T) AD-3 and end Track Node is the end of track (T) AD-4

6.3. Track Navigability

Track Navigability describes how to navigate between the adjacent Track Edges at Track Nodes. The Track Navigability determines which travel options are permitted at points and which are excluded. They are necessary to eliminate the physically impossible train movements (e.g. a movement from the left to the right branch of a point) and define the practically possible movements in the node-edge model.

6.3.1. Definition

Table 8 Definition Track Navigability

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T1-TN	**TrackNavigability**						
T1-TN-1		id	Unique generated ID	String	UUID	1	
T1-TN-2		name	Name of navigability (combination of the names of the neighbouring Track Edges).	String	alphanumeric	1	
T1-TN-3		fromTrackEdge	Track Edge where the Track Navigability starts.	*TrackEdge*	-	1	
T1-TN-4		fromTrackEgdeSide	Side of the starting Track Edge for which the navigability is described.	ENUM	Start End	1	
T1-TN-5		toTrackEdge	Track Edge where the Track Navigability ends.	*TrackEdge*	-	1	
T1-TN-6		toTrackEdgeSide	Side of the ending Track Edge for which the navigability is described.	ENUM	Start End	1	
T1-TN-7		appliesToTrackNode	Track Node to which the Track Navigability instance applies.	*TrackNode*	-	1	

6.3.2. Basis / rules and regulations

Track Navigability represents ordered pairs of navigable Track Edges, referenced by Track Edge attributes. The Track Navigability always refers to one direction only, meaning if navigation between two Track Edge A and B in both directions is possible, two Track Navigabilities ("from Track Edge A to Track Edge B" and "from Track Edge B to Track Edge A") have to be defined.

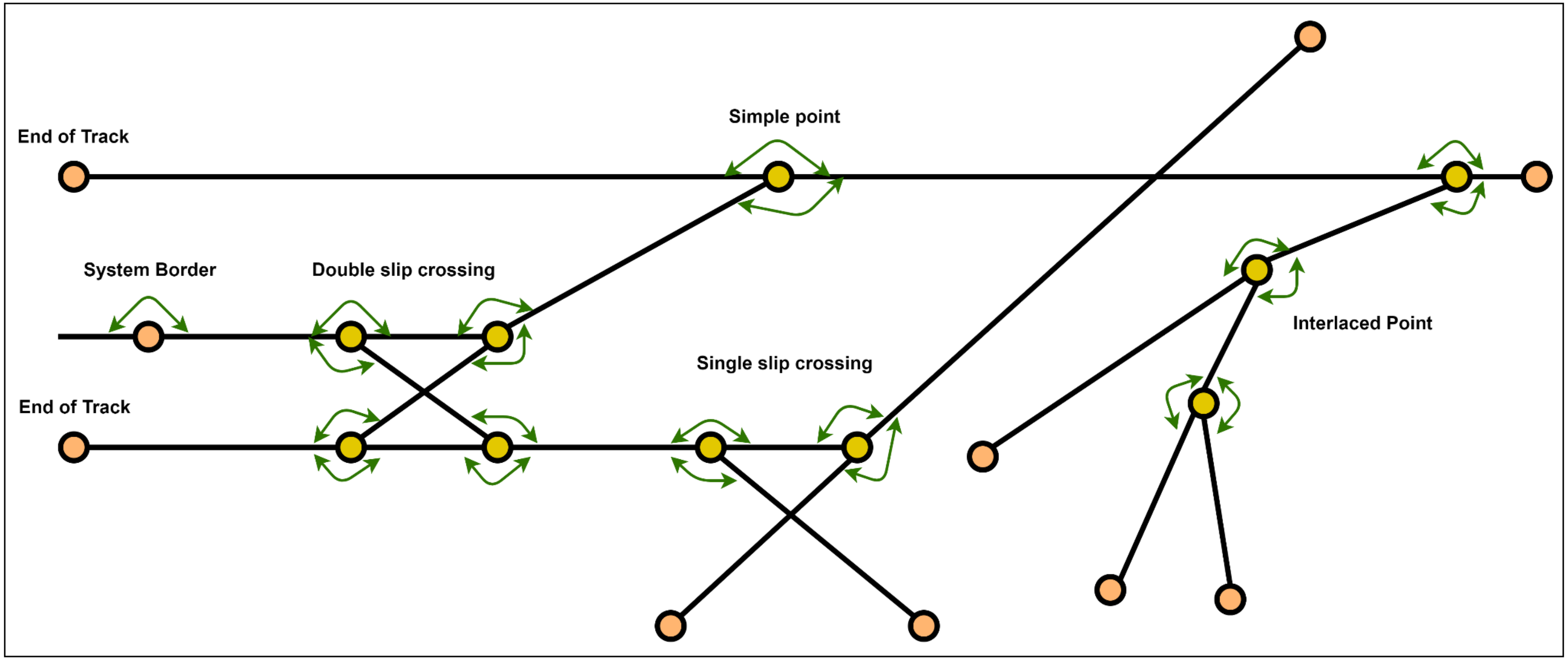


Figure 18 Navigabilities

6.3.3. Engineering rules

Track Navigabilities shall be engineered at Track Nodes to describe the possible branching options for both directions of travel. For

- a simple point 2 pairs (in total 4)
- a single slip crossing 4 pairs (in total 8)
- a double slip crossing 8 pairs (in total 16)
- a system border 1 pair (in total 2)
- a track end or buffer stop none (0)

of Track Navigabilities must be configured.

6.3.4. Dependencies

Track Navigability depends on the type of Track Nodes for which they are engineered, so that the different driving possibilities in the track network are represented.

As Track Edges might have multiple gauges, routing algorithms have to take into account that only Navigabilities between Track Edges that define the same gauge are valid.

7. Tier 2: Spatial topology objects

This chapter defines and describes the spatial topology objects which have the following taxonomy:

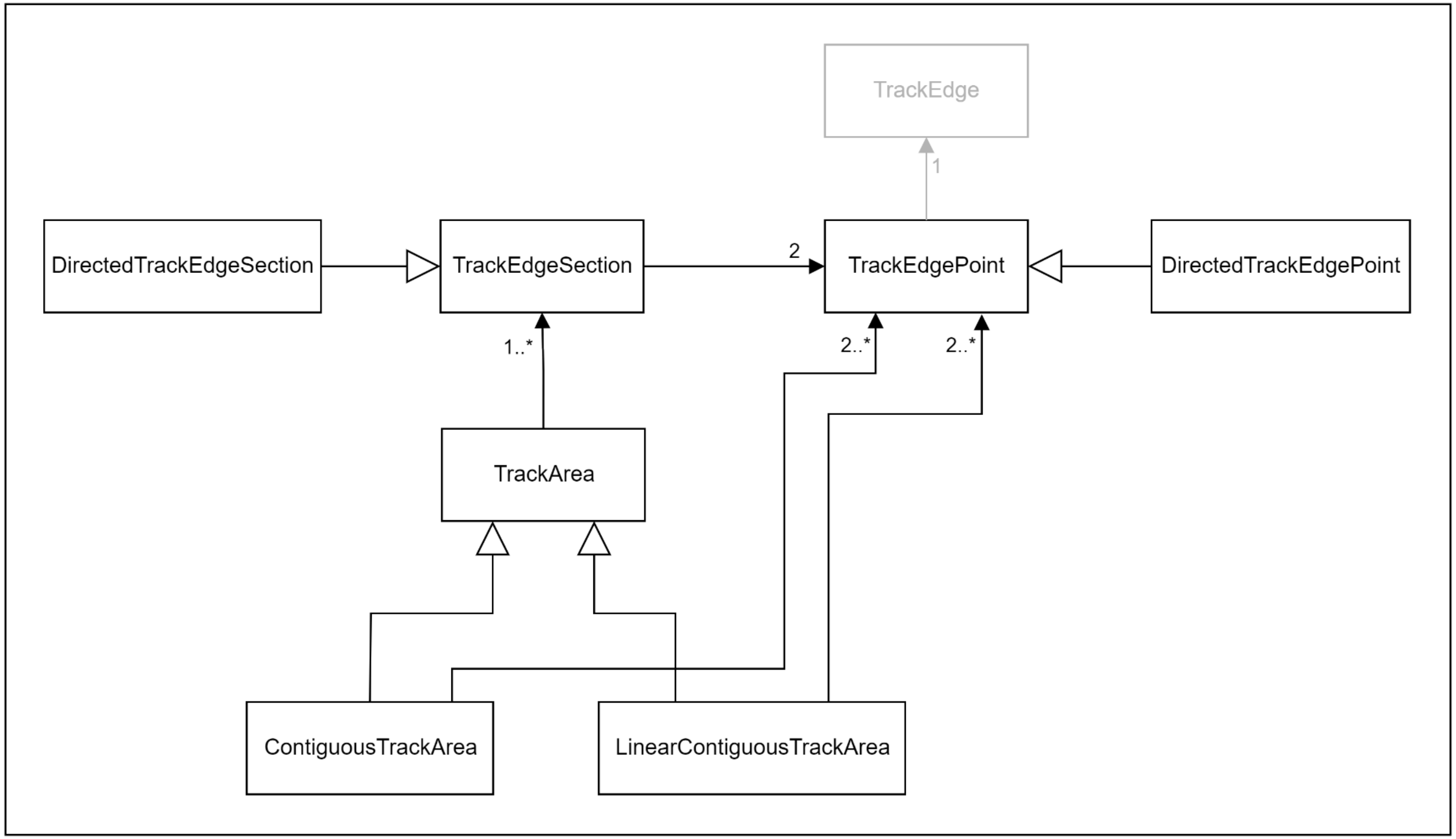


Figure 19 Taxonomy spatial topology objects

In addition, this chapter also contains objects which have implicit and explicit directions definitions. The following clarifications are provided for better understanding of these concepts.

Implicit directions: These directions can be simply derived from the start and end points of the corresponding object e.g. a Track Edge. These are provided for the objects that do not have any explicit requirement based on the usage direction of the Track Edge. Meaning these elements are valid of any/all usage directions of the Track Edge. Objects falling under this category is: Linear Contiguous Track Area

Explicit directions: These directions are specified using a predefined ENUM list. These are provided for the objects that explicit requirements based on the usage direction of the Track Edge. Meaning these elements are valid only for a particular usage direction of the Track Edge based on the specified ENUM value. Objects falling under this category are: Directed Track Edge Sections and Directed Track Edge Points.

7.1. Spot objects

7.1.1. Track Edge Point

Base-element to describe non-directed spot objects (without spatial expansion) and to locate them on (or alongside) a Track Edge with additional attributes.

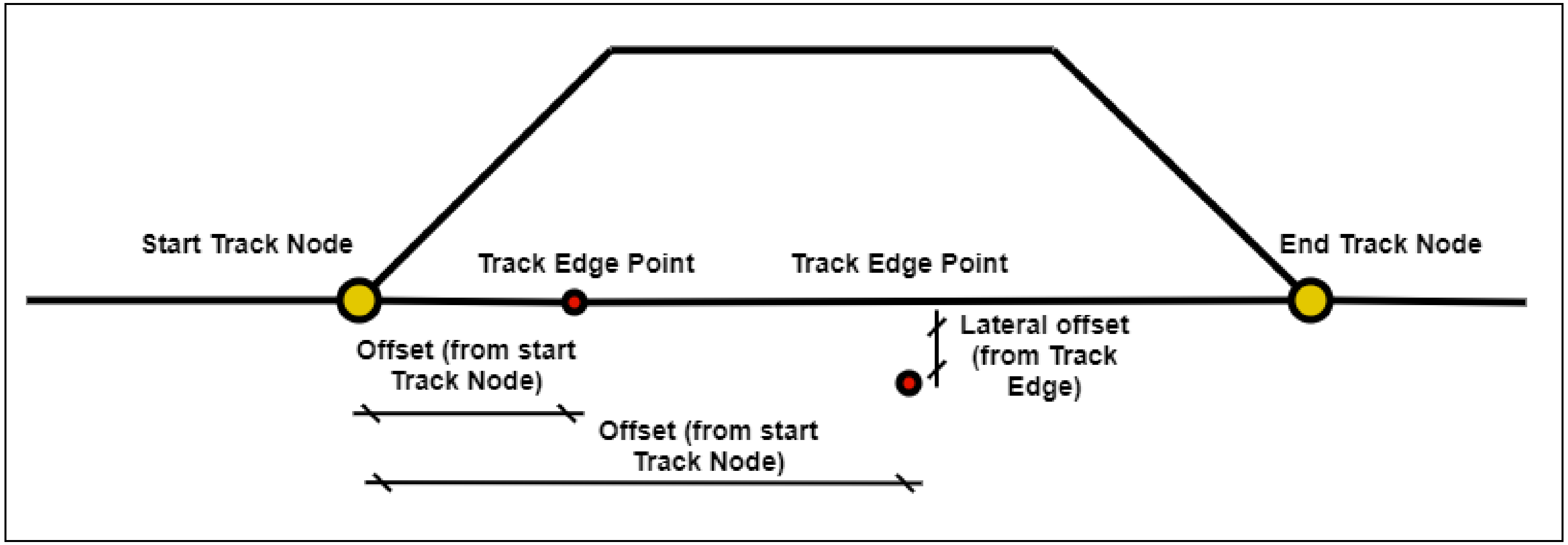


Figure 20 Track Edge Point

7.1.1.1. Definition

Table 9 Definition Track Edge Point

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-SO-TEP	**TrackEdgePoint**						
T2-SO-TEP-1		id	Unique generated ID	String	UUID	1	
T2-SO-TEP-2		name	Name of Track Edge point	String	alphanumeric	1	
T2-SO-TEP-3		isPositioned OnTrackEdge	Reference to the Track Edge	*TrackEdge*	-	1	
T2-SO-TEP-4		offset	Represents the longitudinal offset value in meters from start Track Node (with 3 decimal places). Offset cannot exceed the end node of the referenced edge. Offset value of 0 m means, the Track Edge Point is located at the start Track Node of the referenced Track Edge. Offset value equal to length of reference Track Edge means, the Track Edge Point is located on the end Track Node.	Double	0.000 - 999999.999	1	m
T2-SO-TEP-5		isLocatedAtGeoCoordinates	Geo-Coordinates of the track position (in a specific coordinate system)	*GeoCoordinates*	-	1	
T2-SO-TEP-6		lateralOffset	Represents the lateral offset value in meters from the Track Edge (with 3 decimal places). Positive values represent a distance to the right and negative values a distance to the left, in relation to the Track Edge direction.	Double	0.000 - 99.999	0..1	m
T2-SO-TEP-7		hasOperationalPoint	Defines the operational point which is relevant for this position.	*Operational Point*	-	0..1	
T2-SO-TEP-8		lineReference	Reference to line (with 3 decimal places)	*LineReference*		0..1	

7.1.1.2. Basis / rules and regulations

Track Edge Points shall be used to provide references to elements representing **track assets** like (non-exhaustive list):

- Balises

Note: This list will be updated as more domain objects will be defined.

7.1.1.3. Dependencies

If a usage direction is required for the Track Edge Point, the Directed Track Edge Point shall be used instead (see next chapter 7.1.2 Directed Track Edge Point).

7.1.2. Directed Track Edge Point

Directed Track Edge Point is a specialized class of Track Edge Point which provides an explicit usage direction in relation to the referenced Track Edge.

7.1.2.1. Definition

Table 10 Definition Directed Track Edge Point

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-SO-DTEP	**TrackEdgePoint :: DirectedTrackEdgePoint**						
T2-SO-DTEP-1		direction	Direction in relation to Track Edge direction	ENUM	Start to End End to Start Both	1	

7.1.2.2. Basis / rules and regulations

A Directed Track Edge Point shall be used to provide topological references to a direction dependent track properties e.g. signals or marker boards which are valid only in one direction or other relevant domain objects which are valid for both directions.

7.1.2.3. Engineering rules

Directed Track Edge Points (DTEP) are **direction dependent points,** i.e. different instances of Directed Track Edge Points can be defined depending on its applicability towards underlying track Edge usage direction. (Refer to direction attribute from the above table).

- Start to End
    - Directed Track Edge Points that are valid for travel from start Track Node to end Track Node are set with direction **'Start to End'**.
- End to Start
    - Directed Track Edge Points that are valid for travel from end Track Node to start Track Node are set with direction **'End to Start'**.
- Both
    - Directed Track Edge Points that are valid for both directions of travel with respect to the referenced Track Edge are set with direction **'Both'**.
      Rationale: Although Track Edge Points (TEP) with no definite direction and the DETP with 'both' as direction are same. The reason for using the DTEP' lies on the fact that it offers us an optimised separation from the TEPs referencing start / end points of Track Edge Section (TES). This would eventually simplify the algorithms used by systems to fetch Track Edge and travel direction specific data.

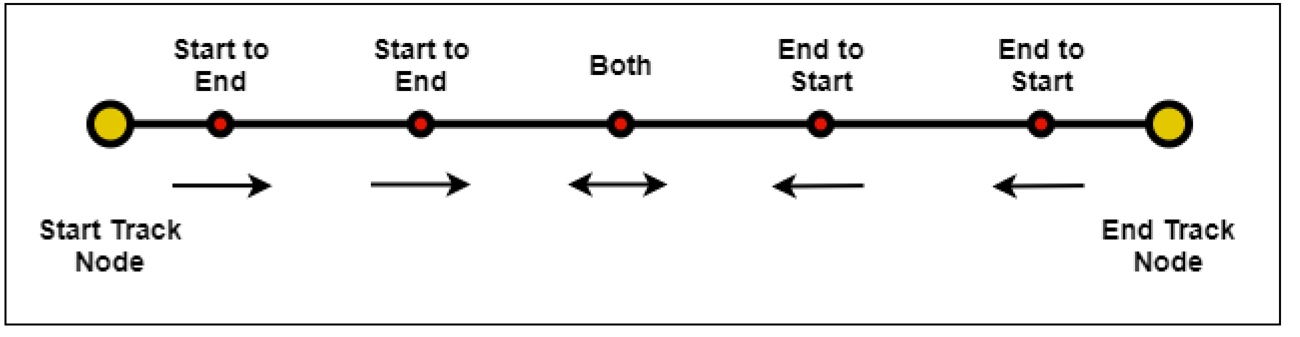


Figure 21 Direction of Directed Track Edge points

7.2. Linear objects

7.2.1. Track Edge Section

Base-element to describe non-directed linear objects (with a linear extension) and to place them on (or at the side of) a Track Edge. A Track Edge Section can only refer to exactly one Track Edge. Sections across multiple Track Edges must be defined as multiple Track Edge Sections, each specific to respective Track Edge.

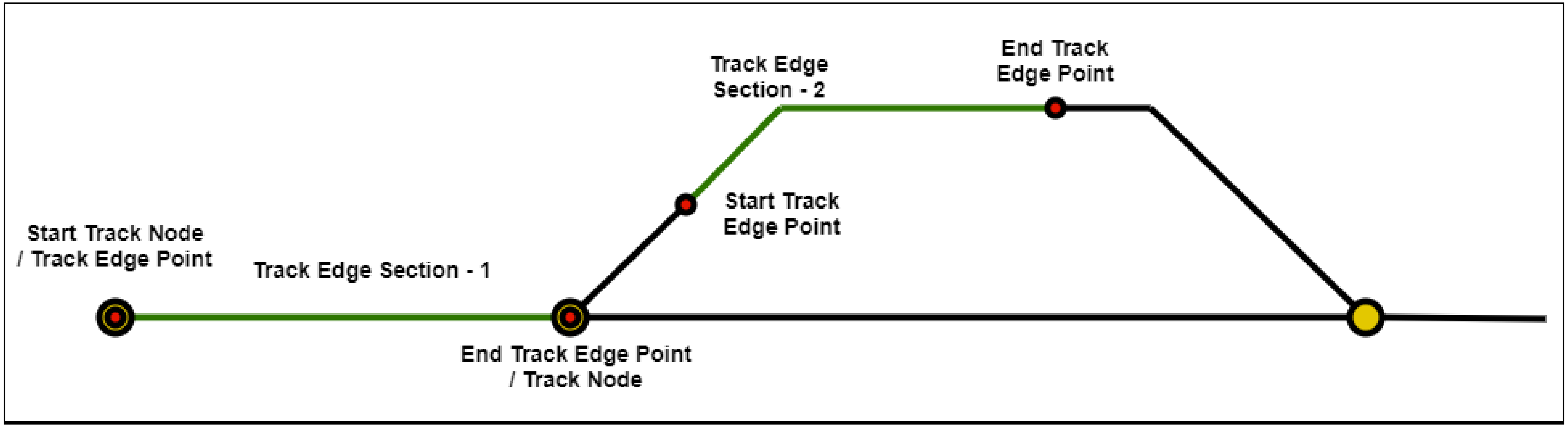


Figure 22 Track Edge Section

7.2.1.1. Definition

Table 11 Definition Track Edge Section

ID	Object	Attribute	Description	Type	Range	Cardi-nality	Unit
T2-LO-TES	**TrackEdgeSection**						
T2-LO-TES-1		id	Unique generated ID	String	UUID	1	
T2-LO-TES-2		name	Name of Track Edge Section	String	alphanu-meric	1	
T2-LO-TES-3		hasStartTrackEdgePoint	Reference to the Track Edge Point, where the Tack Edge Section starts.	*TrackEdge-Point*	-	1	
T2-LO-TES-4		hasEndTrackEdgePoint	Reference to the Track Edge Point, where the Tack Edge Section ends.	*TrackEdge-Point*		1	
T2-LO-TES-5		length	Real length of Track Edge Section in meters (with 3 decimal places).	Double	0.000 - 999999.999	1	m
T2-LO-TES-6		lateralOffset	Represents a constant lateral offset value throughout the Track Edge Section in meters from the Track Edge (with 3 decimal places). Positive values represent a distance to the right and negative values a distance to the left, in relation to the Track Edge direction.	Double	0.000 - 99.999	0..1	m
T2-LO-TES-7		isPartOfTrackEdge	Reference to the Track Edge	*TrackEdge*	-	1	

7.2.1.2. Basis / rules and regulations

Track Edge Sections shall be used to provide references to elements representing **track properties** like (non-exhaustive list):

- Speed Profiles
  - Static Speed Profile
  - Specific Static Speed Profile
  - Axle Load Speed Profile
- Track Geometry
  - Curve
  - Gradients
  - Cant
- Drive Protection Sections

Note: This list will be updated as more domain objects will be defined.

7.2.1.3. Engineering rules

The start Track Edge Point shall be defined as the one that lies on the lower route kilometrage of the Track Edge Section and vice-versa for the end Track Edge Point.

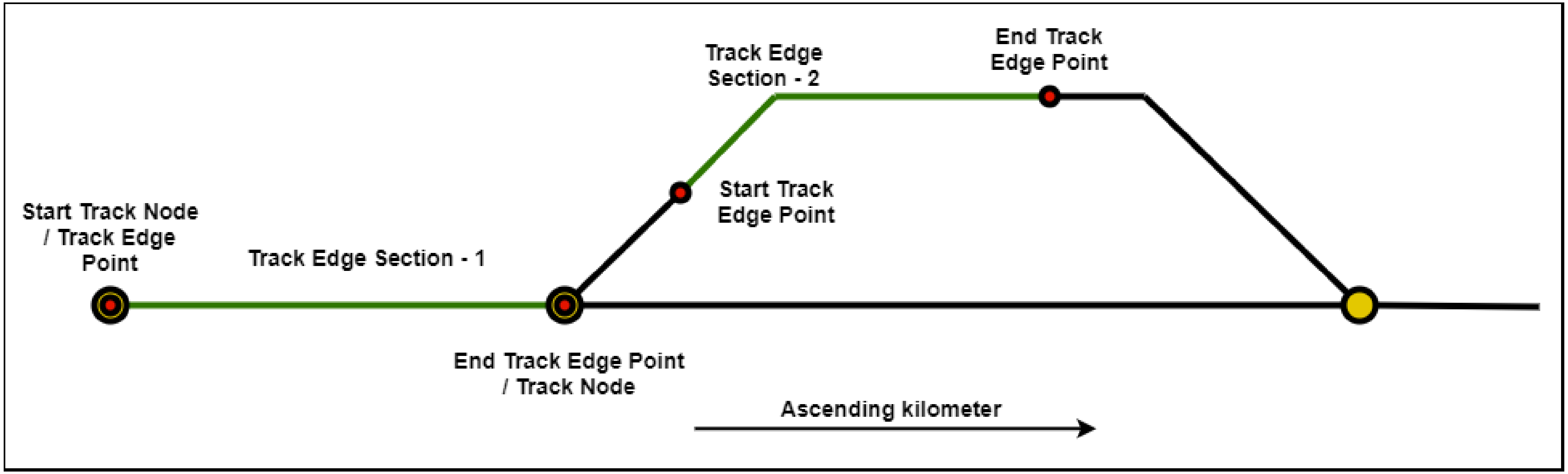


Figure 23 Position of the start and end Track Edge Point

7.2.1.4. Dependencies

If a usage direction is required for the Track Edge Section, the Directed Track Edge Section shall be used instead (see next chapter 7.2.2 Directed Track Edge Section).

7.2.2. Directed Track Edge Section

Directed Track Edge Section is a specialized class of Track Edge Section which provides an explicit usage direction in relation to the referenced Track Edge.

7.2.2.1. Definition

Table 12 Definition Directed Track Edge Section

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-LO-DTES	**TrackEdgeSection :: DirectedTrackEdgeSection**						
T2-LO-DTES-1		direction	Direction in relation to Track Edge direction	ENUM	Start to End End to Start Both	1	

7.2.2.2. Basis / rules and regulations

A Directed Track Edge Section shall be used to provide topological references to direction dependent track properties, e.g. speed profiles which are valid only in one direction and vary in the other.

Similar to the Directed Track Edge Points, the Directed Track Edge Sections are also defined based on the track usage direction, i.e. for Start to End and End to Start direction.

7.2.2.3. Engineering rules

A Directed Track Edge Section shall always have an effective direction in relation to the underlying Track Edge.

- *Start to End* → from start Track Edge Point to end Track Edge Point
    - Directed Track Edge Sections that are valid for ‘Start to End’ direction of travel with respect to Track Edge are set with direction **‘Start to End’**.
- *End to Start* → from end Track Edge Point to start Track Edge Point
    - Directed Track Edge Sections that are valid for ‘End to Start’ direction of travel with respect to Track Edge are set with direction **‘End to Start’**.
- Both → from end Track Edge Point to start Track Edge Point (or) from start Track Edge Point to end Track Edge Point
    - Directed Track Edge Sections that are valid for both directions of travel with respect to Track Edge are set with direction **‘Both’**.

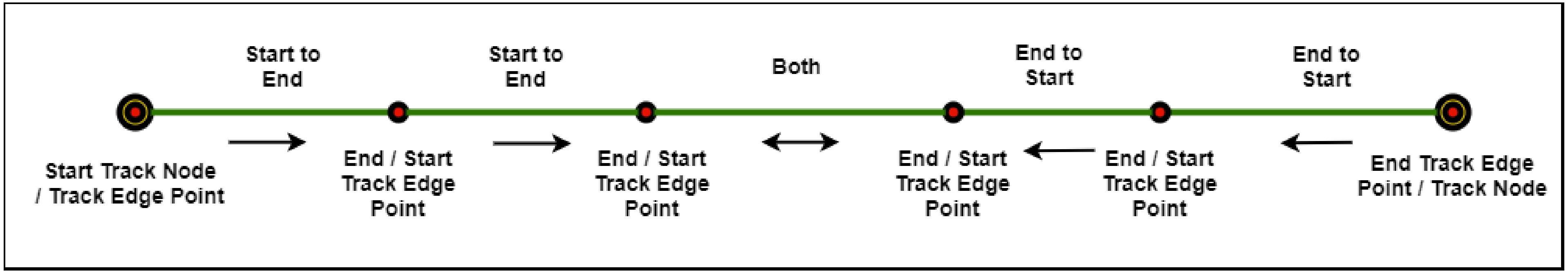


Figure 24 Direction of Track Edge Sections

7.2.2.4. Dependencies

The following table provides an overview based on the usage of Track Edge Section and Directed Track Edge Section for different track properties.

Table 13 Track Edge Section usage types

Track property	Usage type
Speed Profiles (Static, Specific, Axle Load)	Directed Track Edge Section
Drive Protection Sections	Track Edge Section
Curve	Track Edge Section
Gradients	Track Edge Section
Cant	Track Edge Section

7.3. Area Objects

7.3.1. Track Area

A Track Area groups an arbitrary number of Track Edge Sections. The sections don't have to be connected / adjacent to each other. The Track Area groups the sections to a logical entity, usually to illustrate a technical or functional context.

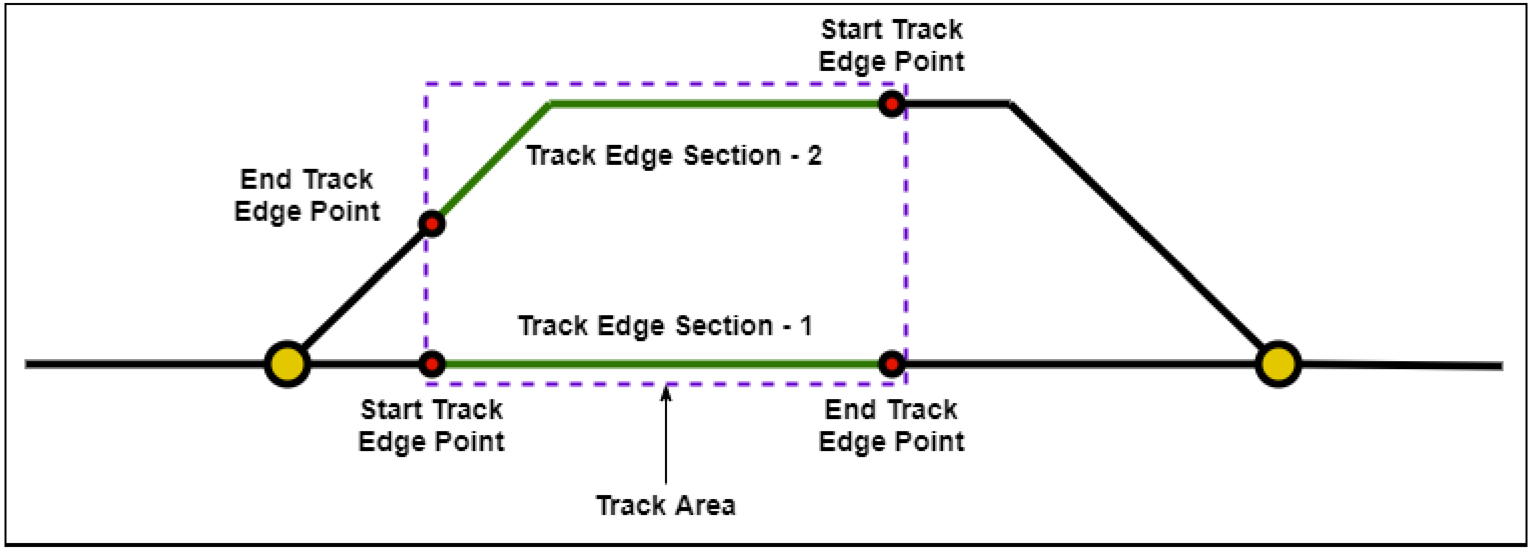


Figure 25 Track Area

7.3.1.1. Definition

Table 14 Definition TrackArea

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-AO-TA	**TrackArea**						
T2-AO-TA-1		id	Unique generated ID	String	UUID	1	
T2-AO-TA-2		consistsOfTrackEdge-Section	List of (directed) Track Edge Sections to be grouped.	*TrackEdgeSection*	-	1..*	

7.3.1.2. Dependencies

Depending on whether a usage direction for the containing Track Edge Sections is required or not, the attribute “consistsOfTrackEdgeSection” shall either contain a list of Track Edge Section or Directed Track Edge Section objects. It shall not contain a mixture of both variants.

Note: Track Area(s) (TA) (and their derived classes Contiguous Track Area (CTA) and Linear Contiguous Track Area (LCTA)) can also be built up of just one Track Edge Section. Despite the fact it shall be classified as a TA/LCTA/CTA and not as a Track Edge Section.

7.3.2. Contiguous Track Area

The Contiguous Track Area is a specialized class of Track Area to group a number of Track Edge Sections, which are **topologically connected** to each other such that they form one or more paths.

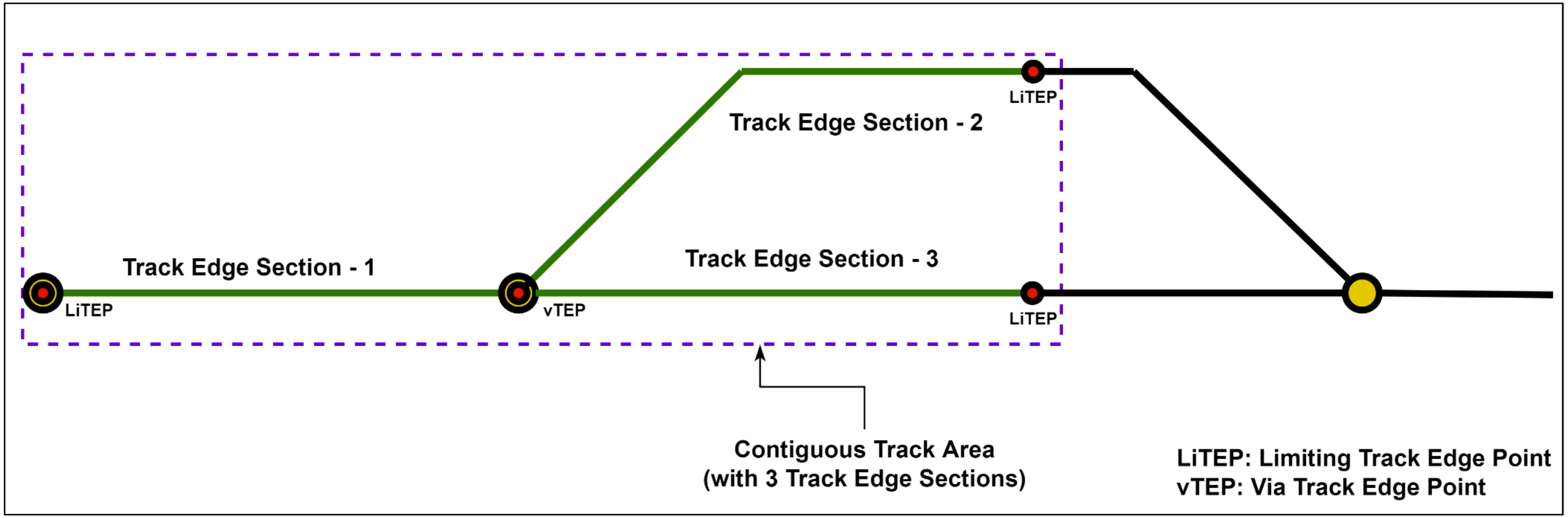


Figure 26 Contiguous Track Area

7.3.2.1. Definition

Table 15 Definition Contiguous Track Area (CTA)

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-AO-CTA	**TrackArea :: Contiguous TrackArea**						
T2-AO-CTA-1		limitingTrackEdgePoint	List of Track Edge Points limiting the de-fined CTA at the extremities.	*TrackEdgePoint*	-	2..*	
T2-AO-CTA-2		viaTrackEdgePoint	List of interconnected Track Edge Points between the Track Edge Sections that are part of defined CTA.	*TrackEdgePoint*	-	0..*	

7.3.2.2. Basis / rules and regulations

There exists one or more paths from a given constituent Track Edge Point at one extremity of the Contiguous Track Area to any other given constituent Track Edge Point at the other extremity of the Contiguous Track Area AND each path is navigable via constituent Track Edge Sections, i.e. all constituent Track Edge Sections are joined together in one shape.

7.3.3. Linear Contiguous Track Area

The Linear Contiguous Track Area is a specialized class of Track Area to group an ordered and directional number of topologically connected Track Edge Sections such that they form exactly one path.

The sequence of sections needs to be unambiguously navigable along the track network. Meaning that, each end of a Track Edge Section coincides with the start / end of the immediately succeeding section in the sequence.
The sequence can be travelled in ascending and descending order given that Track Navigability between Track Edges allows it.

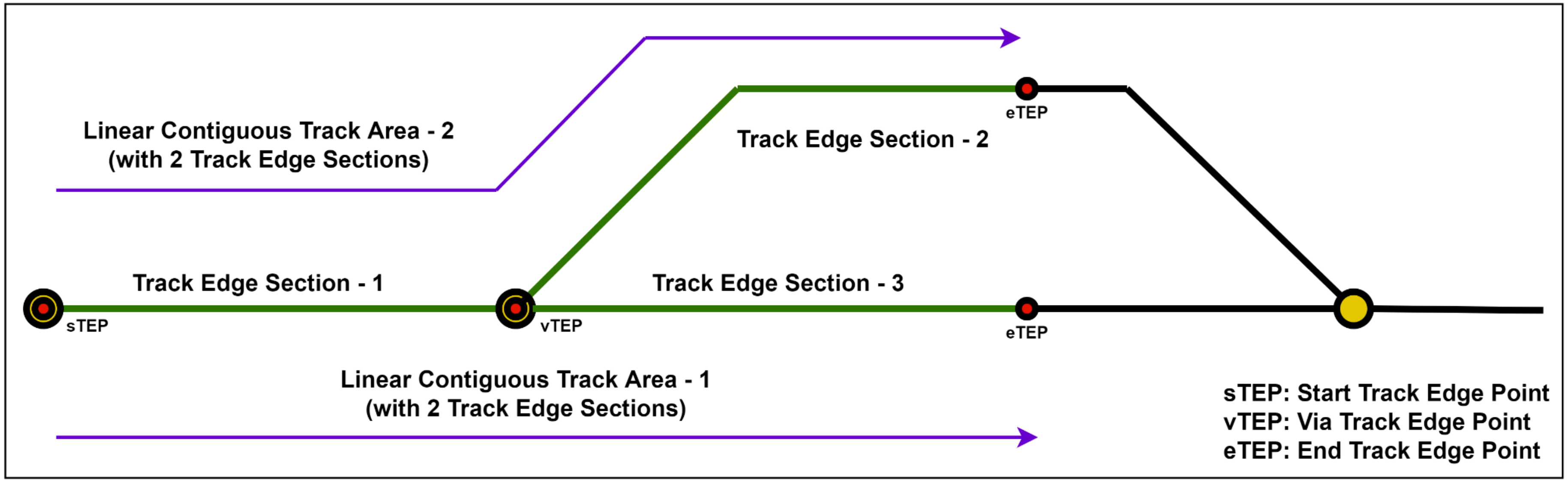


Figure 27 Linear Contiguous Track Area

7.3.3.1. Definition

Table 16 Definition Linear Contiguous Track Area (LCTA)

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T2-AO-LCTA	**TrackArea :: LinearContiguous TrackArea**						
T2-AO-LCTA-1		startTrackEdgePoint	Start Track Edge Point of the first Track Edge Section within the LCTA.	*TrackEdgePoint*	-	1	
T2-AO-LCTA-2		viaTrackEdgePoint	List of interconnected Track Edge Points between the Track Edge Sec-tions that are part of the defined LCTA.	*TrackEdgePoint*	-	0..*	
T2-AO-LCTA-3		endTrackEdgePoint	End Track Edge Point of the last Track Edge Section within the LCTA.	*TrackEdgePoint*	-	1	

7.3.3.2. Basis / rules and regulations

There exists exactly two constituent Track Edge Points at the extremities of the Linear Contiguous Track Area AND there exists exactly one path from any given constituent Track Edge Point at one extremity of the Linear Contiguous Track Area to the other given constituent Track Edge Point at the other extremity of the Linear Contiguous Track Area AND the path is navigable via constituent Track Edge Section, i.e. all constituent Track Edge Sections are joined together in one line.

7.3.3.3. Engineering rules

The LCTA has no explicit direction, but rather it shall be derived implicitly from the start and end Track Edge Points, i.e.

- *Start to End* → from start Track Edge Point to end Track Edge Point
- *End to Start* → from end Track Edge Point to start Track Edge Point

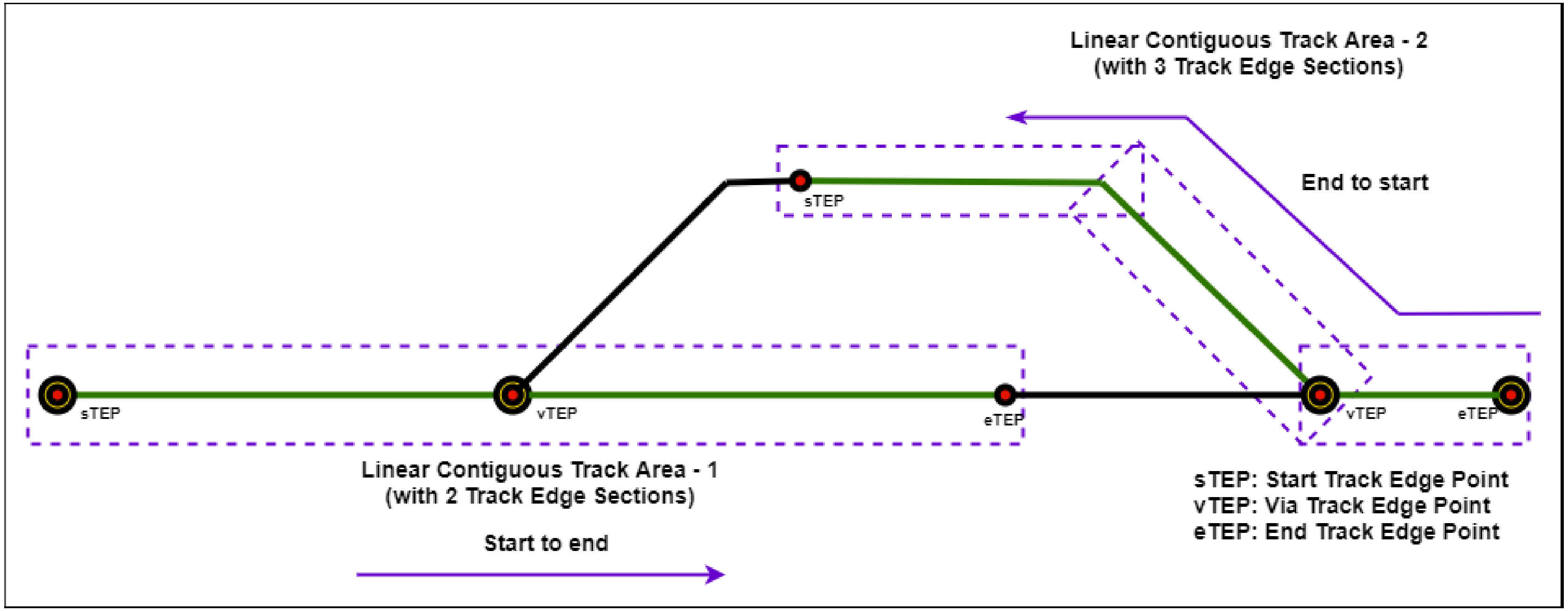


Figure 28: Linear Contiguous Track Area direction

7.3.3.4. Dependencies

In case a LCTA is built up of Directed Track Edge Section*(s),* the direction of the contained Directed Track Edge Section*(s)* have no relation to the direction of the actual LCTA per se and shall not be considered for topological usage purposes.

8. Tier 3: Domain Objects

8.1. Area of Control

The Area of Control (AoC) is a special subclass of Track Area to define the common topologically delimited area of control of the subsystems.

8.1.1. Definition

Table 17 Definition Area of Control

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-AOC	**TrackArea :: AreaOfControl**						
T3-AOC-1		name	Name of the Area of Control	String	alphanumeric	1	
T3-AOC-2		identifier	Identifier of the Area of Control	String	alphanumeric	1	

8.1.2. Basis / rules and regulations

These are specified by the trackside protection system.

8.1.3. Engineering rules

The Track Edge Sections within an Area of Control shall always cover complete Track Edges, an Area of Control must not change somewhere on the Track Edge at a specific Track Edge Point.

An Area of Control shall be delimited by Track Nodes of type System Border (if at least the first adjacent Track Edge is known) or End of Track (if the topology outside the Area of Control is unknown).

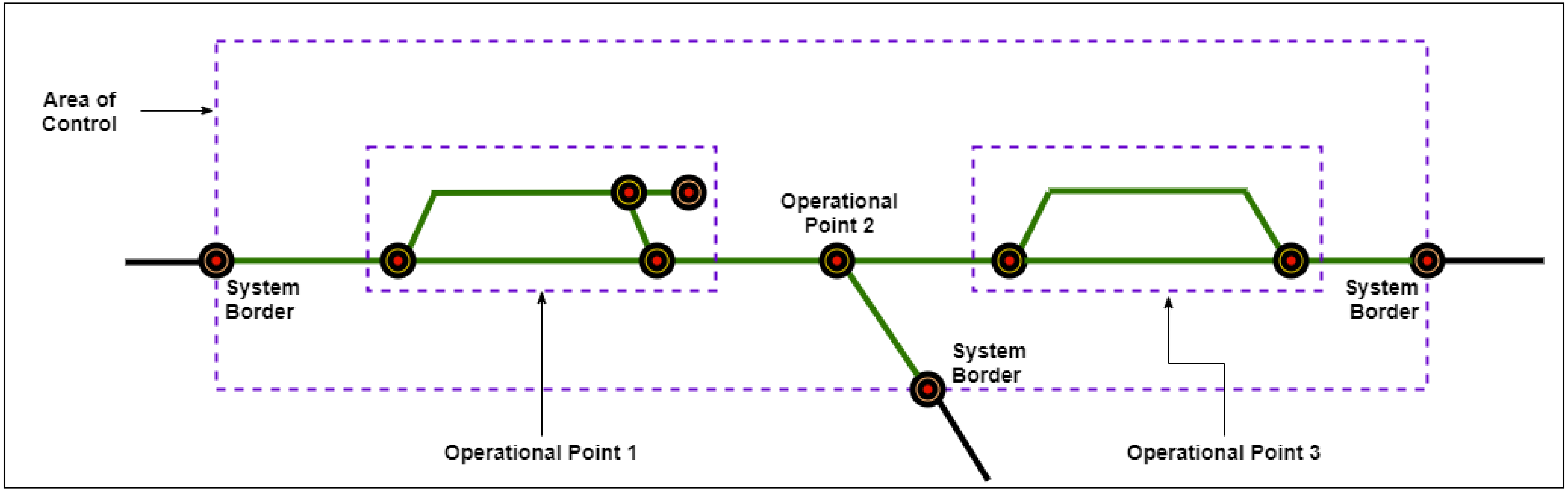


Figure 29 Area of Control

8.1.4. Dependencies

After defining the Area of Control, the Operational Points shall be assigned to the respective AoC (see chapter 5.2).

8.2. Speed Profiles

The permitted speed at which the train is allowed to travel is defined by different kinds of speed restrictions:

- Static Speed Profile
- Specific Static Speed Profile
- Axle Load Speed Profile

The speed restriction categories are independent of each other. This means that one speed restriction category cannot affect, nor be affected by, any other category of speed restrictions.

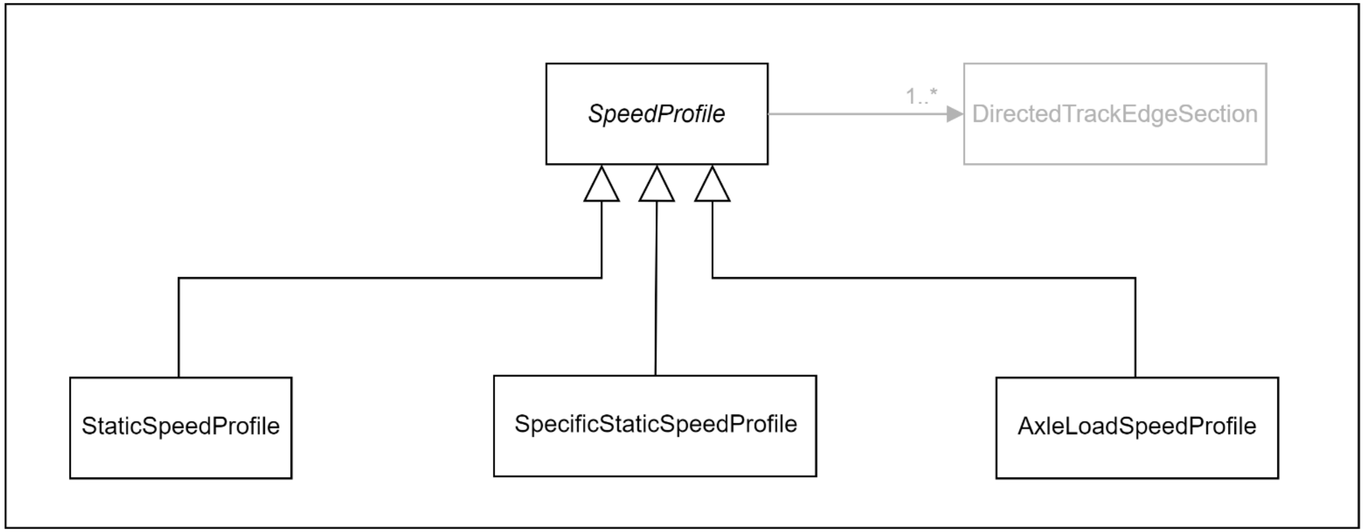


Figure 30 Taxonomy Speed Profile

8.2.1. Speed Profile

8.2.1.1. Definition

Base definition of a speed profile with properties, which are applicable to all speed profile categories. Specific speed profiles are defined as an extension to this base object.

Table 18 Definition Speed Profile

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-SP	***SpeedProfile***						
T3-SP-1		id	Unique generated ID	String	UUID	1	
T3-SP-2		name	Name of the speed profile	String	alphanumeric	1	
T3-SP-3		appliesToTrackEdge-Section	Directed Track Edge Sections which apply to the defined speed profile.	*Directed TrackEdgeSection*	-	1..*	
T3-SP-4		speed	Speed in km/h	Integer	0 - 600	1	km/h

Note: The Speed Profile is an *abstract object*, which cannot be used standalone. Only the derived objects must be used to define a specific speed profile.

8.2.1.2. Dependencies

The Speed Profile always defines a direction for the containing Track Edge Sections. If the Speed Profile is applicable to both directions, the direction of the Track Edge Sections has to be set to “Both” (rather than defining just a Track Edge Section).

The cardinality 1..* for the referenced Track Edge Sections is not to be confused with instantiation of TA(s). In case of speed profiles, this cardinality allows us to use the same object instantiation for several Track Edge Sections that exist on the network with same speed profile values.

8.2.2. Static Speed Profile

The Static Speed Profile (SSP) is a description of the fixed speed restrictions of a given piece of track. The speed restrictions can be related to e.g. maximum line speed, curves, points, tunnel profiles, bridges.

8.2.2.1. Definition

Table 19 Definition Static Speed Profile

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-SSP	***SpeedProfile* :: StaticSpeedProfile**						

Note: The Static Speed Profile does not define additional attributes as already contained in the derived based class.

8.2.2.2. Basis / rules and regulations

The Static Speed Profiles shall be represented as TES with constant speed profile throughout the section. They shall be provided for the entire track network without breaks.

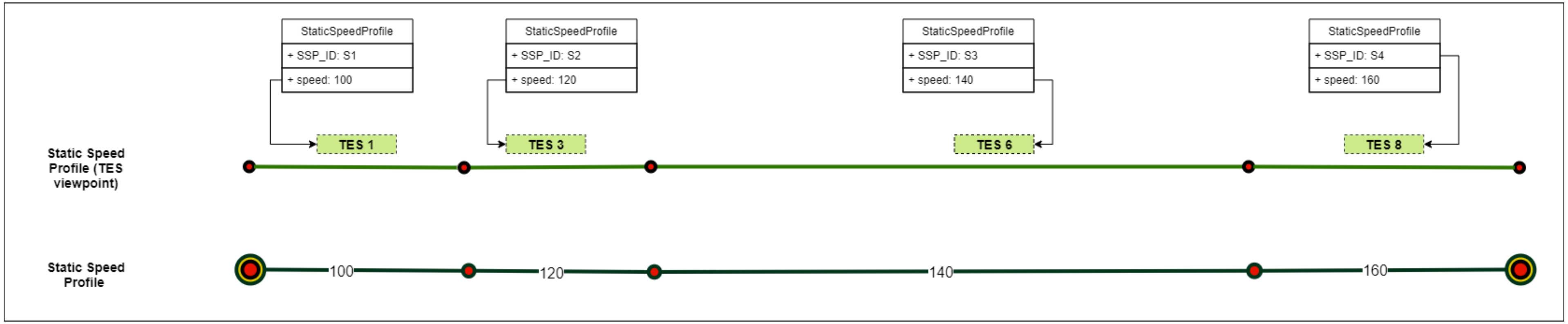


Figure 31: Static Speed Profiles

8.2.2.3. Dependencies

The Static Speed Profiles (if needed) can also be converted to a point-based reference system (TEPs) using the section-based reference (TESs).

It shall be possible to use several Static Speed Profile Categories; one Basic SSP category (defined in this chapter) and specific SSP categories related to the international train categories (described in the next chapter 8.2.3 Specific Static Speed Profiles).

8.2.3. Specific Static Speed Profiles

The specific SSP categories are decomposed into two types:

- The “Cant Deficiency” SSP categories: the cant deficiency value assigned to one category shall define the maximum speed, determined by suspension design, at which a particular train can traverse a curve and thus can be used to set a specific speed limit in a curve with regards to this category.
- The “other specific” SSP categories: it groups all other specific SSP categories corresponding to the other international train categories.

8.2.3.1. Definition

Table 20 Definition Specific Static Speed Profile

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-SSSP	***SpeedProfile* :: SpecificStatic SpeedProfile**						
T3-SSSP-1		cantDeficiency-Category	ENUM value indicating the suitable cant deficiency category of the train. See column range for an elaborative list (Section 7.5.1.82.2 [7]).	ENUM	80mm 100mm 130mm 150mm 165mm 180mm 210mm 225mm 245mm 275mm 300mm	0..1	
T3-SSSP-2		otherSpecificStatic SpeedProfileType	ENUM value indicating the suitable Specific speed profile category. See column range for an elaborative list (Section 7.5.1.82.2 [7]).	ENUM	Specific Cant Specific Freight Train P Specific Freight Train G Specific Passenger Train	1	

8.2.3.2. Basis / rules and regulations

The Specific Static Speed Profiles (SSSP) shall be represented as TES with constant speed profile throughout the section. They do not need to be defined continuous throughout the track network but defined on track network where needed.

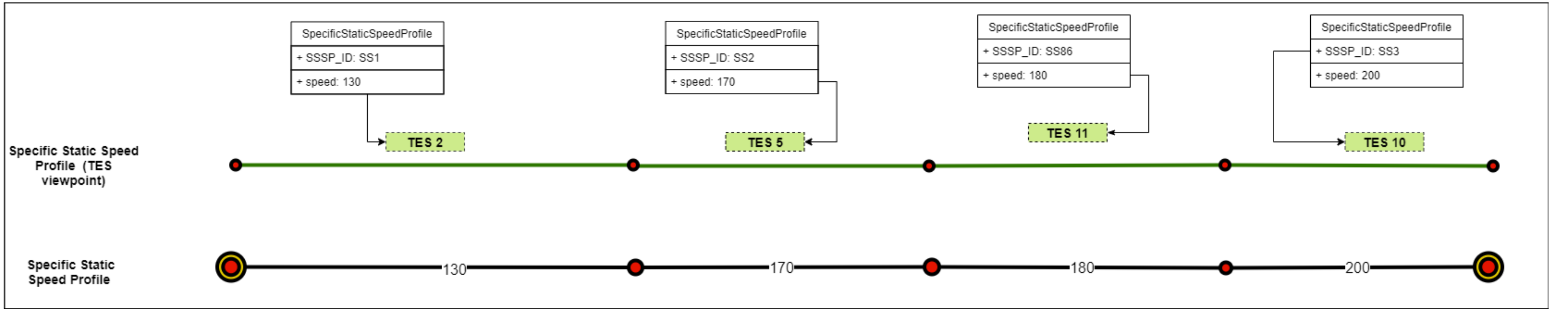


Figure 32: Specific Static Speed Profiles

8.2.3.3. Dependencies

The specific static speed profiles (if needed) can also be converted to a point-based reference system (TEPs) using the section-based reference (TESs).

8.2.4. Axle Load Speed Profile

Definition of speed profile for axle load categories.

8.2.4.1. Definition

Table 21 Definition Axle Load Speed Profile

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-ALSP	***SpeedProfile* ::** **AxleLoadSpeedProfile**						
T3-ALSP-1		axleLoadCategory	ENUM value indicating the suitable Axle load category. See column range for an elaborative list (Section 7.5.1.62 [7]).	ENUM	A HS17 B1 B2 C2 C3 C4 D2 D3 D4 D4XL E4 E5	1	

8.2.4.2. Basis / rules and regulations

The Axle Load Speed Profiles shall be represented as TES with constant speed profile throughout the section. They do not need to be defined continuous throughout the track network but defined on track network where needed.

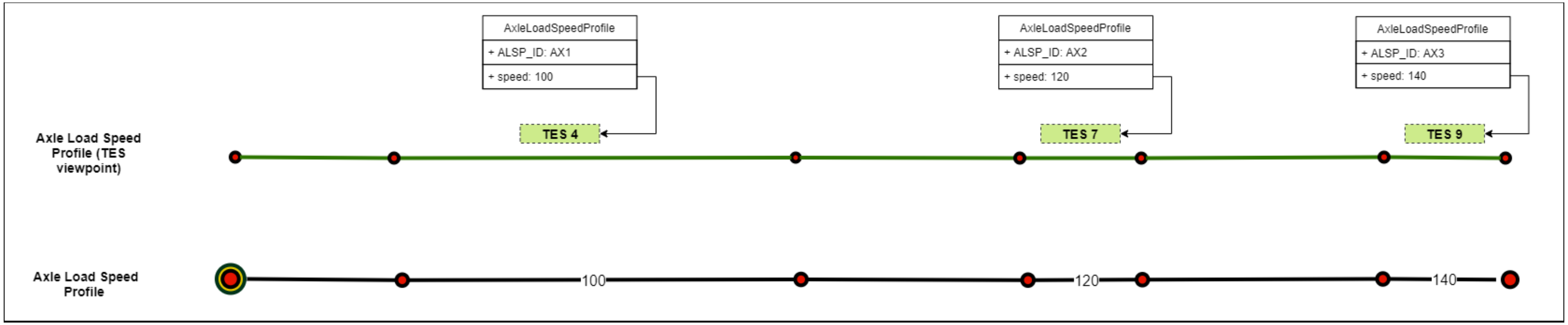


Figure 33: Axle Load Speed Profiles

8.2.4.3. Engineering rules

For each section with a speed restriction due to axle load, the different speed value(s) and for which minimum axle load category this speed value(s) applies shall be specified.

Different speed restrictions depending on the axle load category can be applicable for the same section.

8.2.4.4. Dependencies

The axle load speed profiles (if needed) can also be converted to a point-based reference system (TEPs) using the section-based reference (TESs).

8.3. Gradient

Gradient describes the vertical alignment of the track with the use of the following geometric primitives (vector-based approach):

- Lines: Used for ramps or flat track sections
- Circle sections: Used for transitions between different line sections

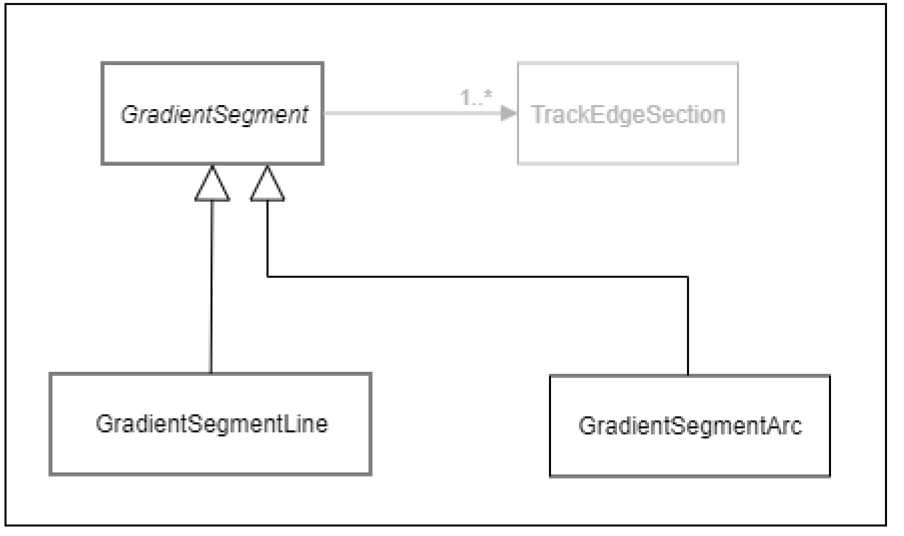


Figure 34: Taxonomy Gradient

8.3.1. Gradient Segment

Base definition of a gradient with properties, which are applicable to all derived elements of the gradient. The specific elements of a gradient are defined as an extension to this base object.

8.3.1.1. Definition

Table 22 Definition GradientSegment

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-GS	***GradientSegment***						
T3-GS-1		id	Unique generated ID	String	UUID	1	
T3-GS-2		name	Name of the gradient profile	String	alphanumeric	1	
T3-GS-3		appliesToTrackEdge-Section	Track Edge Sections which apply to the defined gradient profile.	*TrackEdgeSection*	-	1..*	

Note: The Gradient Segment is an *abstract object*, which cannot be used standalone. Only the derived objects must be used to define a specific gradient element.

8.3.1.2. Dependencies

The Gradient Segments always have an implicit direction given by the referenced Track Edge Sections, which is from the start Track Edge Point to the end Track Edge Point.

The cardinality 1..* for the referenced Track Edge Sections is not to be confused with instantiation of TA(s). In case of Gradient Segments, this cardinality allows us to use the same object instantiation for several Track Edge Sections that exist on the network with same Gradient Segment values.

8.3.2. Gradient Segment Line

The Gradient Segment Line defines the ramps or flat track sections of a gradient section.

8.3.2.1. Definition

Table 23 Definition Gradient Segment Line

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-GSL	***GradientSegment* :: GradientSegmentLine**						
T3-GSL-1		gradient	Gradient in "per mill" (with 3 decimal places)	Double	-99.999 - +99.999	1	per mille (‰)
T3-GSL-2		startAltitude	Altitude at the start of the gradient in meter (with 3 decimal places)	Double	-999.999 - +9999.999	1	m

8.2.1.2. Engineering rules

The representation of the ramps or flat track sections using the geometric primitive line is shown in the following figure:

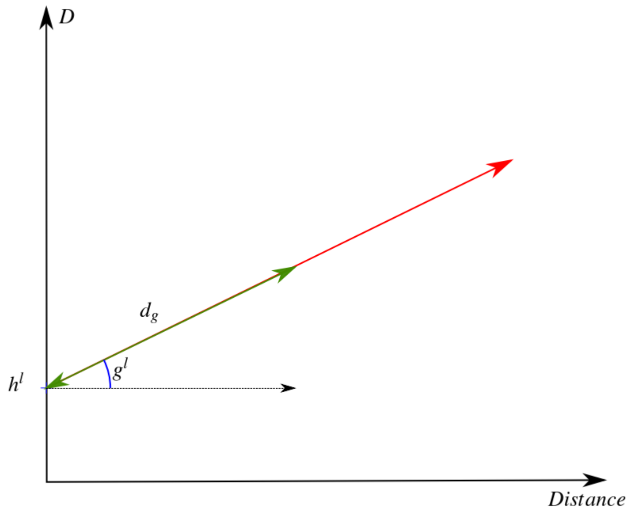


Figure 35 Representation of a Gradient Segment Line

The line has the following parameters:

- h^l: Altitude at the start Track Edge Point of the referenced Track Edge Section
- g^l: Inclination of the track in permille
    - < 0: Downhill in the direction from the start to the end Track Edge Point
    - 0: Plane
    - > 0: Uphill in the direction from the start to the end Track Edge Point
- d_p: Length of referenced Track Edge Section

The desired features at an arbitrary point can be derived using the following equations:

➔ For line sections, the gradient at an arbitrary point along the Track Edge Section is always constant and equal to the initial gradient.
➔ The altitude (h_d) at an arbitrary point can be calculated using the formula:

$$h_d = h^l + \frac{g^l}{1000} d$$

Where d is the distance from start of Track Edge Section to the arbitrary point.

8.3.3. Gradient Segment Arc

The Gradient Segment Arc defines the transitions between different line sections.

8.3.3.1. Definition

Table 24 Definition Gradient Segment Arc

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-GSA	***GradientSegment* :: GradientSegmentArc**						
T3-GSA-1		radius	Radius of the arc in meter (with 3 decimal places)	Double	-9999.999 - 9999.999	1	m
T3-GSA-2		startAltitude	Altitude at the start of the gradient in meter (with 3 decimal places)	Double	-999.999 - +9999.999	1	m
T3-GSA-3		initialGradientAngle	Angle (θ) in degrees (°) between the north-east plane and the track at starting point (with 3 decimal places)	Double	0.000 - 359.999	1	De-gree (°)

8.3.3.2. Engineering rules

The representation of the transition sections using the geometric primitive circle is shown in the following figure:

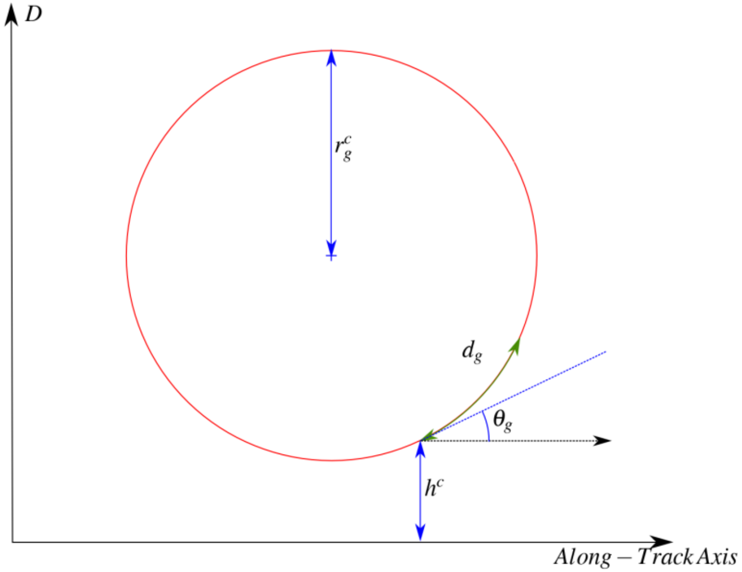


Figure 36 Representation of a Gradient Segment Arc

The circle has the following parameters:

- h^c: Altitude at the start Track Edge Point of the referenced Track Edge Section
- $r^c{}_g$: Radius of the arc resp. circle
  - A circle section of the gradient layer having its centre point above the track has a positive radius, whereas a circle section having its centre point below the track has a negative radius. In this case the track direction is defined in azimuth direction.
- d_g: Length of referenced Track Edge Section
- θ_g: Gradient angle at the start Track Edge Point of the referenced Track Edge Section.

Calculations for gradient and altitude at an arbitrary point along a gradient arc will be introduced in next version.

8.3.4. Example

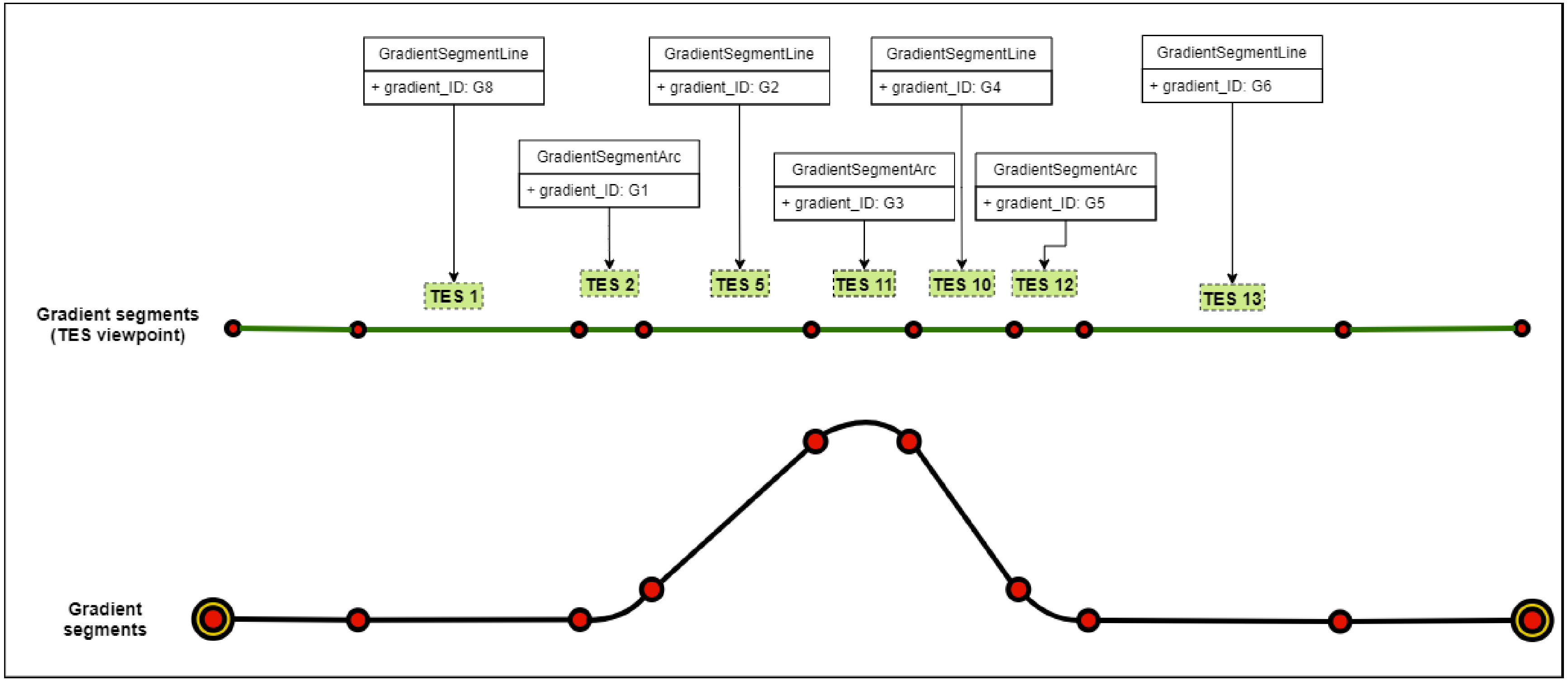


Figure 37: Gradient segments

8.4. Curve

Curve describes the horizontal alignment of the track with the use of the following geometric primitives (vector-based approach):

- Lines (for straight sections)
- Circle sections (for curves)
- Clothoids (for track transition curves)

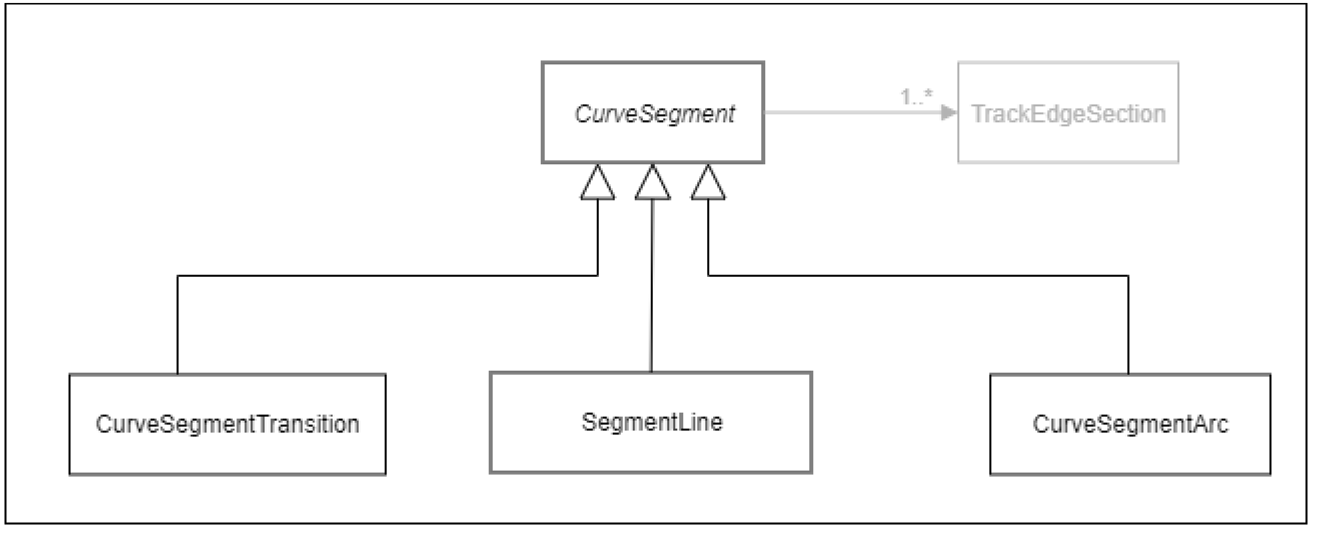


Figure 38: Taxonomy Curve

8.4.1. Curve Segment

8.4.1.1. Definition

Base definition of a curve with properties, which are applicable to all derived elements of the curve. The specific elements of a curve are defined as an extension to this base object.

Table 25 Definition Curve Segment

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-CUS	***CurveSegment***						
T3-CUS-1		id	Unique generated ID	String	UUID	1	
T3-CUS-2		name	Name of curve profile	String	alphanumeric	1	
T3-CUS-3		appliesTo TrackEdgeSection	Track Edge Sections which apply to the defined curve profile.	*TrackEdgeSection*	-	1..*	

Note: The Curve Segment is an *abstract object*, which cannot be used standalone. Only the derived objects must be used to define a specific curve element.

8.4.1.2. Dependencies

The Curve Segments always have an implicit direction given by the referenced Track Edge Sections, which is from the start Track Edge Point to the end Track Edge Point.

The cardinality 1..* for the referenced Track Edge Sections is not to be confused with instantiation of TA(s). In case of Curve Segments, this cardinality allows us to use the same object instantiation for several Track Edge Sections that exist on the network with same Curve Segment values.

8.4.2. Segment Line

8.4.2.1. Definition

The Segment Line defines the straight parts of a Track Edge.

Table 26 Definition Segment Line

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-SL	***CurveSegment* :: SegmentLine**						
T3-SL-1		azimuthAngle	Angle (Ψ) in degrees (°) between the north direction and the line (with 3 decimal places).	Double	0.000 - 359.999	1	De-gree (°)

8.4.2.2. Engineering rules

The representation of the straight sections using the geometric primitive line is shown in the following figure:

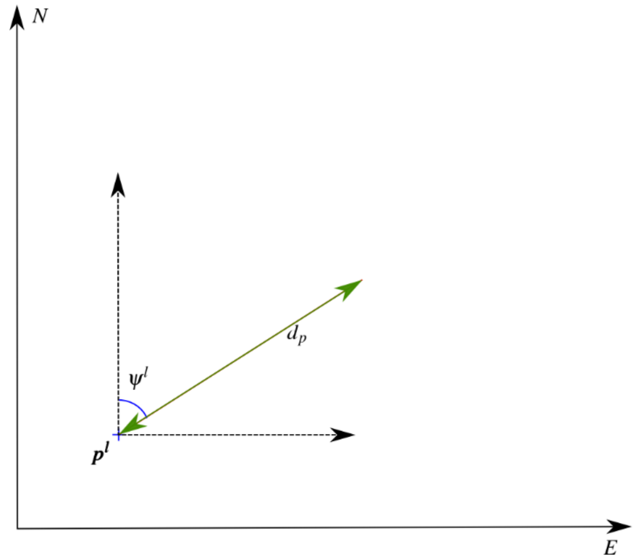


Figure 39 Representation of a Segment Line

The line has the following parameters:

- p^l: Starting Point, Geocoordinate of the start Track Edge Point of the referenced Track Edge Section
- d_p: Length of referenced Track Edge Section
- Ψ^l: Azimuth angle

The desired features at an arbitrary point can be derived using the following equations:

➔ For a line section, the azimuth remains constant throughout the section. Hence, the azimuth at any arbitrary point is equal to the initial azimuth.

Calculations for the coordinates at any arbitrary point will be introduced in next version.

8.4.3. Curve Segment Arc

The Curve Segment Arc defines the curved parts of a Track Edge with a constant radius over the whole curve.

8.4.3.1. Definition

Table 27 Definition Curve Segment Arc

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-CSA	***CurveSegment* :: CurveSegmentArc**						
T3-CSA-1		radius	Radius of the curve arc in meter.	Integer	-99999 - +99999	1	m
T3-CSA-2		initialArcLength	Distance from the north pole of the circle to start-ing point (with 3 decimal places)	Double	0 - 99999.999	1	m
T3-CSA-3		hasCenterAtGeo-Coordinates	Geo-Coordinates of the centre point of the arc (in a specific coordinate system)	*GeoCoordinates*	-	1	

8.4.3.2. Engineering rules

The representation of the curve sections using the geometric primitive circle is shown in the following figure:

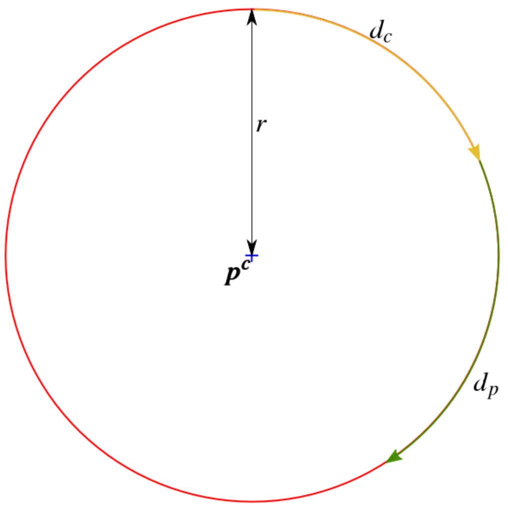


Figure 40 Representation of a Curve Segment Arc

The circle has the following parameters:

- p^c: Geocoordinates of the centre point of the arc resp. circle
- r: Radius of the arc resp. circle (the radius of the curve)
  Note: A circle section having its centre point to the right of the track has a positive radius, whereas a circle section having its centre point to the left of the track has a negative radius. In this case the track direction is defined in azimuth direction.
- d_p: Length of referenced Track Edge Section
- d_c: Initial arc length from the north pole of the circle to the start Track Edge Point of the referenced Track Edge Section

The desired features at an arbitrary point can be derived using the following equations:

➔ The radius of the arc section at an arbitrary point along the Track Edge Section is always equal to the radius of the initial radius of the arc.

Calculations for Azimuth and coordinates at arbitrary point will be introduced in the next version.

8.4.4. Curve Segment Transition

The Curve Segment Transition defines the transitions from the straight to the curved (circle) sections. Currently only clothoids are supported as transition elements.

8.4.4.1. Definition

Table 28 Definition Curve Segment Transition

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-CST	***CurveSegment*** **::** **CurveSegmentTransition**						
T3-CST-1		hasCenterAt GeoCoordinates	Geo-Coordinates of the centre point of the clothoid (in a specific coordinate sys-tem)	*GeoCoordinates*	-	1	
T3-CST-2		clothoidParameter	Clothoid parameter, a fixed and positive constant (with 3 decimal places).	Double	0.001 - 99999.999	1	
T3-CST-3		initialArcLength	Distance from the centre point of the clo-thoid to the starting point (with 3 decimal places)	Double	0 - 99999.999	1	m
T3-CST-4		azimuthAngle	Angle (Ψ) in degrees (°) between the north direction and the orientation of the clothoid center (with 3 decimal places).	Double	0.000 - 359.999	1	De-gree (°)

8.4.4.2. Engineering rules

The representation of the transition sections using the geometric primitive clothoid is shown in the following figure:

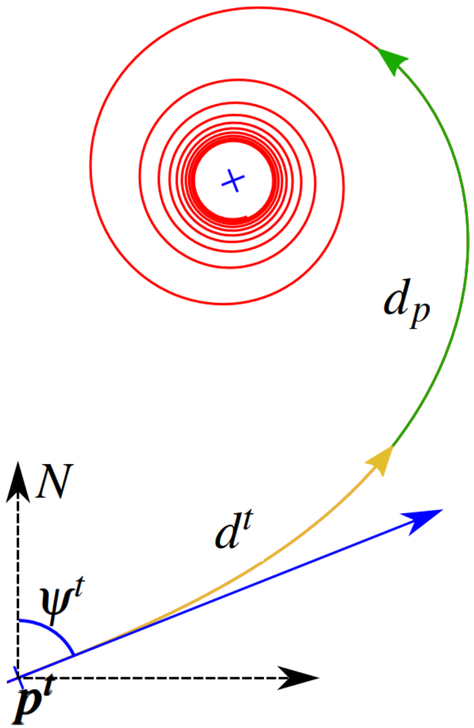


Figure 41 Representation of a Curve Segment Transition

The clothoid has the following parameters:

- p^t: Geocoordinates of the centre point of the clothoid
- d_p: Length of referenced Track Edge Section
- d_t: Initial arc length from centre of clothoid to the start Track Edge Point of the referenced Track Edge Section
- Ψ: Azimuth angle at the centre of clothoid

The desired features at an arbitrary point can be derived using the following equations:

- ➔ The rate of change of radius (r) with respect to the distance (d) or a radius along an arbitrary point along the transition section is provided by the equation:

  r(d) $= \frac{(k^t)^2}{d+d^t}$

  Where,

  k^t is the clothoid parameter. A clothoide with k = 1 is called a standard clothoid.

  r is radius at the arbitrary point

  d is the distance from start of Track Edge Section to the arbitrary point

Calculations for Azimuth and coordinates at arbitrary point will be introduced in the next version.

8.4.5. Example

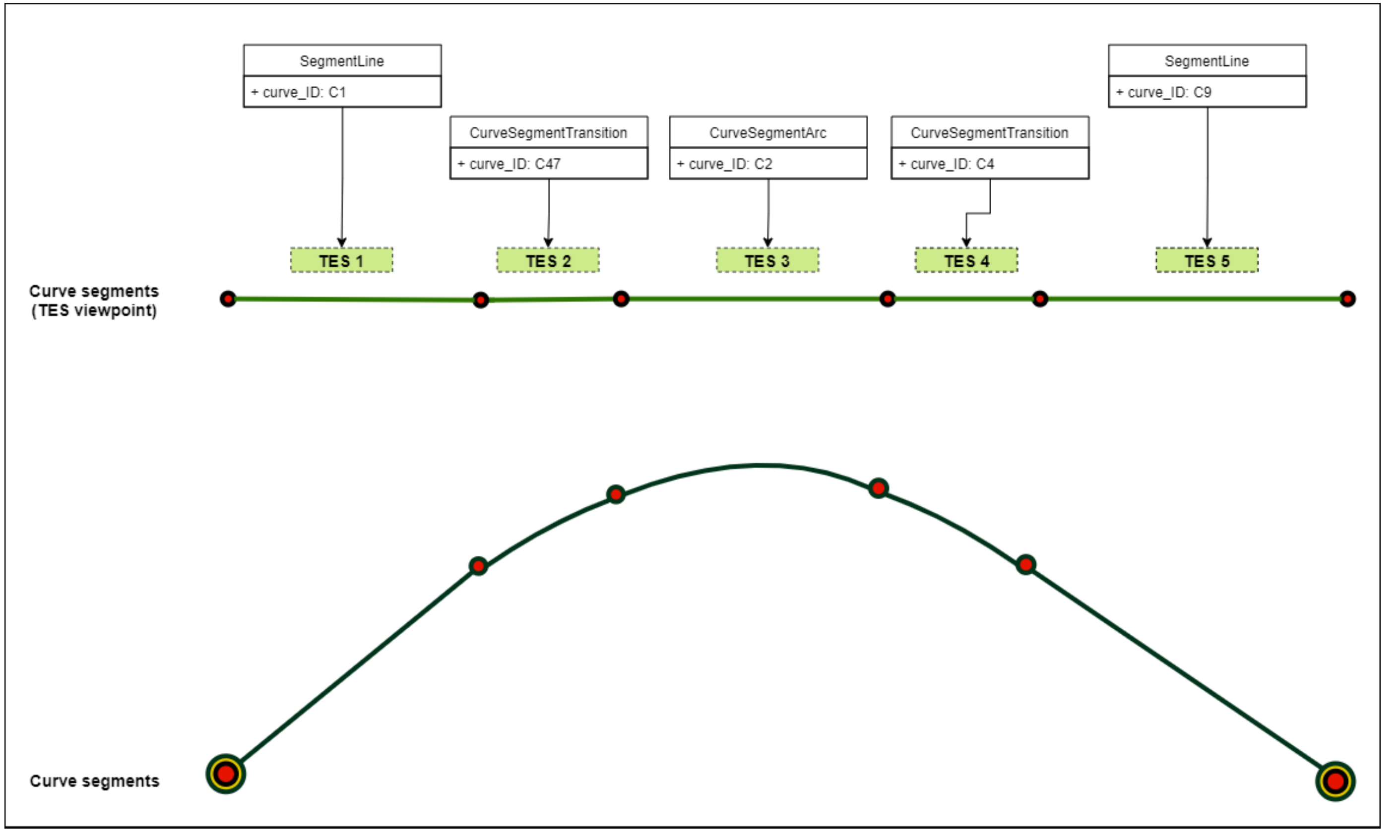


Figure 42: Curve segments

8.5. Cant

Cant describes the rate of change in elevation (height) between the two rails of a railway track with the use of the following geometric primitives (vector-based approach):

- Line: Used for constant cant segments and transitions between constant cant segments

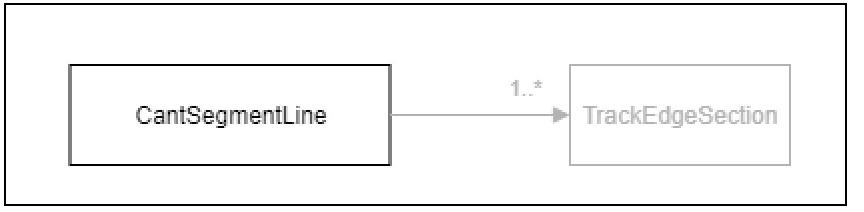


Figure 43: Taxonomy Cant

8.5.1. Cant Segment Line

The Cant Segment Line defines both constant cant segments and transitions between constant cant segments.

8.5.1.1. Definition

Table 29 Definition CantSegmentLine

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-CAS	**CantSegmentLine**						
T3-CAS-1		id	Unique generated ID	String	UUID	1	
T3-CAS-2		name	Name of cant profile	String	alphanumeric	1	
T3-CAS-3		appliesToTrackEdgeSection	Reference to the Track Edge Sections for which the defined cant profile applies.	*TrackEdgeSection*	-	1..*	
T3-CAS-4		startCant	Cant value in mm at the start of the Track Edge Section	Integer	-999 - +999	1	mm
T3-CAS-5		endCant	Cant value in mm at the end of the Track Edge Section	Integer	-999 - +999	1	mm

8.5.1.2. Dependencies

The Cant Segments always have an implicit direction given by the referenced Track Edge Sections, which is from the start Track Edge Point to the end Track Edge Point.

The cardinality 1..* for the referenced Track Edge Sections is not to be confused with instantiation of TA(s). In case of Cant Segments, this cardinality allows us to use the same object instantiation for several Track Edge Sections that exist on the network with same Cant Segment values.

8.5.1.3. Engineering rules

The representation of the cant sections using the geometric primitive line is shown in the following figure:

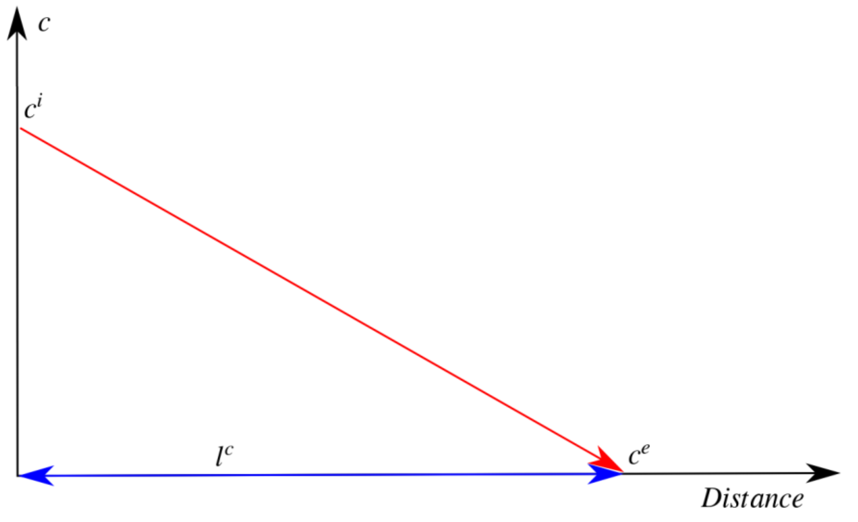


Figure 44 Representation of a Cant Segment Line

The line has the following parameters:

- c^i: Cant at the start Track Edge Point of the referenced Track Edge Section
- c^e: Cant at the end Track Edge Point of the referenced Track Edge Section
- l^c: Length of referenced Track Edge Section

If a section has a constant cant segment, then c^i and c^e are equal. For transition sections the values of c^i and c^e are different.

The desired features at an arbitrary point can be derived using the following equations:

➔ Cant at an arbitrary point along the section can be calculated using the formula,

$$c = c^i + \frac{c^e - c^i}{\mathrm{lc}} d$$

Where d is the distance from start of the Track Edge Section to an arbitrary point on the section.

➔ Roll angle ϕ at an arbitrary point can be calculated using the formula,

$$\phi = \arctan\left(\frac{c}{t^c}\right)$$

where t^c is the track width between the centre of the running rails.

The reference for the cant value is the right rail in the implicit direction of the referenced track edge section. Positive values indicate that the left rail is higher than the right one (right curve), negative values that the left rail is lower than the right one (left curve).

8.5.2. Example

The curves shall be represented as TES with appropriate constant cant throughout the section.

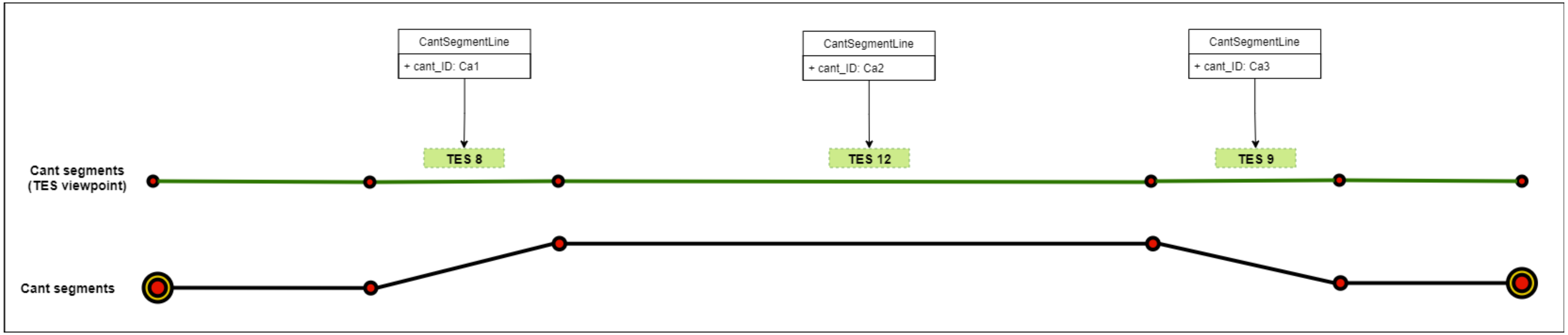


Figure 45: Cant segments

8.6. Allocation Section

Allocation Sections are located as Linear Contiguous Track Areas (LCTA) where one or more clearance gauge conflicts between different tracks arise. The conflict arises when the clearance gauges of different tracks overlap each other. Out of this conflict an exclusive, symmetric interdependency between two or more Allocation Sections can be deduced.

8.6.1. Definition

Table 30 Definition Allocation Section

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-ALS	**AllocationSec-tion**						
T3-ALS-1		id	Unique generated ID	String	UUID	1	
T3-ALS-2		name	Name of the allocation section	String	alphanumeric	1	
T3-ALS-3		appliesToLinear-ContiguousTrackArea	Reference to the LCTA, which defines the extend of this allocation section. The LCTA should contain references to Track Edge Sections. The effective direction of the LCTA can be derived from the start and end TEPs of the LCTA. The direction always leads away from conflict area to non-conflict area of clearance gauge (needed for the risk path search).	*LinearContiguous TrackArea*	-	1	
T3-ALS-4		isDependentOn	This is an exclusive dependency to other Al-location Sections. The dependency refers to the adjacent allocation sections, which might be affected by a moveable object or move-ment permission extent when the current al-location section is fully or partially occupied by a moveable object or movement permis-sion extent.	*AllocationSection*	-	1..*	

8.6.2. Basis / rules and regulations

Exclusive dependency means that if one Allocation Section is fully or partially occupied by a track-bound moveable object or if it is fully or partially contained in a granted movement permission, no movement permission may be granted over any dependent Allocation Section.

A non-complete list of usages is:

- Points, interlaced points
- Diamond crossings
- Single and double slip crossings
- Three rail dual gauge tracks and gauntlet tracks.

All use cases and the according modelling principles can be affiliated to three basic assets:

- a diverging of Track Edges in a Track Node (point)
- a crossing of Track Edges (diamond crossing)
- an interlacing Track Edge or clearance profile (gauntlet).

8.6.3. Engineering rules

- Allocation Sections may overlap each other.
- Each Allocation Section has 1..* dependent Allocation Section.
- Allocation Sections that share a common piece of track (with length > 0) shall not have an exclusive interdependency.
- Allocation Sections are directed using the start and end Track Edge Point of the LCTA to enable the risk path search. The direction always leads away from the dependent Allocation Section (from conflict area to non-conflict area of clearance gauge).
- If the track diverges within an Allocation Section in the direction of the Allocation Section (interlaced points / crossings), both branches need their own Allocation Sections.

An example representation of allocation sections is illustrated below:

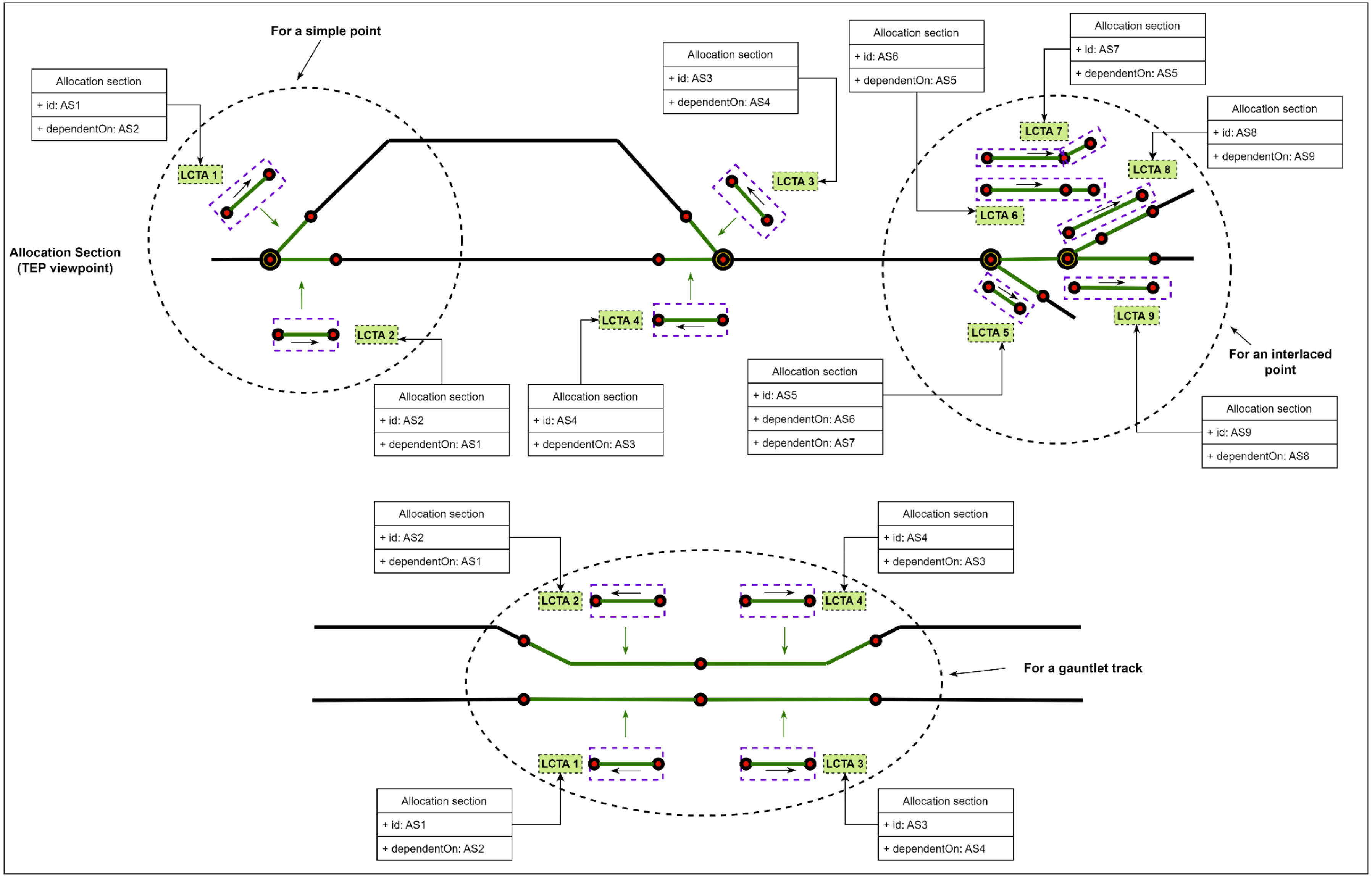


Figure 46 Allocation Sections

8.7. Drive Protection Section

A Drive Protection Section (DPS) represents a track section that can be brought to different drivability states or give flank protection to ensure the drivability or safety of a track route. As such, it is an abstraction for any location on the railway network that may adopt different states due to controllable trackside assets (e.g. points or level crossings).

8.7.1. Definition

Table 31 Definition Drive Protection Section

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-DPS	**DriveProtection-Section**						
T3-DPS-1		id	Unique generated ID	String	UUID	1	
T3-DPS-2		name	Name of the Drive Protection Section	String	alphanumeric	1	
T3-DPS-3		applie-sToTrackEdgeSec-tion	Reference to Track Edge Section, for which the drive protection is valid.	*TrackEdgeSection*	-	1	
T3-DPS-4		flankProtectionDi-rection	Static configuration of the direction (in rela-tion to the TrackEdgeSection) in which the DPS is able provide flank protection (only relevant for points and derailers). This at-tribute does not imply any explicit usage di-rections for the DPS.	ENUM	None Start to End End to Start Both	1	
T3-DPS-5		minimalDrivability	Minimal default drivability state if no feed-back from element is available.	ENUM	None Full Limited	1	

8.7.2. Basis / rules and regulations

Drive Protection Sections (DPS) must be engineered at all locations in the track network where external assets with either movable components or level crossings are present.

In detail, these are (non-exhaustive list):

- Simple points (with and without movable frogs)

- Slip crossings (single and double)
- Diamond crossings with movable frogs
- Derailment devices
- Level crossings
- Turntables and Traversers
- Gates
- Movable bridges

8.7.3. Engineering rules

- Simple points:
    - Two DPSs, one for each end position (right and left position). Start is located at the point tip and end at the end of the tongues. For points with movable frogs the end of DPS is located at the end of the movable frogs (to be derived from point design).
    - Naming convention: DPS-{point number}-{L|R}
    - Minimal default trafficability will be “None”
- Double slip crossings:
    - Eight DPSs, four on each side. Start is located at the point top and end at the end of the tongues (to be derived from point design).
    - Naming convention: DPS-{point number}-{A|B}-{L|R}-{1-2}
    - Minimal default trafficability will be “None”
- Single slip crossings:
    - Four DPSs, two on each side. Start is located at the point tip and end at the end of the tongues (to be derived from point design).
    - Naming convention: DPS-{point number}-{A|B}-{L|R}
    - Minimal default trafficability will be “None”
- Diamond crossing with moveable frogs:
    - Four DPSs, two on each side. Start is located at the intersection of the diamond crossing and end at the end of the moveable frog (the whole moveable element must be covered) (to be derived from point design).
    - Naming convention: DPS-{point number}-{A|B}-{L|R}
    - Minimal default trafficability will be “None”
- Derailer:
    - One DPS, the extension of the DPS shall be at least as long as the mechanical part lying on the track with a derailer in place.
    - Naming convention: DPS-{point number}
    - Minimal default trafficability will be “None”

- Level crossings:
    - One DPS, for each track that passes over the level crossing. The extent of the DPS must correspond to the width of the road or path over the associated track.
    - Naming convention: DPS-{level crossing number}-{1..n} (1..n represents the number of tracks)
    - Minimal default trafficability will be “Limited”
- All other elements:
    - The engineering of a DPS for other elements such as turntables, ramp tracks, gates, lifting platforms and movable bridges must be individually analysed and carried out depending on the situation, as these elements do not have a standardised shape and extension. However, as a basis, the DPS must at least cover all movable elements in the track and correspond to the number of possible movement paths of the element.

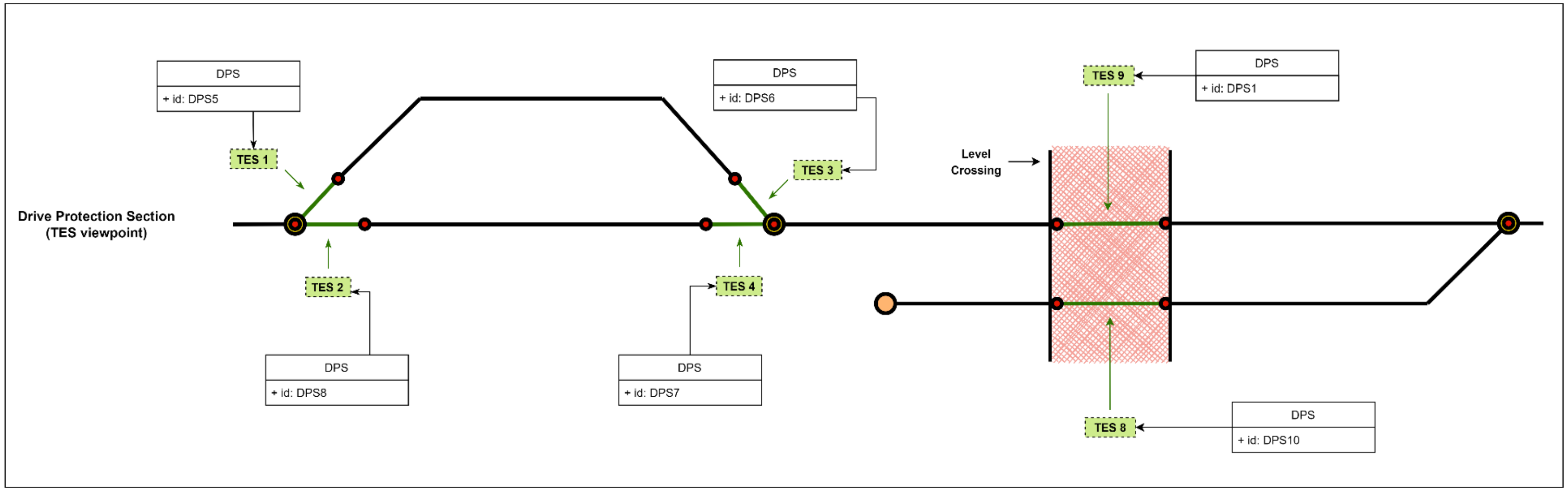


Figure 47: Drive Protection Sections for simple points and level crossings

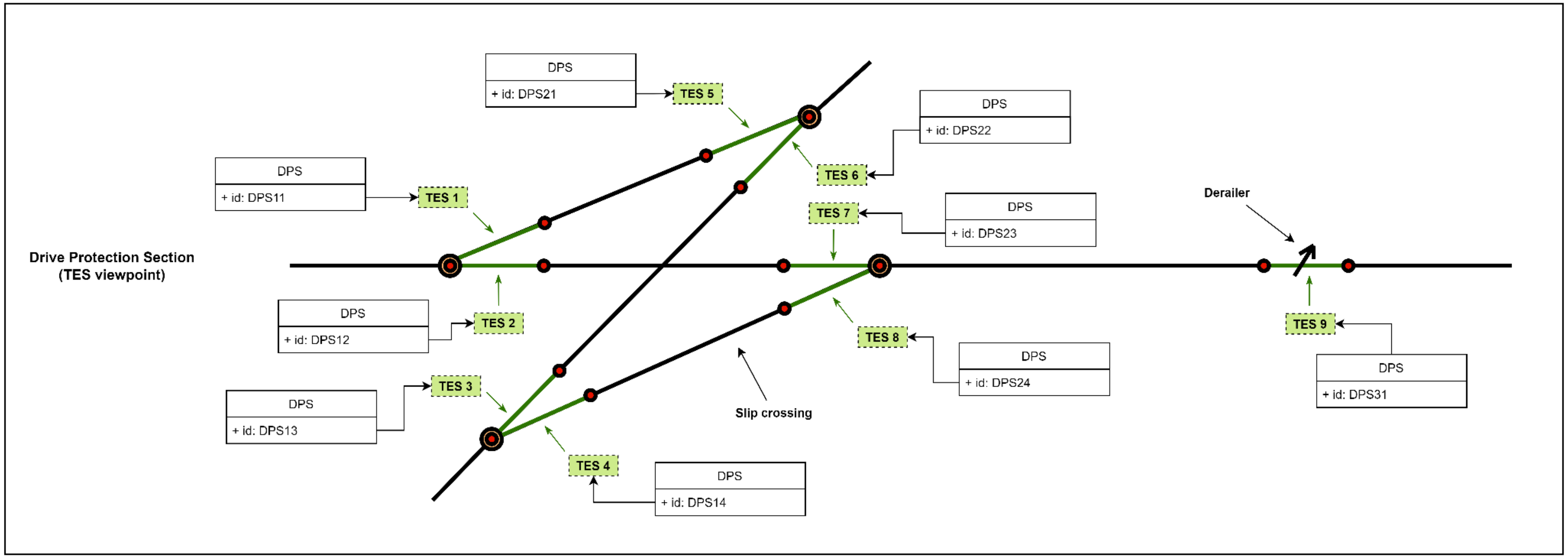


Figure 48: Drive Protection Sections slip crossings and derailer

8.7.3.1. Flank Protection

A DPS representing a point might be used to provide flank protection, but only in the direction from the point tip to the point end. In the other direction, the flank protection cannot be provided, as the point can be trailed. A DPS representing a derailer can provide flank protection in the intended derailment direction.

The attribute "flankProtectionDirection" is used to generally determine for a DPS whether it can be used for a flank protection request or not. This is particularly relevant in order to be able to determine for a DPS group in which position and for which direction a point (corresponding to one DPS from the group) could provide flank protection if it is operationally required. The value of the attribute should normally be set automatically during the engineering process, depending on the track layout and on underlying engineering rules.

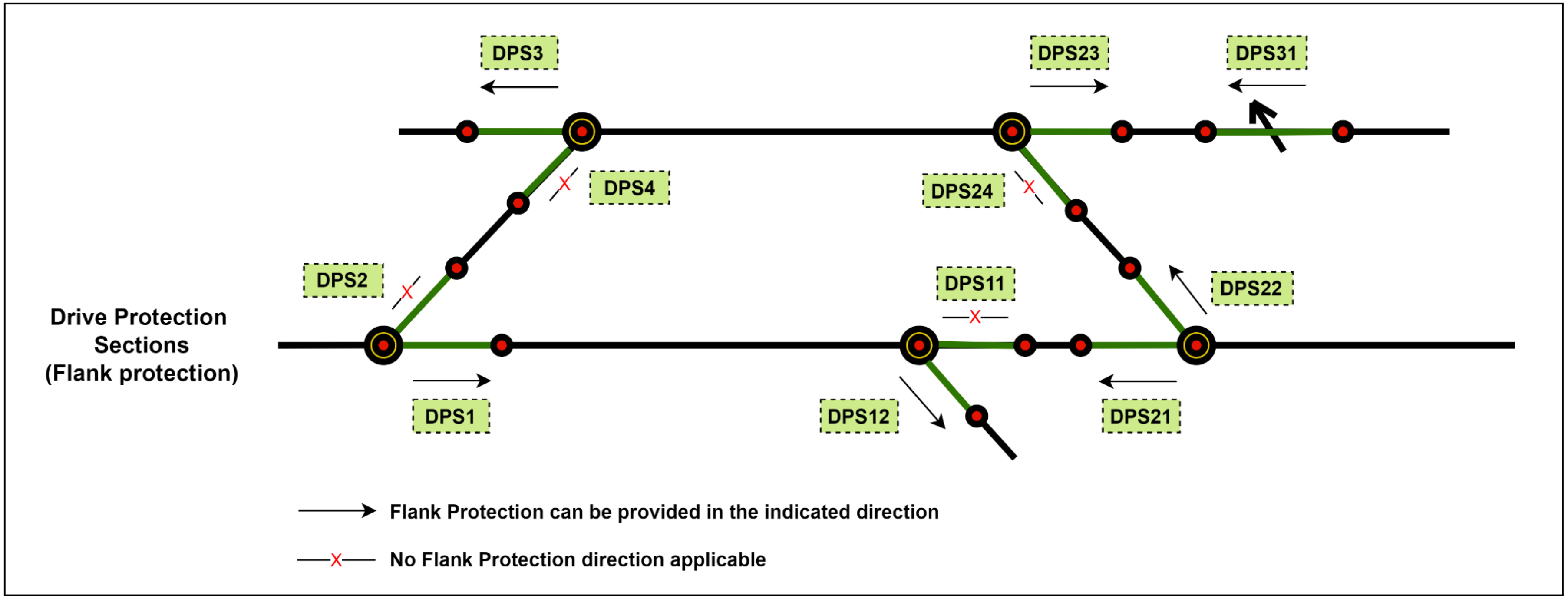


Figure 49 DPS and Flank Protection

8.7.4. Dependencies

After all the DPSs for an element have been created, the resulting Drive Protection Section Groups must be created (see next chapter 8.8 Drive Protection Section Group).

Comparison between Drive Protection Section and Allocation Section to highlight the difference between both concepts:

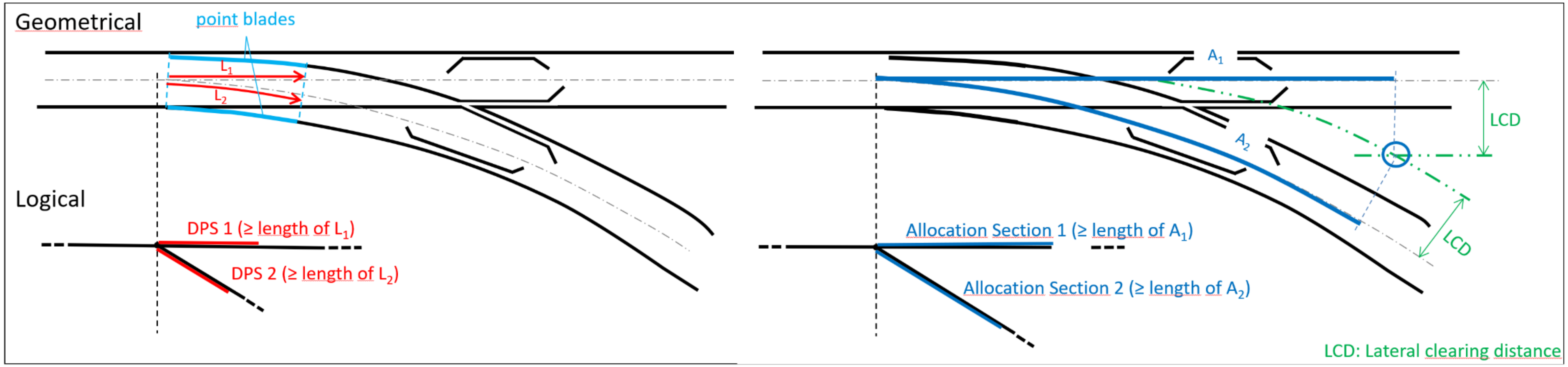


Figure 50 Drive Protection Section and Allocation Section

- DPS
  - Track Edge Section that is as long as the movable parts of the point (length of L_1 and L_2 from the point tip to the end of the movable section of the tongues)
- Allocation Section
  - Track Edge Section that is as long as the clearance gauge violation area (length of A_1 and A_2 from the point tip to the fouling point)

8.8. Drive Protection Section Group

A Drive Protection Section Group (DPS Group) groups all DPSs that can only change their state depending on each other, meaning that a request for a different trafficability state on one DPS will affect any other DPS in the group.

8.8.1. Definition

Table 32 Definition Drive Protection Section Group

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-DPSG	**DriveProtection SectionGroup**						
T3-DPSG-1		id	Unique generated ID	String	UUID	1	
T3-DPSG-2		name	Name of the DPS Group.	String	alphanumeric	1	
T3-DPSG-3		consistsOf DriveProtectionSection	List of all interdependent Drive Protection Sections.	*DriveProtection Section*	-	1..*	

8.8.2. Basis / rules and regulations

A DPS must always be assigned to a DPS group, even if the group only contains exactly one DPS.

8.8.3. Engineering rules

- Simple points:
  - The two associated DPSs are combined into one DPS group.
  - Naming convention: DPSG-{point number}
- Double slip crossings:
  - The four DPSs on each side are combined into a separate DPS groups (in total two DPS groups).
  - Naming convention: DPSG-{point number}-{A|B}
- Single slip crossings:
  - The two DPSs on each side are combined into a separate DPS groups (in total two DPS groups).
  - Naming convention: DPSG-{point number}-{A|B}
- Diamond crossing with moveable frogs:
  - All four DPSs are combined into one DPS group.
  - Naming convention: DPSG-{point number}
- Derailer:

- The one DPS is combined into one DPS group.
- Naming convention: DPSG-{point number}

- Level crossings:
  - All DPSs are combined into one DPS group.
  - Naming convention: DPSG-{level crossing number}
- All other elements:
  - DPS groups for other movable elements, such as lifting bridges, gates, or turntables must be configured manually, as the dimensions of these elements are not standardised and therefore the number and grouping of the DPSs cannot be configured automatically.

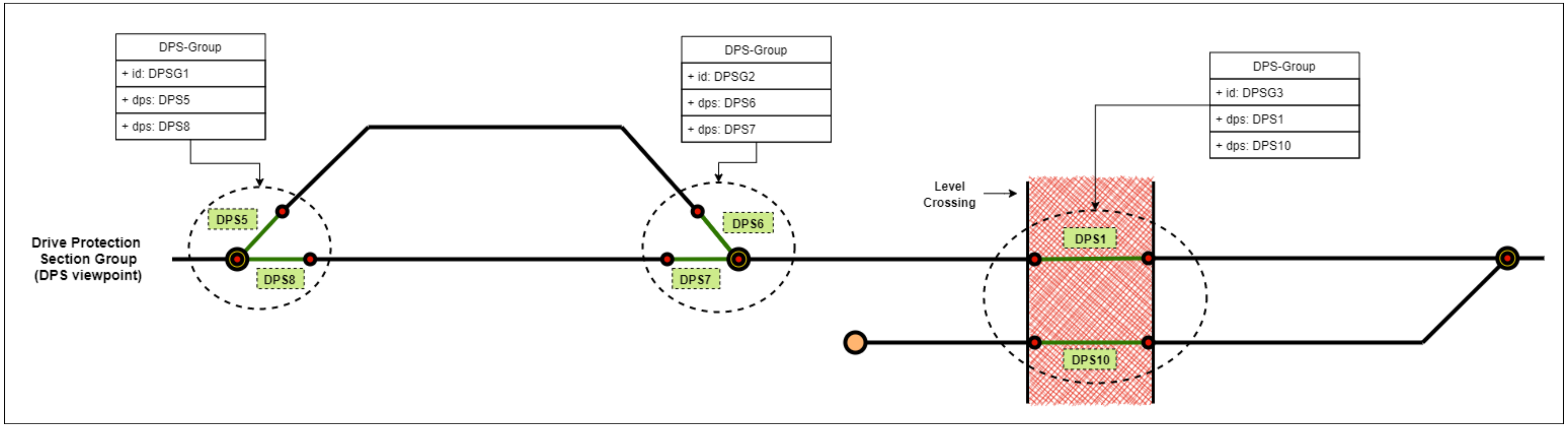


Figure 51: Drive Protection Section groups for simple points and level crossing

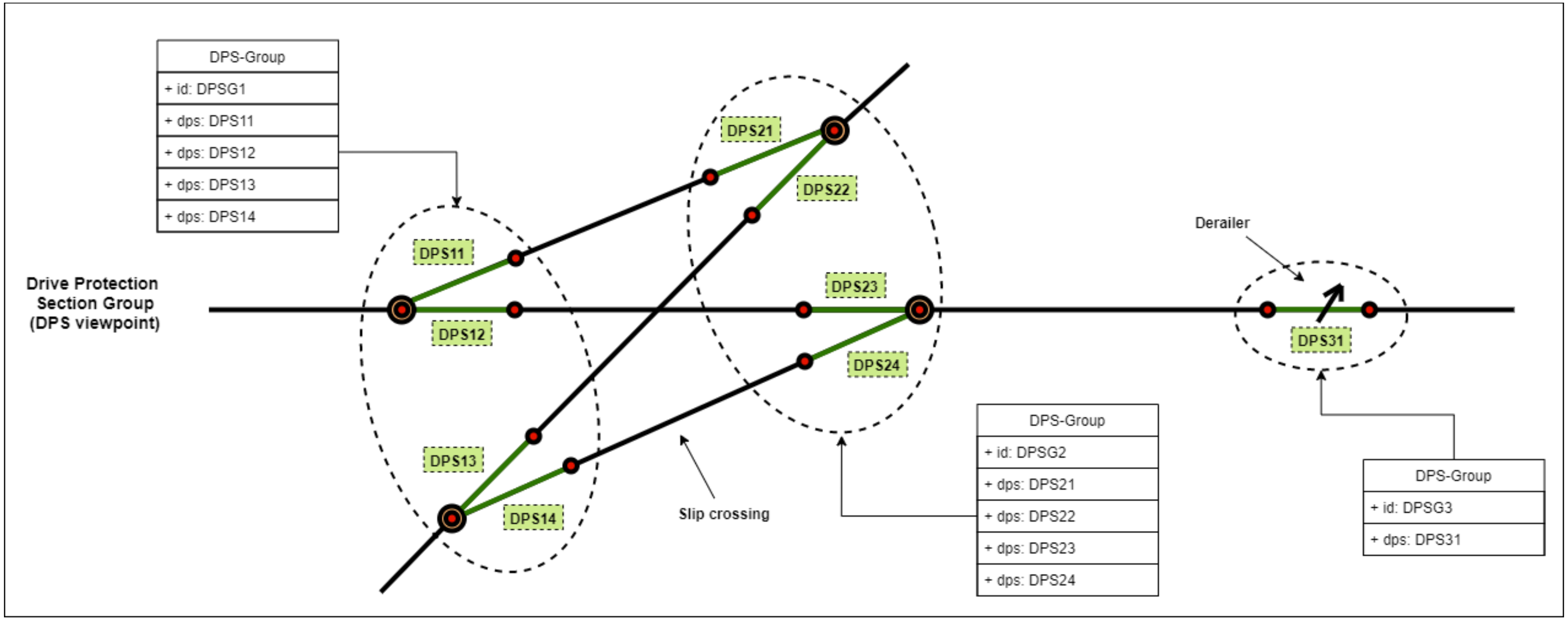


Figure 52: Drive Protection Sections groups for slip crossings and derailer

8.8.4. Dependencies

Before configuring the DPS group, the associated DPSs must have been created.

8.9. Balise

Balises (resp. Eurobalises when used for ETCS) are technical devices in the railway track bed that store information (telegram) and transmit it to rail vehicles passing the location of the balise.

8.9.1. Definition

Table 33 Definition Balise

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-BAL	**Balise**						
T3-BAL-1		id	Unique generated ID	String	UUID	1	
T3-BAL-2		appliesToTrackEdgePoint	Reference to the Track Edge Point on which this balise is located.	*TrackEdgePoint*		1	
T3-BAL-3		positionInGroup	Position of the balise in the corresponding balise group (N_PIG, Section 7.5.1.81 in [7]).	Integer	1..8	1	
T3-BAL-4		baliseTelegram	Content of the balise telegram in case this balise represents a virtual balise (in the long format of length defined by Section 4.3.1.2 in [9]).	Binary	1023 Bit	0..1	

8.9.2. Basis / rules and regulations

The balises shall be represented using a TEP on the topology as it is not associated with a direction. The positionInGroup describes the relative position of the balise in a balise group.

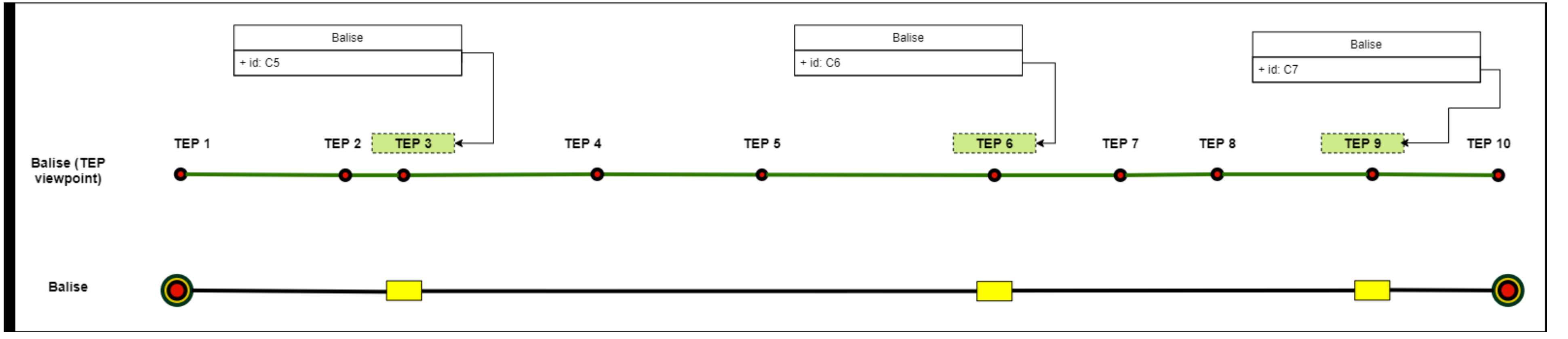


Figure 53: Balise

8.10. Balise Group

One or more balises to which the same reference position is assigned in the track.

8.10.1.Definition

Table 34 Definition Balise Group

ID	Object	Attribute	Description	Type	Range	Cardinality	Unit
T3-BALG	**BaliseGroup**						
T3-BALG-1		id	Unique generated ID	String	UUID	1	
T3-BALG-2		name	Name of the balise group in the format: {countryIdentifier}_{baliseGroupIdentifier}	String	alphanumeric	1	
T3-BALG-3		countryIdentifier	Country or region identifier (NID_C, Section 7.5.1.86 in [7])	Integer	0 - 1023	1	
T3-BALG-4		baliseGroupIdentifier	Identity number of the balise group. (NID_BG, Section 7.5.1.85 in [7])	Integer	0 - 16382	1	
T3-BALG-5		consistsOfBalises	Balises in this balise group	*Balise*	-	1..8	

8.10.2.Basis / rules and regulations

The balise groups do not have any topological relations but have a relation towards the different balises that are part of the current balise group. The topological references can be derived from the individual balises, if needed.

Every balise group has its own coordinate system. The orientation of the coordinate system of a balise group (i.e., nominal or reverse direction) is identified as balise group orientation. The origin of the coordinate system for each balise group is given by the balise number 1 (called location reference) in the balise group. The nominal direction of each balise group is defined by increasing internal balise numbers.

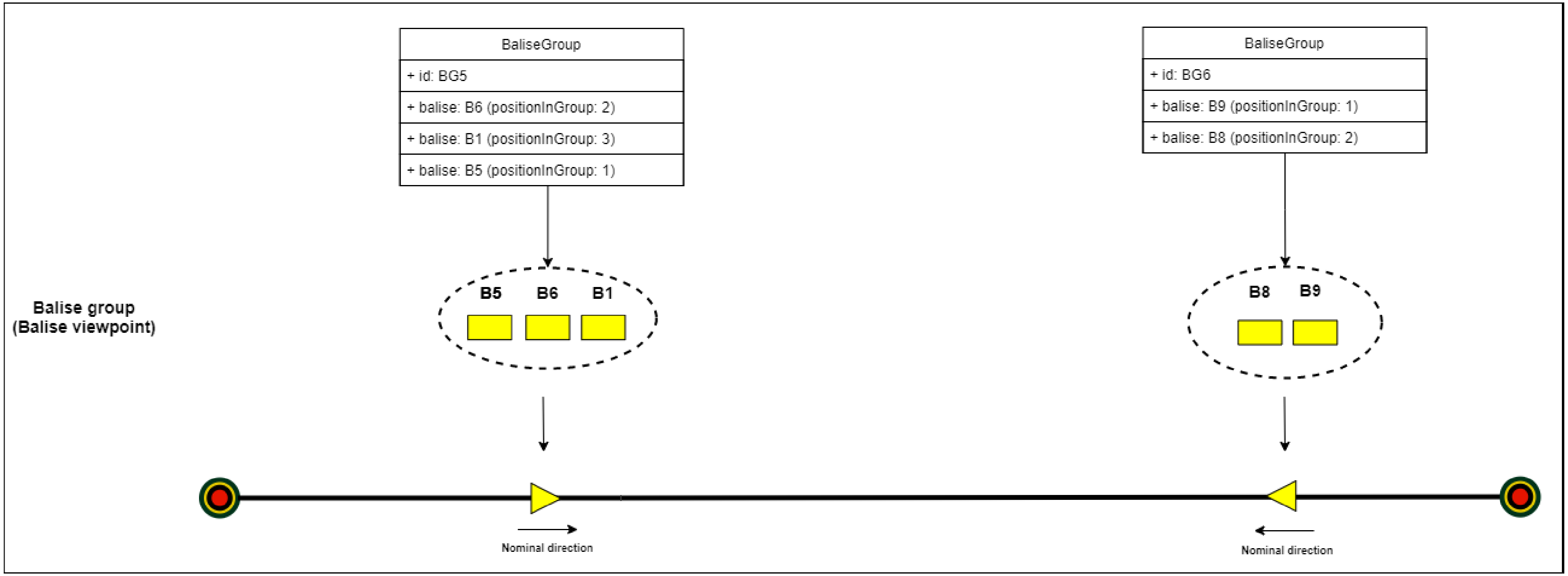


Figure 54: Balise groups

9. Open Points

- Azimuth (and e.g. gradient and cant) as a point-based track geometry object, based on the requirements of LOC-OB
- Additional attributes for the Balise (type of Balise (fixed or transparent), location accuracy Q_LOC_ACC), based on the requirements of LOC-OB
- Flank Protection: To be checked by APS that this is a configuration parameter and not something that can be calculated during runtime in APS
- Agree on the modelling proposal for dual gauge tracks (see chapter 6.1.4) with APS and PE
- Additional attributes to indicate the neighboring Area of Controls for one Area of Control
- Map DPS and DPS-Groups to the corresponding Field-Elements resp. Track Assets