RCA

Reference CCS Architecture

An initiative of the ERTMS users group and the EULYNX consortium

Digital Map - Evaluation Reference Model

Preliminary issue

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1 Introduction

1.1 Release information

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1.3 Purpose of the document

In the current state, the Topology Domain inside the RCA Domain Knowledge [3] lacks certain aspects, that are required by several subsystems and interfaces (such as track geometry).

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.

While the actual BNT model already covers these aspects and could be used as base to extend this domain accordingly, the question has been raised by RCA members, if the topology model should be even closer to the *plain RTM* model regarding nomenclature/terms, structure, relations and/or openness.
Regarding this decision this document identifies the requirements as decision criteria, introduces the possible approaches and evaluates them against the criteria.

During the development (BNT study [5]) it was a crucial requirement to adapt to existing standards such as the RailTopoModel (RTM) [6]. Besides a few aspects (geometry, bi-temporal data management), that were not yet covered by the RTM standard, the general applicability of the RTM for the SBB needs has been confirmed. Therefore, the physical BNT model has been derived from the logical RTM model with some extensions for the application within RCA (see comparison BNT vs. plain RTM in chapter 4). This step includes some simplification and clarification, i.e. which positioning reference is used for a spot object (like Eurobalise).

By design, the BNT model is compatible (meaning: transferable) to RTM, so the conversion from the physical implementation of BNT to the logical RTM model is possible and vice versa (conversion rules, see chapter 4).

The applicability and compatibility of the selected approach should be evaluated not only from the perspective of data preparation systems, but also the runtime interfaces transmitting operational data in order to avoid complex transformations or even ambiguities within RCA data flow. The selected approach is also the source for the extensions of the topology domain model in the RCA domain knowledge (here: navigability, geometry).

1.4 Terms and Abbreviations

For terms and definitions refer to the RCA Glossary [2] or the RCA Digital Map Concept [12].

1.5 Structure

The evaluation document uses the following basic structure:

- Scope definition
- Analysis of requirements, which serve as evaluation criteria in a later step
- Description of approaches
- Evaluation of approaches regarding requirements
- Conclusion including the decision for the approach

2 Scope

The scope of this evaluation comprises the following perspectives and kind of data (Figure 1):

1. *RCA PREP (Preparation) Systems* such as Topo4, parts of DCM (Figure 2): all RCA systems that are responsible for preparation and providing *Map Data* to the operational systems. The (engineering) map data is the product of the compiling process (presumably part of Topo4), which transforms the engineering data into the required structure of the RCA and Planning System.
2. *RCA OP (Operational) Systems* such as PE, SL, OA or CCS On-Board (Figure 3): all RCA trackside and onboard systems that are responsible for the actual operation. Based on the loaded and activated (engineering) map data operational messages are sent and received. These messages can refer to or even contain parts of (engineering) map data, e.g. the ATO trackside creates and sends segment profile messages (operational data), which are based on and contain the (engineering) map data required for the train path.

The engineering process itself is *excluded* from this document, since it is not clear, if it is even part of RCA standardisation. Also, according to the RCA, the Planning System (PAS) itself including long term planning data with different granularity is not part of the scope of this document.

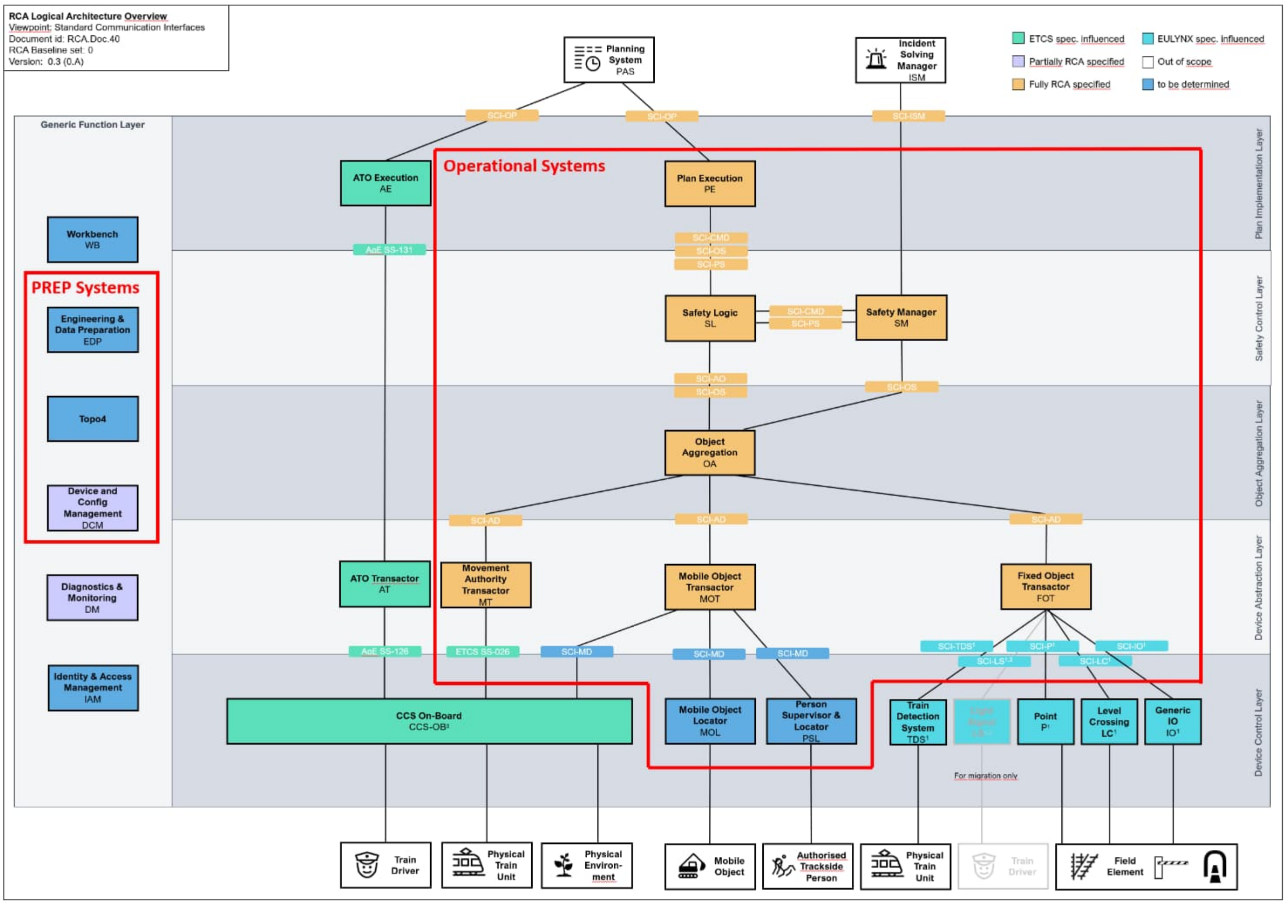


Figure 1: RCA PREP and Operational (OP) Systems

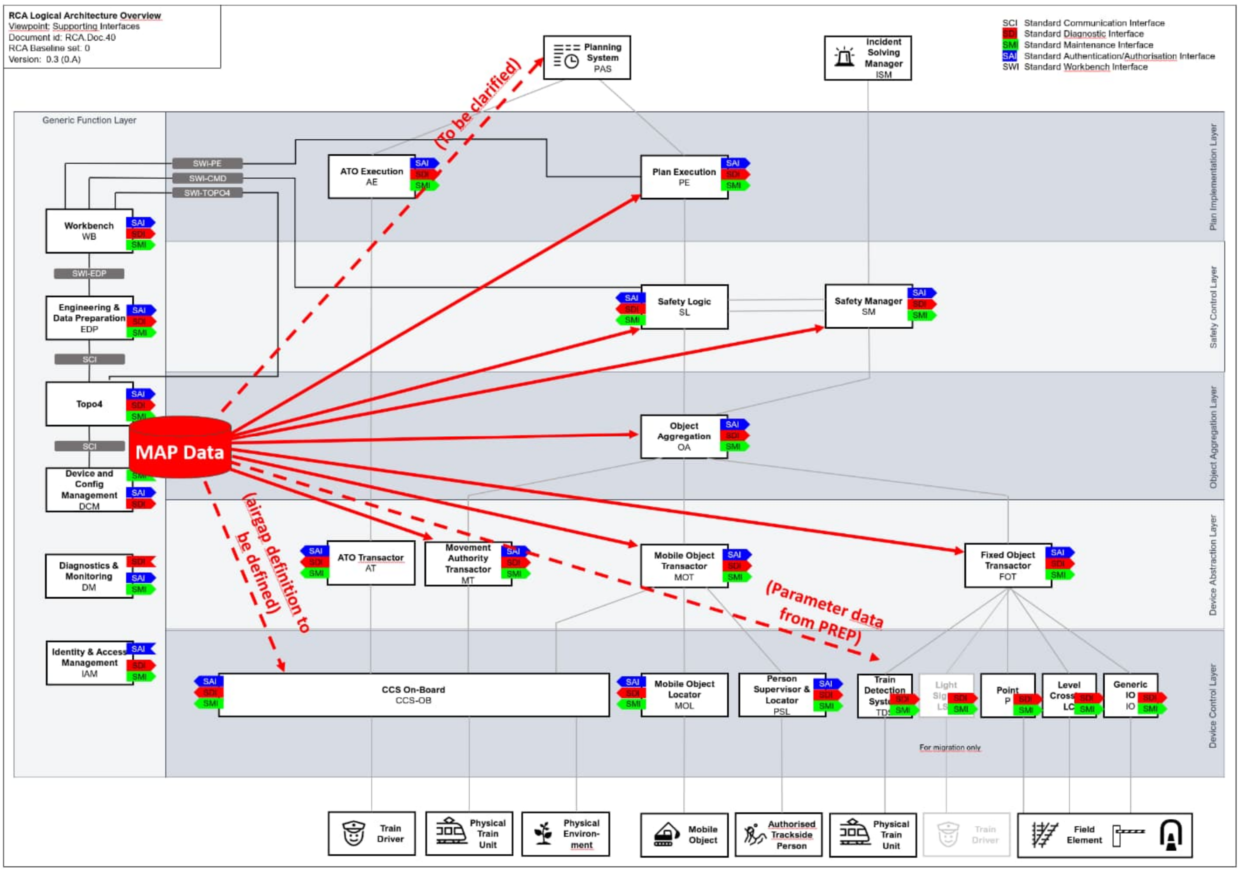


Figure 2: Distribution of Map Data for Loading, Activation and Operation

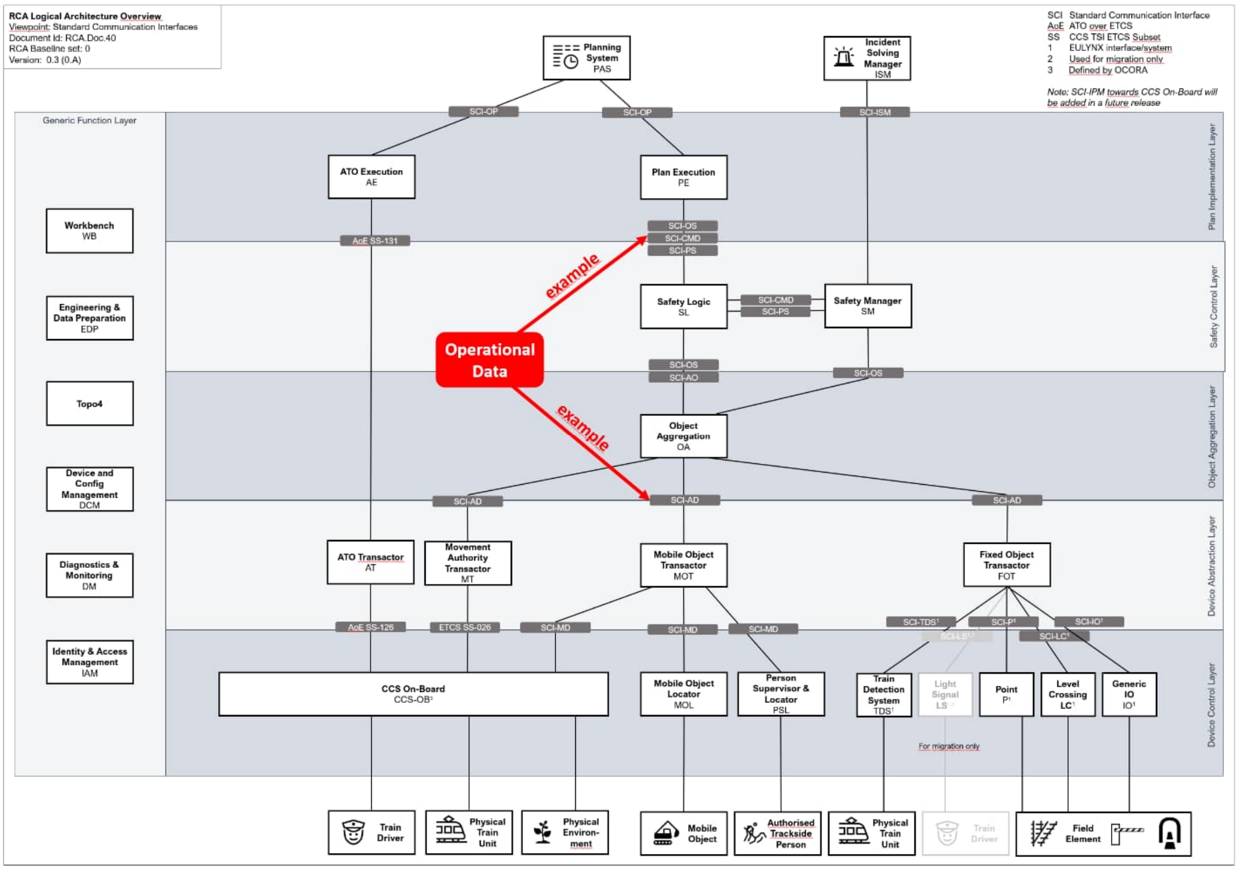


Figure 3: Messages of Operational Data during Operation (Examples only, not complete)

3 Reference Data Model Requirements

This chapter analyses the requirements that must be fulfilled by the two topology models (BNT and RTM) depending on the selected perspective (PREP (Preparation) vs. OP (Operational) Systems).

3.1 Requirement analysis

Table 1: Requirements for reference model

Category	Requirement	RCA PREP Systems	RCA OP Systems
Data Content, Topology	Topological description of the tracks and their relations to each other	**Required**, e.g. compiling engineered topology for APS	**Required**, e.g. loading map data topology for APS
Data Content, Referability	Referable positions for spot, linear, areal elements	**Required**, e.g. compiling engineered topology for APS incl. Drive Protection Section, balises, points, …	**Required**, - e.g. loading map data topology for APS incl. Drive Protection section, balises, points - e.g Usage Restriction Areas (URA), ...
Data Content, Navigability	Possible train movement paths can be modelled	**Required**, e.g. for engineering and compiling map data for APS	**Required**, e.g. for conflict detection in TMS or APS
Data Content, Geometry	Track geometry incl. radius, gradient, superelevation/cant, track points	**Required**: e.g. providing engineered geometry for localisation	**Required**: e.g. map data with geometry for localisation
Data Content, Attributes	Detail object data (asset classes, attributes)	**Required**, e.g. signal, balise, switch and object attributes	**Required**, e.g. signal, balise, switch and object attributes
Granularity, Aggregation	Support of several detail levels (macro, meso…), e.g. if an “edge” always represents a “track” or also a “line” (with more than one track) or something different on another aggregation level	**Not required:** only micro/track-level perspective needed (might change in future, e.g. HMI abstraction on “line level”)	**Not required:** only micro/track-level perspective needed (might change in future, e.g. HMI abstraction on “line level”)
Variants	Multiple variants of same situation	**Not required:** Only next version of engineering data and map data for provisioning (variants are not required).	**Not required:** Only next version of engineering data and map data for provisioning (variants are not required).
Versions	Multiple versions of the same model elements, reflecting modifications of the represented infrastructure	**Required:** One active version, 0…* planned versions reflecting upcoming changes	**Required:** One active version, 0…* preloaded versions reflecting upcoming changes
Temporality, Traceability	Include validity time information and support history	**Not required** for Topo4/DCM: simple version allocation incl. planned validity time should be sufficient. (could only be helpful for engineering, if engineering will be included in RCA standardisation, since engineering data should be bi-temporal to trace changes)	**Required:** for operational data temporal validity is possible, e.g. Usage Restriction Areas

Category	Requirement	RCA PREP Systems	RCA OP Systems
Efficiency, Performance	Efficient structure for real-time processing	**Not required:** map data update (pre-loading) does *not* happen in real-time	**Required:** operational performance shall not be influenced by avoidable data transformations
Efficiency, Capacity	Efficient structure for data transmission	**Not required:** map data is updated with a very low frequency (depending on the Area of Control once a day up to less than one update per year)	**Required:** very high message frequency, e.g. movement authority to all trains which are requested and issued based on map data, and for that, the map data are queried (by PE / SL). Thus, the map data need an efficient structure for these queries
Efficiency, Storage	Efficient structure for data storage	**Not required:** no relevant limitations for storing engineering or map data	**Required**: limitations expected especially in onboard/peripheral systems
Conformity, Interoperability	Consideration of existing international standards	**Required (indirectly):** since the standardisation of Engineering Data or Operational Data inherits to PREP data	**Required**: to ensure interoperable railway operation e.g. ERTMS standard, ATO standard, EULYNX interfaces
Safety, Data structures	SIL function compatible: e.g. avoid complex model transformation, avoid floating point values	**Required (indirectly):** PREP process should be rather supported by tools instead of operational systems. However, the needs of Operational Data regarding safety inherit to PREP data flow as well.	**Required**: many functions with SIL>0 (e.g. APS) expected
Safety, Content integrity	Unambiguous modelling without modelling variants (degree of freedom)	**Required**: for provisioning of reliable map data, also to be applied within safe functions	**Required**: safe functions rely on unambiguous data structures

The identified requirements are used as evaluation criteria of the different reference models in a following step (chapter 6).

3.2 Scenarios

As the analysis in Table 1 shows, both perspectives partially require different properties of a reference model. However, since the operational system needs to bridge the gap between (engineering) map data and operational data, the map data reference system should be compatible for both perspectives. So basically, there are two options:

1. RCA PREP systems and operational systems use the same reference model, not only on logical level but also on physical level. A transformation of data structure within the operational system is not required in this case. Depending on the model of the imported engineering data, which is not under consideration here, transformation efforts are required as part of the engineering process, e.g. from RTM based EULYNX-PREP data format to the RCA topology model.

2. RCA PREP systems and operational systems refer to the same logical domain model but are implementing this model in different ways on physical level (according to their specific needs). E.g. the (engineering) map data uses a representation that is closer to RTM, and the operational systems build the messages based on BNT. In this case, the operational system needs to transform the provided map engineering data into an internal representation, that fits to the operation data. Not only in the

safety-related context it needs to be ensured, that this transformation does not lead to inconsistency issues, mapping problems, unambiguity's, etc.
So, the conditions for "model compatibility" must be defined, if this approach is selected.

3.3 Model compatibility and model conformity

3.3.1 Model compatibility conditions

As an initial approach the basic conditions to reach "model compatibility" are discussed. At least the following conditions must be fulfilled, if different models are used within the RCA data flow:

- Use the same topological or topographic/geometry anchor points (within one layer)
  - No edge/node mapping tables required for unambiguous transformation
  - No element/node shifting/relocation required (e.g. due to different node definitions)
- Use the same way of element positioning (referencing topology)
  - Clearly decide for point vs linear vs area positioning for each referenced object
  - If several kinds of referencing are applied: define the role of each system (e.g. distance vs. line kilometer/mileage vs absolute coordinate)

3.3.2 Model conformity conditions

If, beyond compatibility, *conformity* with RTM shall be reached, the following requirements from RTM apply (see [6] IRS.30100.673 - 676):

Conformant Systems:

- *may include all RailTopoModel concepts, or a subset of these concepts;*
- *may extend the RailTopoModel, e.g. with additional packages and classes;*
- *shall not alter the concepts provided under the present IRS[1] and their relations, irrespective of whether these concepts are required, recommended, or optional, except for the cases described below.*

This gives a certain freedom to cherry-pick relevant aspects of the model and still call the outcome conformant with the model. Conformity hereby is the stronger requirement than compatibility, as it means that for each class of the designed model, a direct equivalent from the RTM model can be found, and all relations among the members of this set RTM classes are maintained in the picked extract (see also discussion in chapter 5).

[1] International Railway Solution (IRS) ©: a structured framework of documents prepared and published by UIC for use within the railway sector. They blend together a range of voluntary solutions to support the design, construction, operation and maintenance of the railway system and the services that the sector provides.

4 Approaches

This chapter introduces the considered approaches, which are the candidates for the later evaluation against the already identified requirements.

The considered approaches can be characterized as follows (see also introduction in chapter 1):

- *BNT*: Intuitive approach, which is the base for the abstracted existing RCA domain model. The model has been developed by the SBB and can be described as physical implementation of the logical RTM including some modifications, which should still allow a lossless and unambiguous transformation between both models (if transformation rules are defined, see below).
- *RTM*: Connexity graph approach developed by UIC including derived models and formats such as railML3 or EULYNX PREP, which are physical implementations based on the logical RTM and already include specific objects and attributes. Compared to BNT these approaches are closer to the RTM standard regarding nomenclature/terms, possibilities for positioning and relations. Basically, the RTM release 1.1 is used as reference, but some concepts from the preliminary RSM[2] 1.2_alpha release [9] are included for missing objects regarding geometry.

More details are given by this chapter, including statements regarding compatibility/transferability and conformity. Regarding compatibility it is to be noted, that the transfer from RTM to BNT is assumed to be the only relevant direction, as it represents the use case of importing RTM based engineering data into the RCA data flow (compile process). The other direction (BNT → RTM) might be required if a system outside of RCA works on RTM basis and communicates with an RCA subsystem (e.g. PAS – PE).

In addition, chapter 9 (Annex A: Example topology definition) presents some examples for modelling in BNT.

4.1 Topology

While RTM follows a connexity graph approach, BNT uses the intuitive model approach for topology including the information of a connexity graph (which result in general compatibility to RTM):

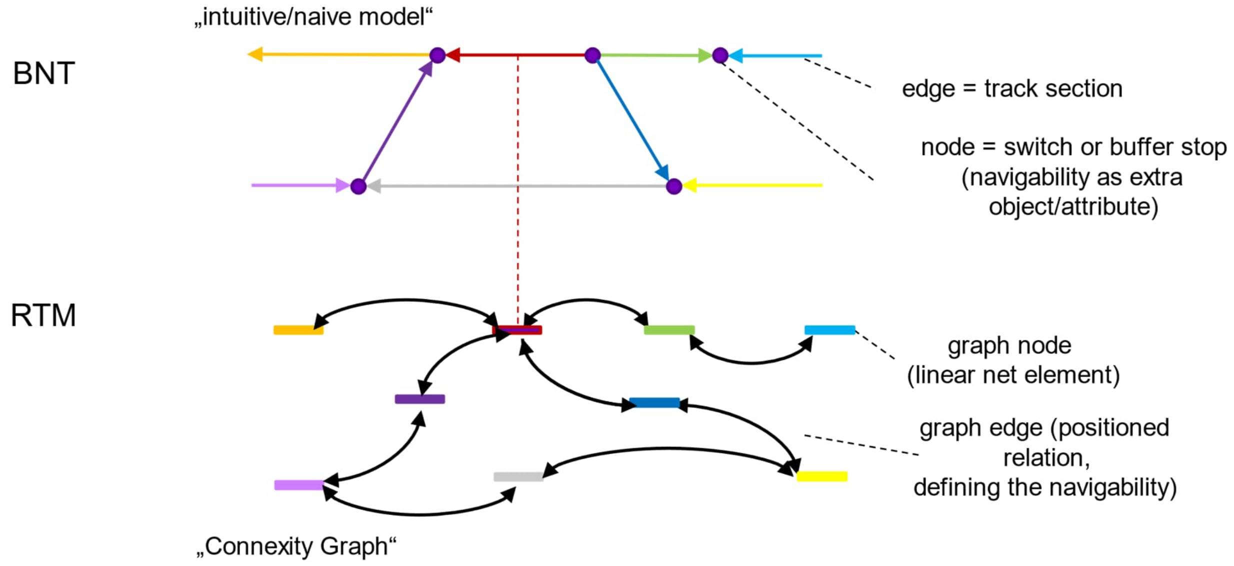


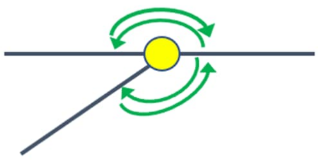
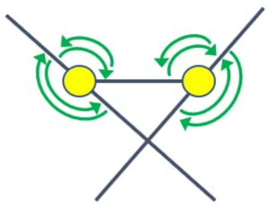
Figure 4: Topology Overview BNT vs RTM

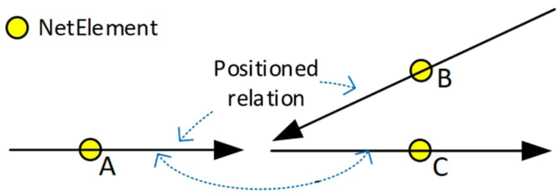
[2] Starting from release 1.2, the name has changed to RSM (RailSystemModel)

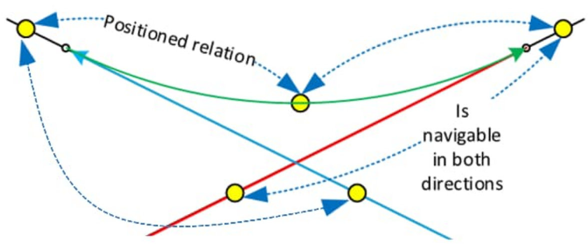
The following table compares both approaches in more detail:

Table 2: Topology - BNT vs RTM

<table>
<tr><th>BNT</th><th>RTM</th></tr>
<tr><td>Nodes: A TrackNode is a position on the topological model of the track network where a TrackEdge begins or ends like branches (points, diamond crossings), track ends (buffer stops) or system borders (like an Area of Control border or the border between two infrastructure operators)</td><td>The RTM model contains the NonLinearElement which might correspond to the BNT TrackNode. But RTM does not use this element in its network topology definition, where only LinearElements and PositonedRelations (see below) are relevant to build the connectivity graph.</td></tr>
<tr><td>Edges: A TrackEdge is a linear object that connects exactly two TrackNodes. TrackEdges are directed. Each route path between two TrackNodes is represented by a TrackEdge.</td><td>Graph Nodes: A LinearElement represents the track sections. Directed linear object, but the direction is arbitrarily defined as there is no equivalent to the BNT Track Node.</td></tr>
<tr><td>Navigability: Navigability represents ordered pairs of navigable edges, referenced by edge attributes. The navigability always refers to one direction only, meaning if navigation between two edges A and B in both directions is possible, two navigabilities (“from edge A to edge B” and “from edge B to edge A”) have to be defined.
→ Topology Relations

Examples:
- Simple Switch (4 Navigabilities):

- Single-Slip Switch (8 Navigabilities):
</td><td>Graph Edges: PositionedRelation represents directed connections between LinearElements (Nodes) and define the navigabilities. The navigability for one Positioned Relation defines how to navigate between two connected net elements A and B: None, A to B only, B to A only or Both.
→ Topology Relations

Examples:
- Simple Switch (2 Positioned Relations with navigability “Both”, an additional third relation with navigability “None” might be possible for the relation between B and C):


- Single-Slip Switch (4 Positioned Relations with Navigability “Both”):

</td></tr>
</table>

- Basically, both BNT and RTM describe the basic topology of a track network according to a similar concept: Track sections and navigabilities between the sections.
- BNT defines branches (switches), track ends or system boundaries directly using TrackNode objects, while in RTM this is only indirectly recognizable through the evaluation of the navigability between

track sections (the corresponding object in RTM is just an entity as any other trackside entity, the role that it makes up the topology is not described).

- The Navigability description is both associated with the Track Node (intuitive approach) and the connected Track Edges, the latter eases a transformation towards the Connexity graph model
- Compatibility (Transformation BNT → RTM): Both formats can be transformed in a lossless way as follows:
    - BNT → RTM: nodes disappear, since they are defined explicitly in RTM. Edges are transferred to Linear Elements, Navigability is transferred to Positioned Relations.
    - RTM → BNT: nodes need to be derived from Positioned Relations in combination with Linear Elements (possible in an automatic way). The rest: see BNT → RTM in the opposite direction.
- Conformity (BNT vs RTM):
    - Navigability / PositionedRelation and TrackEdge / LinearElement can be considered as equivalent classes, as they have the same relationship to one another.
    - Although TrackNode has an equivalent with the NonLinearElement, it would be a class that lives in the BNT model only because the NonLinearElement is not used in RTM to describe the network topology.

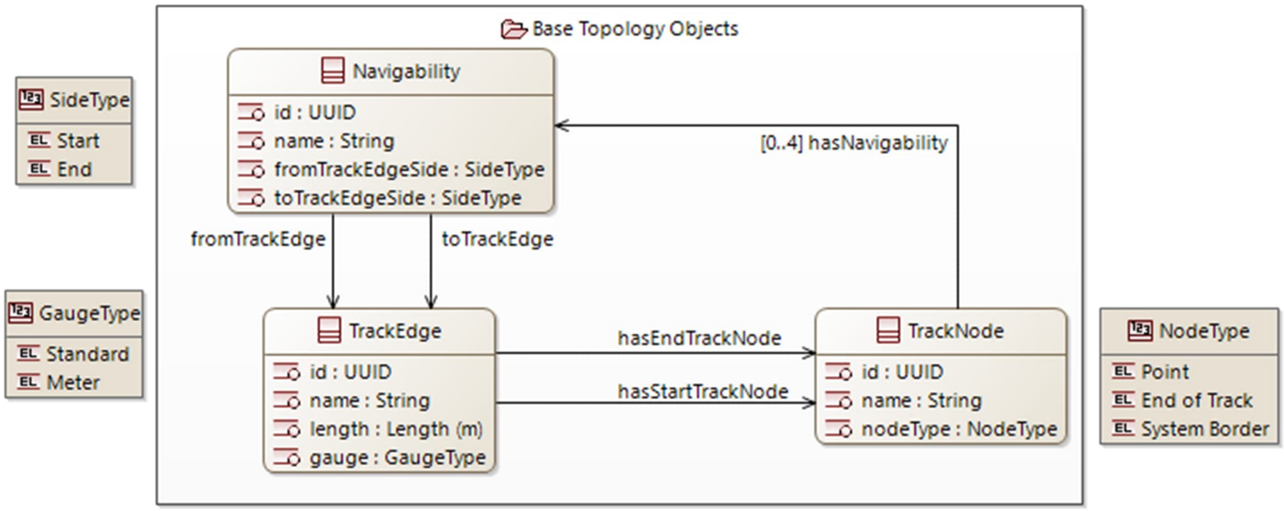


Figure 5: Topology - BNT classes

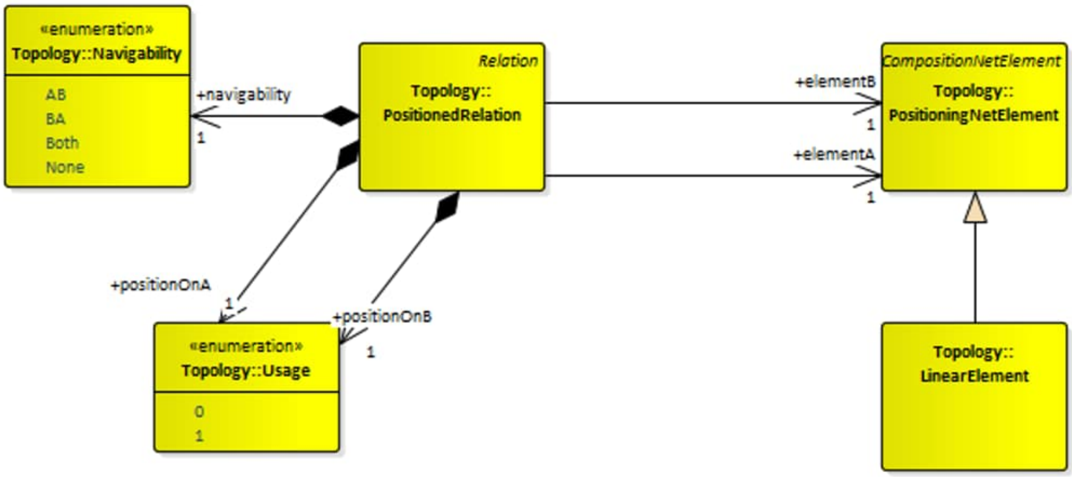


Figure 6: Topology - RTM classes

4.2 Spot locations

Table 3: Spot locations - BNT vs RTM

BNT	**RTM**
Spot locations used to place objects on edges – Position on one edge – Lateral offset for distance from track – Alignment relative to edge direction – Multiple positioning systems are available to define the position in space (e.g., coordinates or linear reference systems)	*Net Entity*: Functional element linked to the topology (Net Elements + Relations) via *Location* Relations. Example: A spot object, like a signal, has a spot location on a Linear Element: – Intrinsic position on element – Linear coordinate + Lateral offset (perpendicular, metric) – Effective direction relative to direction of linear element

- In principle, spot located elements can be mapped with both BNT and RTM
- Both BNT and RTM offer higher flexibility to define positions in space due to the usability of different positioning and coordinate systems
- Compatibility (Conversion BNT ←→ RTM): Both formats can be transformed in a lossless way as follows:
  - BNT → RTM: the used topological reference of a spot object can be directly transferred to RTM. This could be the mandatory intrinsic coordinate of RTM and/or a linear reference system for the specific edge.
  - RTM → BNT: vice versa
  - Basic condition: RTM model has the same reference system information included
- Conformity BNT vs RTM:
  - The class diagram as in Figure 7 does not comply with RTM as it includes the linear position into the TrackEdgePoint class itself
  - Proposal for adaption: In order to reach conformity, the attributes *offset* and *vertical distance* could be separated as a class mapped onto RTM:LinearCoordinate, then the TrackEdgePoint could be mapped onto RTM:SpotLocationCoordinate

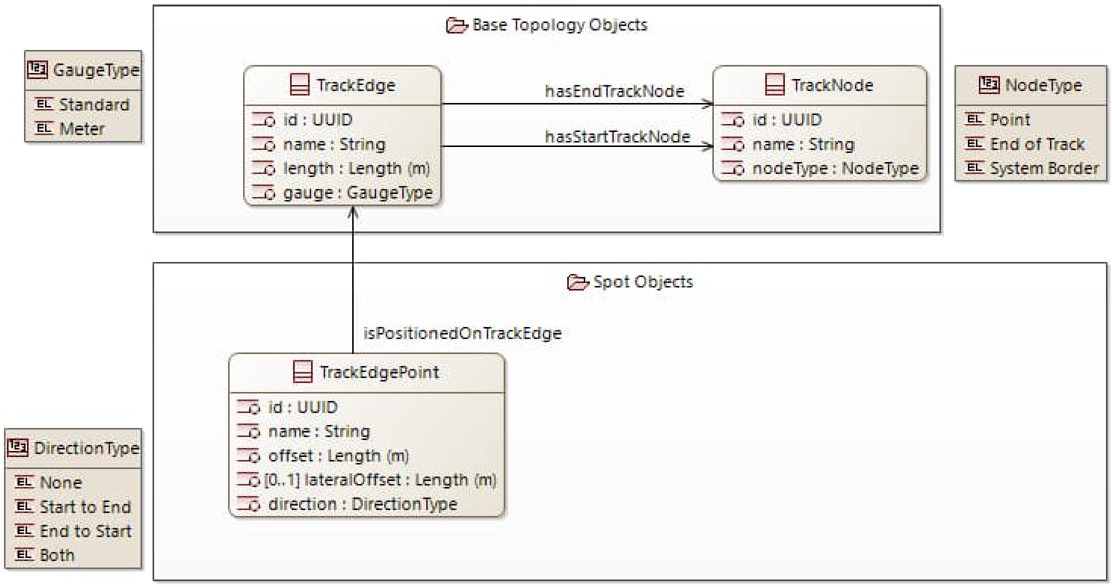


Figure 7: Spot location - BNT classes

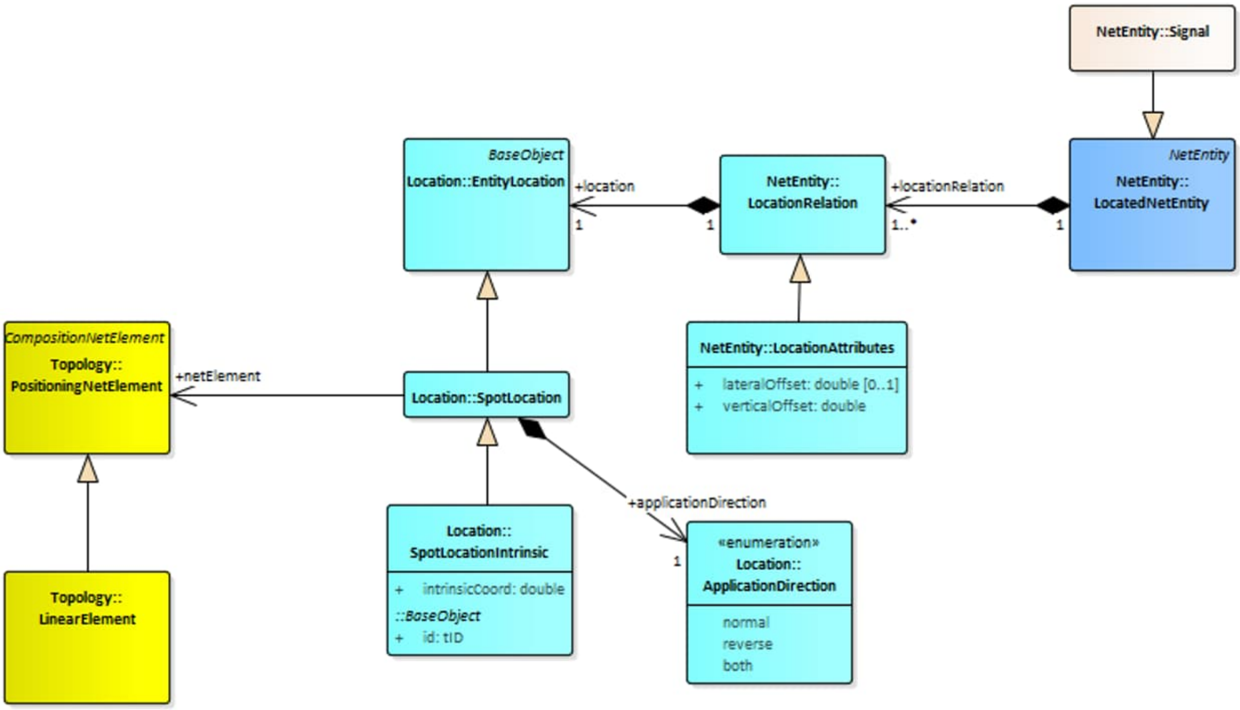


Figure 8: Spot location – RTM classes

4.3 Linear locations (within one TrackEdge)

Table 4: Linear locations: BNT vs RTM (e.g. ATO segment profile)

BNT	**RTM**
Track Edge Section • Refers to one single *TrackEdge* • Basic element for describing linear and reticular objects • References exactly one track edge • Position (beginning, end) and alignment relative to edge direction	*Linear Element*: • Node • Intrinsic position (0..1) indicates relative position on lines segment, specifying the direction • Distances: Linear Element is attached to Linear Positioning System (1..n), e.g. with start and end kilometers • Linear Location represents section on a linear element with application direction

- In principle, linear elements can be mapped with both BNT and RTM
- BNT offers special forms of aggregations of linear elements, which describe the relationships of the elements to each other.
- RTM offers higher flexibility due to the usability of different positioning and coordinate systems on the one hand, but on the other hand this also causes higher complexity in the definition of the objects
- Compatibility (Conversion BNT → RTM): Both formats can be transformed in a lossless way as follows:
  - Basic condition: RTM model has the same reference system information included
  - BNT → RTM: the used topological reference of a linear object can be directly transferred to RTM.
  - RTM → BNT: vice versa
- Conformity BNT vs. RTM:
  - The RTM class LinearLocation reflects both the TrackEdgeSection and the LinearContiguousTrack Area from BNT, as it already allows a stretch over several NetElements (~ TrackEdges)
  - Thus, model conformity is hard to achieve
  - The TrackEdgeSection contains its limiting TrackEdgePoints as well as a TrackArea (of any subtype in BNT) is a collection of TrackEdgeSections => basic compatibility is already reached with the SpotLocation = TrackEdgePoint mapping

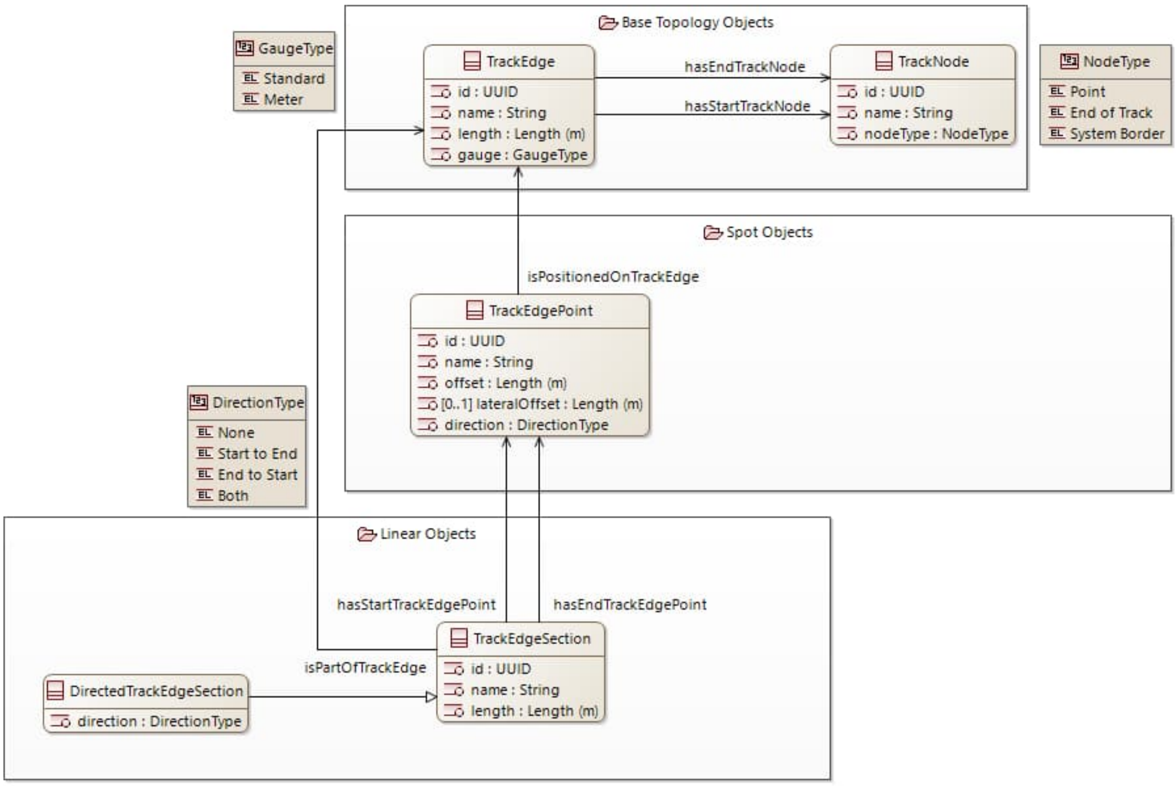


Figure 9: Linear location - BNT classes

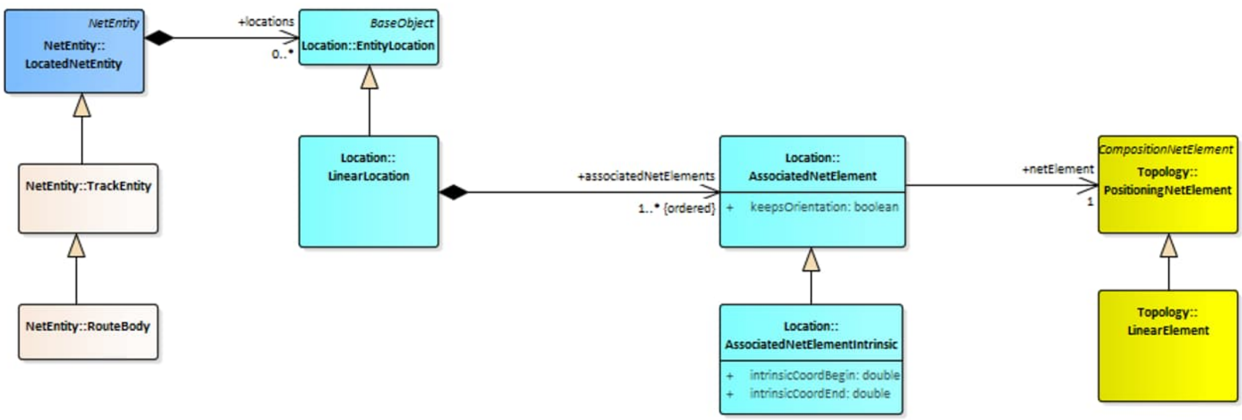


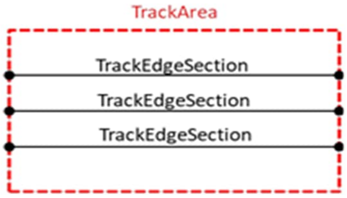
Figure 10: Linear location - RTM classes

4.4 Areal locations

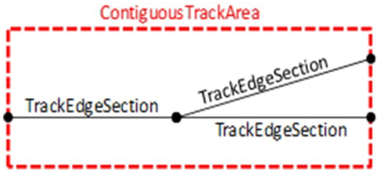
Table 5: Areal locations: BNT vs RTM (e.g. work zone)

BNT	RTM
Track Areas: Collection of *TrackEdgeSections*: • *TrackArea*: A *TrackArea* is an area that consists of one or more *TrackEdgeSection*. There are no restrictions whether those *TrackEdgeSections*	*Area Location*: A section can be mapped to more complex structures than Linear Locations, e.g. an Area Net Element, which covers a switch.

<table>
<tr>
<td>
are joined or not.



- *ContiguousTrackArea:* A *ContiguousTrackArea* is an area which consists of one or more *TrackEdgeSections* joined together.



- *LinearContiguousTrackArea:* A *LinearContiguousTrackArea* is an area that consists of one of more *TrackEdgeSections* joined together so that they represent one single path.

</td>
<td></td>
</tr>
</table>

- While BNT realizes the referencing of areal objects just by a collection of linear elements, RTM offers a specific positioning class (e.g. also allowing polygons)
- Compatibility (Conversion BNT → RTM):
  - if RTM uses complex structures (e.g. polygon) than it cannot be transferred to BNT and vice versa
    Note: up to now there is no identified RCA use case requiring complex structures like "polygon". However, it can be added if it is needed in BNT (even on system level).
  - if the collection of linear elements, as supported by both models, is sufficient for the relevant data in RCA, then the transformation rules are similar to linear element
- Conformity with RTM:
  - Similar as for Linear objects, the mapping of the RTM AreaLocation doesn't fit with the RCA TrackArea, ContiguosTrackArea and LinearContiguousTrackArea
  - Proposal for adaption: Therefore, we suggest also here to rely on the spot location which is the simplest shape on a topology model

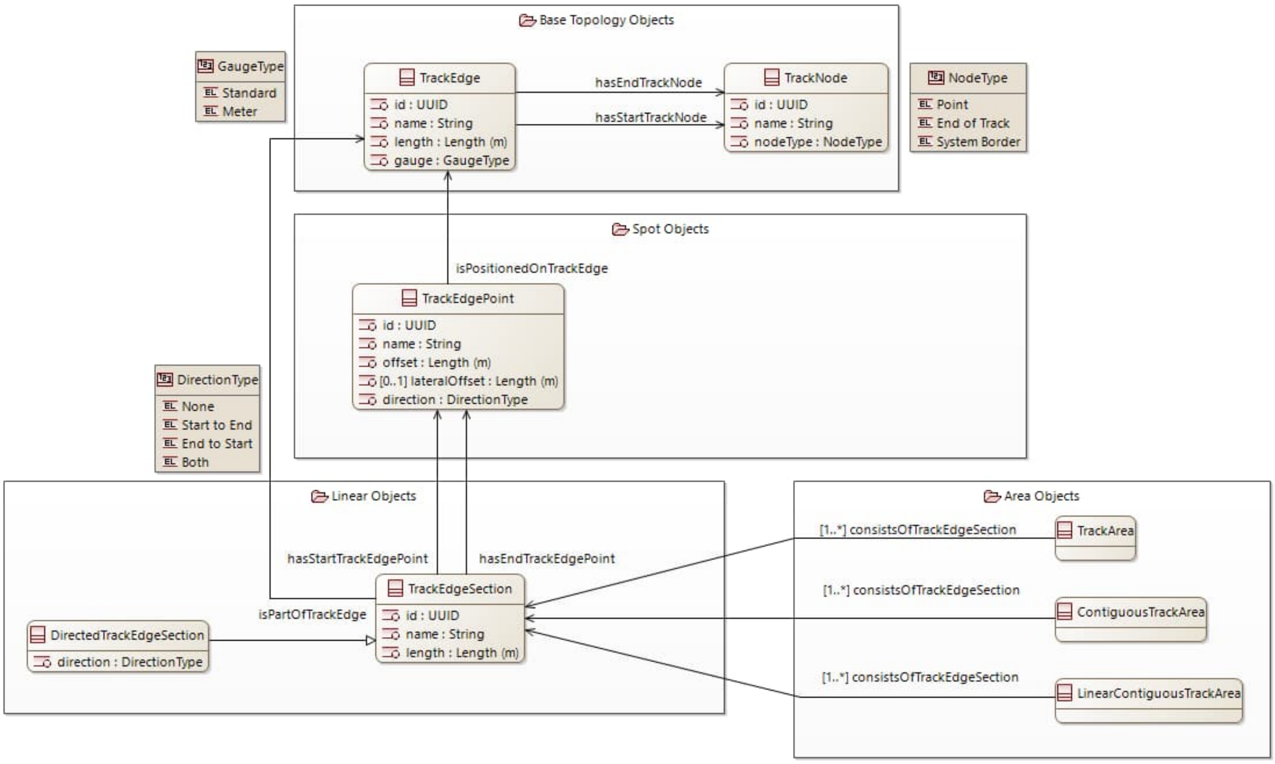


Figure 11 Area location - BNT classes

4.5 Geometry

Table 6 Geometry - BNT vs RTM

BNT	**RTM**
TrackEdgePoints are used to define: • *Gradient* • *CurveRadius* • *Cant* These objects are used as markers and define the position where a value changes. Specified is the new value that applies in the direction specified by the TrackEdgePoint. Only changes are described and not the extension or length of the track to which the value applies.	*LinearLocations* are used to define: • *VerticalAlignment* (gradient) • *HorizontalAlignment* (curve) • *LaterialInclination* (cant) The alignments or inclinations are split into seg-ments. Each segment defines either a transition, arc or straight line and has the relation to the linear location.

- Both BNT and RTM offer the possibility to describe curves, gradients and cants with different naming and positioning concepts.
  - BNT uses spot locations to define changes in curve radius, gradients and cants, whereas RTM uses linear locations to define those segments on the track with equal values.
- While BNT offers the representation that are expected to be required by the operational systems, RTM focus on modelling the actual alignment/inclination elements of the track geometry (especially relevant for engineering process).

- Compatibility (Conversion BNT → RTM):
  - BNT → RTM: two spot locations of BNT define the borders of an RTM segment.
    - Since BNT does not support transitions yet, only straight line or arc segments can be delivered.
  - RTM → BNT:
    - The beginning of the alignment- or cant-segments (the start-point of the linear location) has to be used as the TrackEdgePoint to define the location, where a curve radius, a gradient or a cant change. As BNT does not differentiate between transition, arc or line, this information will be lost after the conversion.
- Conformity BNT vs RTM:
  - The BNT class diagram as in Figure 12 does not comply with RTM as it models “relevant changes” instead of “linear segments” and it does not contain transitions.

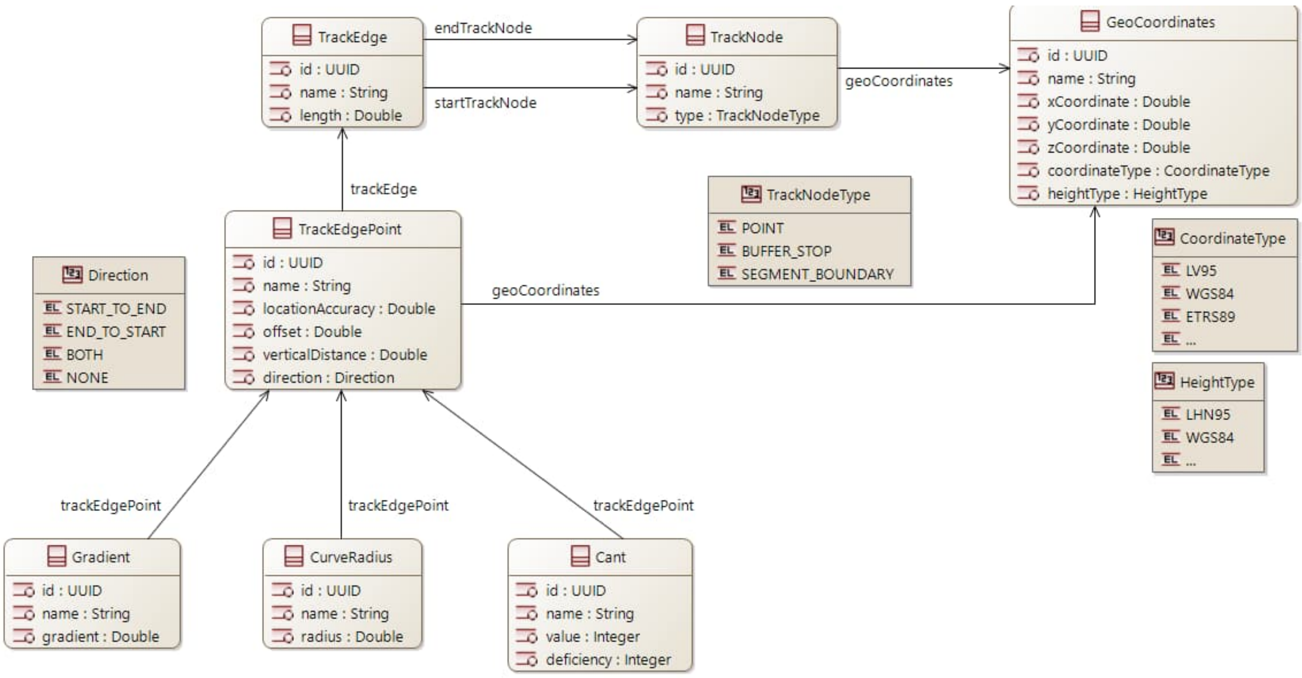


Figure 12 Geometry - BNT classes

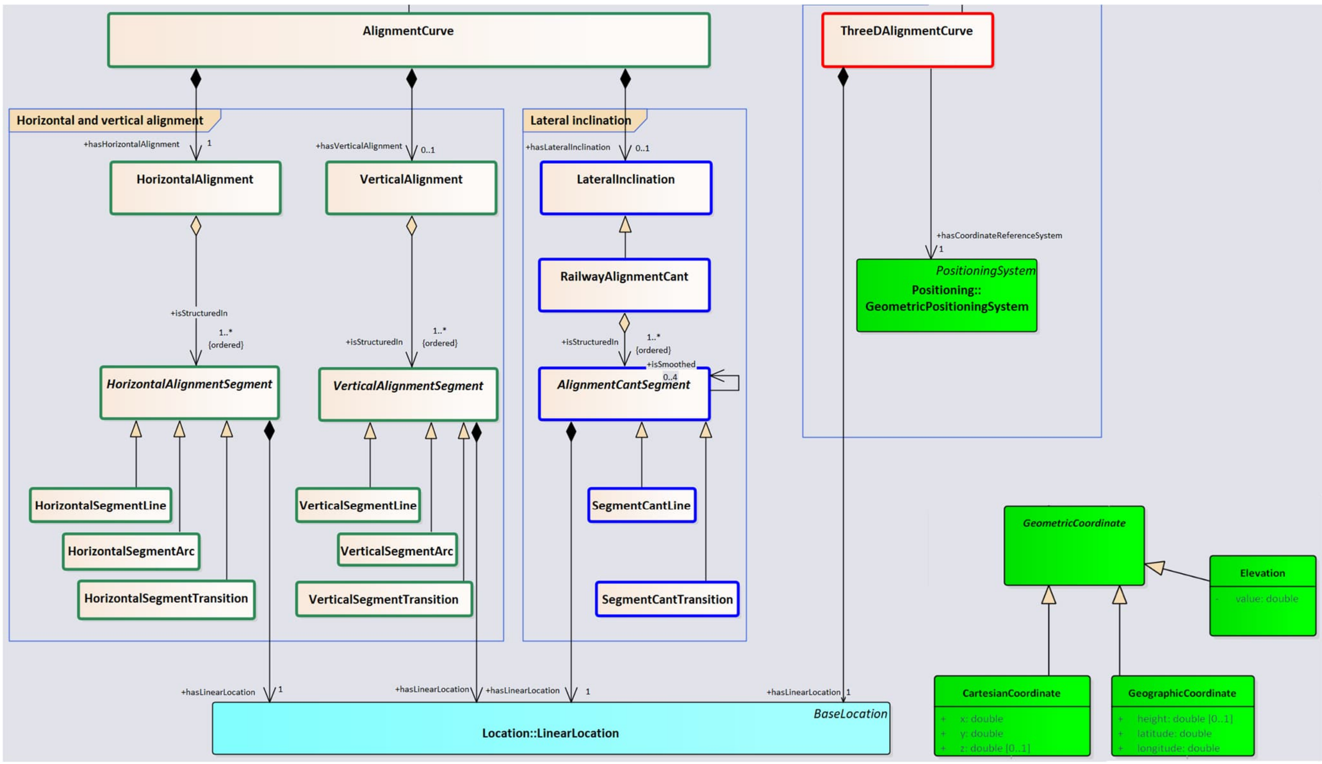


Figure 13 Geometry - RTM classes

(this diagram is taken from the RSM 1.2alpha model)

4.6 Aggregation levels

Table 7: Aggregation levels: BNT vs RTM

BNT	**RTM**
BNT by default in the micro level (nodes for branching → minimum number of nodes required for referenceability and navigability)	Aggregation of objects: *Composition Net Element* • Nano View: The components of a switch (e.g. drives) are represented as separate Net Entities • Micro View: Net Entities coalesce to a Net Entity representing the whole switch • Meso View: Aggregation to operating points • Macro View: Network of lines and stations

- RTM supports more aggregation layers, which could be an advantage if required in this context. Still, in order to use this concept aggregation rules needs to be clearly defined in addition to RTM for the specific use case.

4.7 Domain specific data

Table 8: Domain specific data: BNT vs RTM

BNT	**RTM**
Already includes a set of objects and attributes as required for RCA systems (still developing in RCA object catalogue of Digital Map Cluster)	• RTM as logical meta model does not define specific objects/elements or attributes • RTM based railML3 or EULYNX-PREP fill this gap o EULYNX-PREP: objects/attributes for engineering of conventional interlocking o railML3: objects/attributes for capacity/timetable as well as ETCS / ITMS

Since both, RTM derived models and BNT, define specific objects and attributes for certain use cases, the needs for RCA are expected to be covered by this pre-work. However, due to the specific nature regarding abstraction applied by RCA systems (especially APS compared to today's interlocking systems), specific classes for RCA must be defined (e.g. allocation section, drive protection section, capability model, …).

4.8 Temporality

Table 9 Temporality: BNT vs RTM

BNT	**RTM**
• Temporality deals with the question in which time frame the information of a data set is valid, i.e. in which time frame a data set describes the operational reality. This is mapped with the attributes validFrom and validTo. If the time window is completely in the future, the data set represents a planned operational reality; if it is completely in the past, the data set represents an operational reality that once existed.	• RTM offers a TimeAxis package with basic classes to define points in time and time intervals resp. validity periods • The definitions of validity periods are currently not used in the engineering domains, neither in RTM nor in EULYNX -PREP • EULYNX-PREP has the plan to include the temporality in a future release using a new domain "Project Management"

• In the case of track systems, several objects often go into operation at the same time. These are grouped together into construction phases. A start and end time is defined for each construction phase. The construction phases are to be defined in such a way that all objects assigned to them go into or out of operation at the same time.	

BNT has conceptionally designed objects and attributes to handle temporality, but they are not yet part in neither the RCA object catalogue [10] nor in the RCA domain model. RTM in contrary currently only contains basic classes to express time intervals or validity periods which are not used in the engineering domains. EULYNX-PREP has addressed the need to define temporality by creating the project management work package, but modelling has not yet been started.

5 Discussion: “RTM conformant” approach

5.1 Motivation: “Overhead” of plain RTM

As can be seen in the chapters above (4.1 - 4.8), RTM distinguishes considerably more classes and attributes than BNT, for modeling roughly the same objects. There are several cases to be considered:

- For some properties or facts, RTM offers more alternatives to describe them. Therefore, RTM e.g. supports aggregation levels (4.6), or allows intrinsic coordinates along with absolute linear coordinates (see 4.2, 4.3)
- For some features, RTM just distinguishes more classes in order to maintain clarity in the model, e.g.:
  - NetElements are realized as PositioningNetElements adding some more properties to the features inherited from the parent class; and the PositioningSystem again is not part of the PositioningNetElement, but it’s own class again, in order to allow for different positioning systems to be used.
  - Objects on the Network are modelled as NetEntitites, but their location is its own class, being realized as a spot, linear or area location
  - Coordinates are not stored in the location, but in separate classes, as a location can be described in several Coordinate Systems

This has several effects:

1. Due to the many options, their specific usage in an RTM implementation is still wide-open and needs to be defined (and documented). There is no such thing as an “RTM format” that can be directly and unambiguously derived from RTM. Rather, every RTM implementation needs its own document, describing the way RTM has been interpreted in the specific case.
2. The class structure creates some overhead of classes that are required by a complete implementation, but which might not create much meaning to the implementation. E.g. the separation of the AssociatedPositioningSystem from NetElement, or of the Separation of the EntityLocation from the NetEntity.

Therefore, in this chapter, a “slim” version of RTM shall be presented and discussed, reducing the overhead to a minimum (while not completely eliminating it, as the separation of the LinearCoordinate from the TrackEdgePoint will show).

5.2 Description of “RTM conformant” approach based on BNT

In order to present an alternative that combines full RTM conformity with the simplifications applied by BNT, an additional “RTM conformant” approach is introduced in this chapter. This approach will be included into the evaluation. It is derived from the shown BNT approach and tries to reach RTM conformity with a minimum number of adaptions.

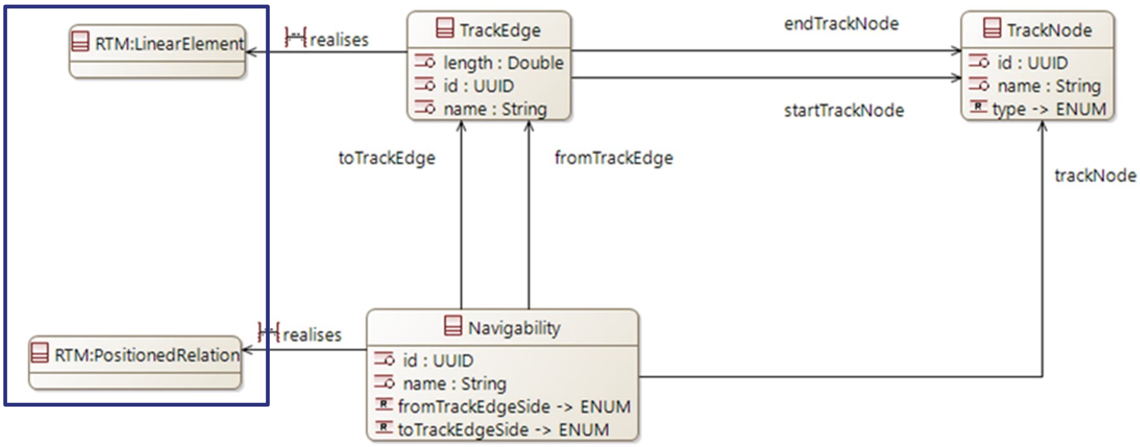


Figure 14 Topology - RTM conformant approach

The topology diagram Figure 14 shows no differences compared to BNT: The Navigability and TrackEdge classes can be directly mapped against RTM classes. The TrackNode, as already mentioned above, is a BNT-only concept.

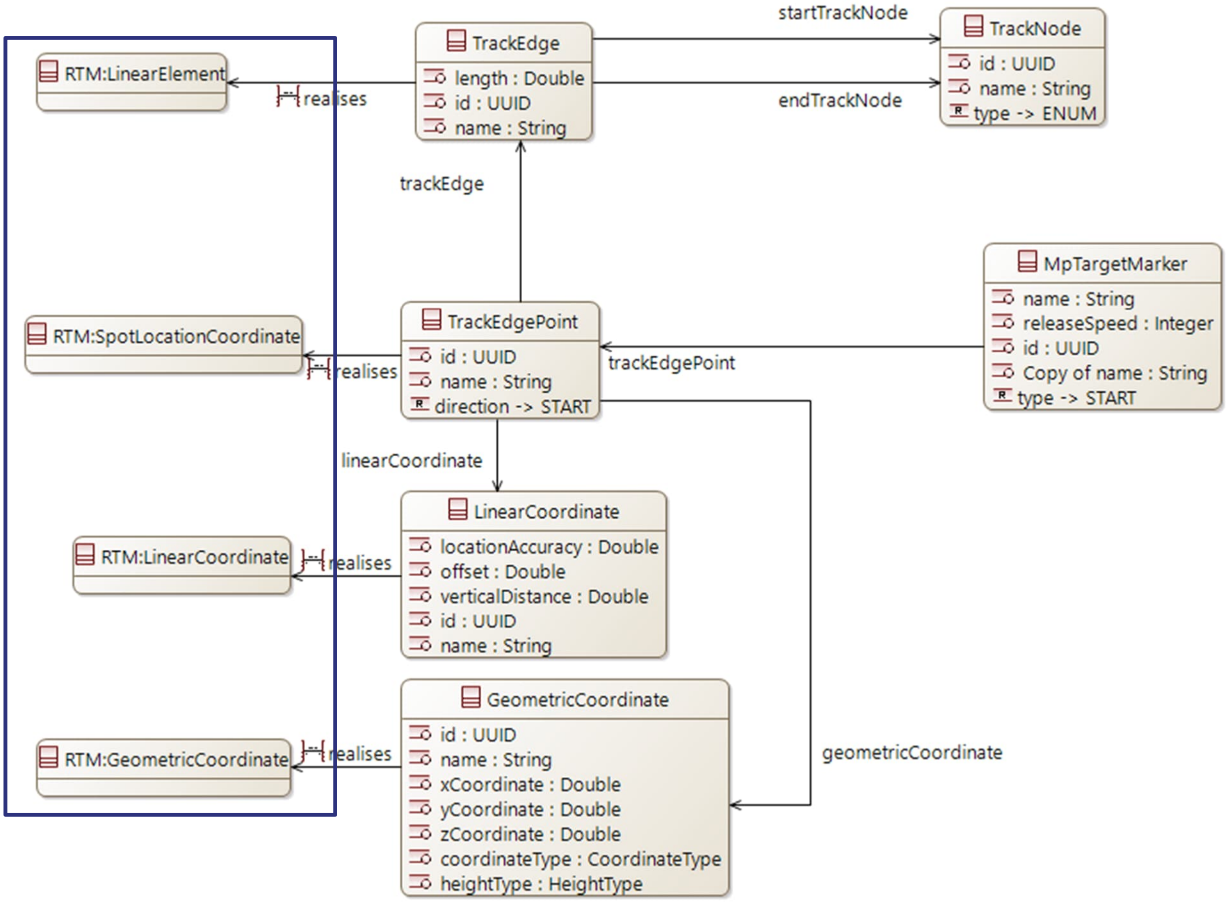


Figure 15 Spot Location - RTM conformant approach

For spot locations, the fundamental change is the separation of the offset, vertical distance and location accuracy attributes in their own class LinearCoordinate. By that, the TrackEdgePoint can be mapped against the RTM SpotLocationCoordinate class. Also, the LinearCoordinate and GeographicCoordinate Classes have a direct equivalent on RTM side.

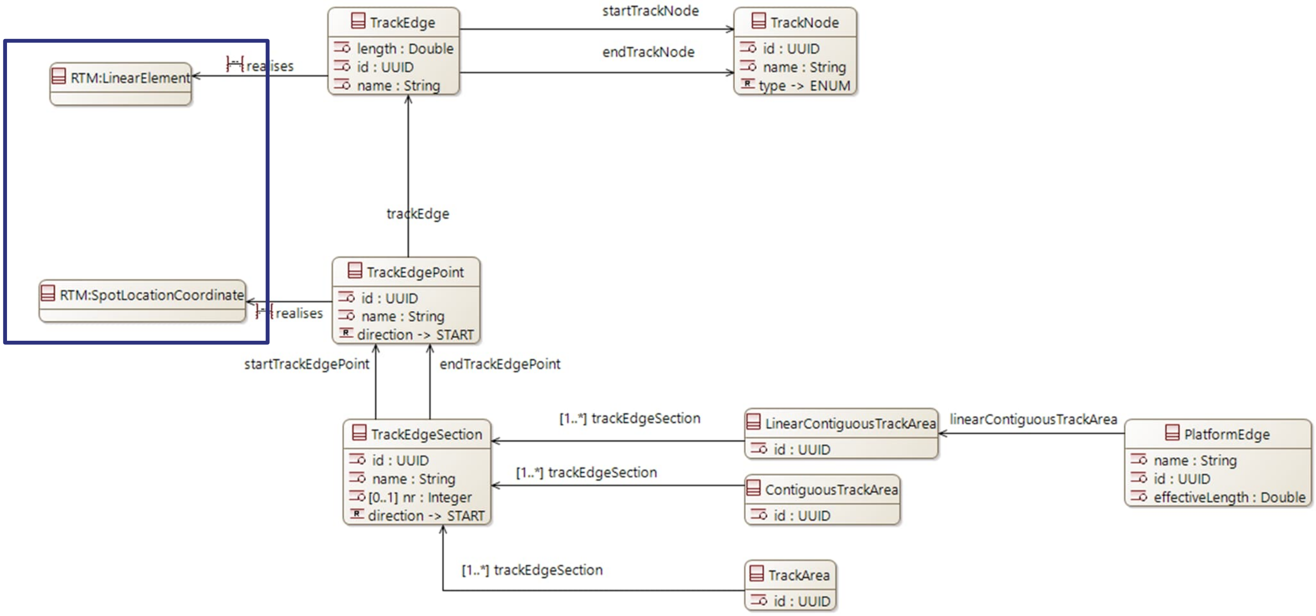


Figure 16 Linear Location - RTM conformant approach

Linear and area locations, in contrast, are not mapped against RTM classes in this simple proposal. They rely on the fact that spot locations are easily mapped against RTM.

5.3 RTM development perspective

RTM is under ongoing development; the current roadmap is to extend the current topology model towards a RailSystemModel (RSM) by improving the topological and geometrical positioning and entering some basic railway infrastructure domains, e.g., signalling and track layouts. Also, a time frame is added to the model which could facilitate bi-temporalities (including validity times and versioning).

In any of the discussed alternatives, the RCA reference model would need to follow the changes these developments will impose but may also take advantage of the new content.

For the conformant alternative, RCA would be stronger bound to RTM development processes and development speed, while for the compatibility approach followed by BNT, the connection would be less close and allow for more own decisions.

For instance, the geometry description in RTM is currently (also in RSM 1.2 development version) independent from external standards like the OGC Simple Features [11] (This standard provides from a spatial data handling point of view a definition of basic geometry types and their notation. Such a standard would ease the utilization of the model in spatial data software and formats on the physical level.)

Choosing the conformity alternative would mean to this example that RCA would need to follow the development path of RTM whether this standard (or a comparable alternative) will be introduced or not. Choosing the compatibility alternative, RCA could make up its own decision and just refine the conversion rules between the affected RTM and RCA/BNT classes.

Of course, it must be ensured that BNT will continue to be developed and maintained in the future. In addition, in the case of further development, it must be regularly checked that the compatibility between BNT and RTM is maintained.

5.4 Debate on “RTM conformant” adaptions to BNT

As already noted in chapter 5.1 the RTM-conformant approach limits itself to the base topology and spot-shaped locations. For more complex locations, a higher deviation between RTM and BNT can be observed. This limitation wouldn’t harm compatibility, as illustrated in Figure 17: Any complex linear or area location can be broken down to spot locations at its borders. This breakdown is technically possible for any model. In BNT it's even conveniently supported by the model itself, as TrackEdgeSections are defined by their limiting TrackEdgePoints and Track Areas are defined as a composition of TrackEdgeSections.

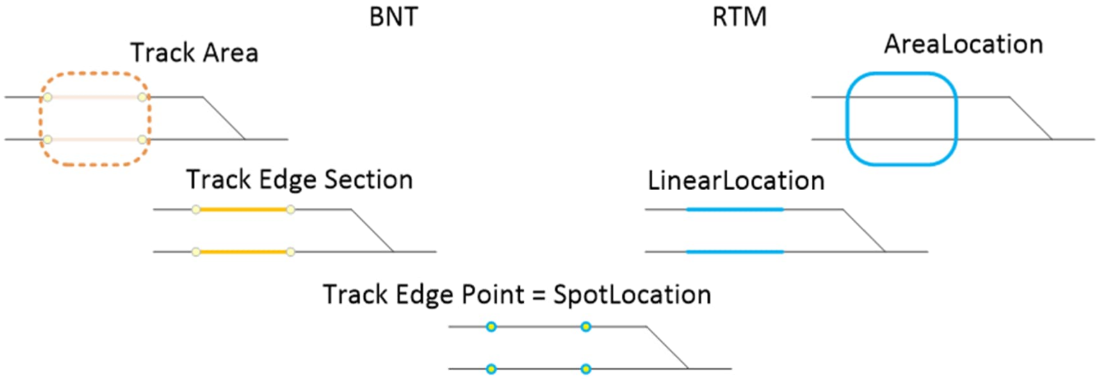


Figure 17 Locations in BNT and RTM

However, there would still be the need for a set of transformation rules for linear and area locations, regulating these processes, as for the original BNT model. The RTM-conformant adaption of BNT has a low benefit for actual performance of data conversion, but eases the human-readability of the model and its transformation from and into plain RTM, EULYNX or railML3 applications.

In order to fully comply with RTM, the BNT model would furthermore need some content that is not going to be used by RCA but is mandatory for RTM. e.g.:

- An intrinsic coordinate system for every LinearElement and intrinsic coordinates for all Spot Locations. The intrinsic positioning approach from RTM uses float point values and is thus not feasible for SIL-certifiable applications. It could speed up calculations and position comparisons that are not safety critical. It must be ensured by the data handling processes that this approach is never used in safety-related applications.

These additions add overhead to fulfil RTM requirements, but do not add any value to the model. In cooperation with RTM, possibly an understanding could be reached that these additions should be made optional in future versions of RTM.

6 Evaluation

The following table weights the introduced criteria (requirements) and evaluates the approaches accordingly. The evaluation uses the scale starting from “0” (not fulfilled) up to “1” (fully supported), while grades in between are allowed.

Table 10: Evaluation of approaches

Category	Requirement	Weight PREP	Weight OP	BNT		RTM-conformant		(plain) RTM	
Data Content, Topology	Topological description of the tracks and their relations to each other	1	1	1	fulfilled, see approach description	1	fulfilled, see approach description	1	fulfilled, see approach description
Data Content, Referability	Referable positions for spot, linear, areal elements	1	1	1	fulfilled, see approach description	1	fulfilled, see approach description	1	fulfilled, see approach description
Data Content, Navigability	Possible train movements can be modelled	1	1	1	fulfilled, see approach description	1	fulfilled, see approach description	1	fulfilled, see approach description
Data Content, Geometry	Track geometry incl. radius, gradient, superelevation/CANT, track points	1	1	1	fulfilled, see approach description (track points + relevant geometrical changes, if required). The actual track geometry elements (arc, transition, straight line) are not modelled, since they are not (yet) expected to be required by the operational systems.	1	Is covered by domain common:geometry, e.g. also already used in railML3	1	Is covered by domain common:geometry, e.g. also already used in railML3

Category	Requirement	Weight PREP	Weight OP	BNT		RTM-conformant		(plain) RTM	
Data Content, Attributes	Detail object data (asset classes, attributes)	1	1	1	Data object catalogue exists for a lot of RCA systems (to be discussed and completed)	1	Data object catalogue existing for a lot of RCA systems (to be discussed and completed) could be utilized	1	plain RTM contains nothing, but deviated railML3 and EULYNX PREP models could be partially used (for the overlapping part). However, the available definitions of BNT could be also transferred to a plain RTM approach.
Granularity, Aggregation	Support of several detail levels (macro, meso…)	0	0	-	(not relevant)	-	(not relevant)	-	not relevant
Variants	Multiple versions of same situation	0	0	-	(not relevant)	-	(not relevant)	-	not relevant
Temporality, Traceability	Include validity time information and support history	0	1	1	Validity times can be modelled. The grouping to construction phases is supported	1	See BNT	0,5	basic concepts for timeline are there but not applied yet e.g. in EULYNX PREP → needs some further work (in the current state)

Category	Requirement	Weight PREP	Weight OP	BNT		RTM-conformant		(plain) RTM	
Efficiency, Performance	Efficient structure for real-time processing	0	1	1	model has been optimized for data processing in APS/TMS	0,8	transformation to optimized formats must and can be done by operational system in case of clear transformation rules (Affects less classes than for plain RTM)	0,5	transformation to optimized formats must and can be done by operational system in case of clear transformation rules
Efficiency, Capacity	Efficient structure for data transmission	0	1	1	by filtering of the really required objects and attributes the model can be very efficient	0,5	overhead of RTM (see approach description limits the efficient usage of capacity (Affects less classes than for plain RTM)	0	overhead of RTM (see 5.1) limits the efficient usage of capacity
Efficiency, Storage	Efficient structure for data storage	0	1	1	by filtering of the really required objects and attributes the model can be very efficient	0,5	overhead of RTM (see approach description limits the efficient usage of capacity (Affects less classes than for plain RTM)	0	overhead of RTM (see approach description limits the efficient usage of capacity
Conformity, Interoperability	Consideration of existing international standards	1	1	1	BNT is designed to be closer to needs of operational systems, so the transformation effort to interoperable systems/message structures can be expected to be very low	0,5	RTM is designed for static (engineering) data with a special connexity graph, so the transformation effort to interoperable systems/message structures can be expected to be higher	0,5	RTM is designed for static (engineering) data with a special connexity graph, so the transformation effort to interoperable systems/message structures can be expected to be higher

Category	Requirement	Weight PREP	Weight OP	BNT		RTM-conformant		(plain) RTM	
Safety	SIL function compatible: e.g. avoid complex model transformation, avoid floating point values	1	1	1	designed for usage in safety-related applications considering the constraints	0,5	adaption of RTM for safety-related applications required	0	intrinsic positioning not suitable. Also, the model is more complex compared to BNT
Safety, Compatibility, Unambiguousness	Unambiguous modelling without modelling variants (degree of freedom)	1	1	1	no grade of freedom	0,8	would be a restricted subset of RTM for the required objects. Risk of using the intrinsic positioning at the wrong place (SIL) remains.	0,5	very open, could be restricted for the required objects
Sum		6	11	**PREP: 8/8 OP:12/12**		**PREP: 6,8/8 OP:9,6/12**		**PREP: 6/8 OP:7/12**	

Result:

As the previous analysis shows, BNT fully satisfies the criteria of the evaluation, while plain RTM cannot fulfil some of them. The compromise, a conformant subset of RTM classes fitting the considered scope, ranks in between: It basically fulfils all the requirements, but some in a less elegant or efficient way than the BNT solution. This would be the price of being RTM-conformant.

The good result for BNT is not surprising, as BNT has been designed just along the requirements that have been used for this evaluation, while RTM has been developed with a larger variety of use cases in mind, and only low consideration for operational systems.

7 Conclusion

~~We~~Based on the result of the previous evaluation, the usage of plain RTM as a topology model for RCA is not recommended. It has several gaps and disadvantages regarding the usage in an operational application.

Feasible alternatives are either a conformant subset of RTM classes adapted to RCA usage, or the existing BNT model, that provides not conformity, but good compatibility with RTM. In general, it has been shown that all reference models are able to cover the complete set of required data content, including the aspects of navigability and geometry. An important point to highlight is that the BNT model facilitates the “intuitive” Node-Edge graph model, but is designed very close to RTM’s Connexity graph model, hence allowing easy transformation between both approaches.

The main differences between the BNT and the introduced “RTM-conformant approach” are:

- BNT: As the evaluation of this documents shows, the BNT model used by RCA is the best suited model to fulfil the analyzed requirements. However, while being compatible to RTM, BNT cannot be labeled conformant to RTM (although the conversion effort is low).
- “RTM-conformant approach”: The price for conformity has some drawbacks regarding efficiency and some extra efforts to ensure the usage in a safety-critical operational environment. In addition, the “conformant approach” still requires rules to ensure compatibility between two RTM based formats (e.g. limit positioning to TrackEdgePoints, as it is proposed here). So, there seems to be no practical advantage of using a more conform modelling approach.

Another characteristic of BNT is the independence from ongoing RTM development, which is an advantage in the short sight, as own modelling ideas can be introduced faster. On the long run, it could turn out as a disadvantage, as it also means that BNT / RCA will always have the responsibility to maintain the separate model, while using RTM, some maintenance questions can be handled by the RTM user community in a bigger forum.

Based on the evaluation result and the discussion, the involved RCA clusters come to the following decision:

- The BNT approach should remain the basis for the RCA domain knowledge model, since the more important compatibility for importing RTM based data is given and the disadvantages of conformer RTM approaches outweigh the advantages within this considered scope.
- Therefore, the concepts for “navigability” and “geometry” (and maybe also “temporality”) should be transferred from BNT model to the abstracted RCA domain knowledge model, since it will be required by several RCA subsystems.
    - Regarding “geometry”: if the actual track geometry elements (arc, transition, straight line) are required by a RCA subsystem, the concepts of RTM might be included for this aspect.
- Consequently, the first scenario as introduced in chapter 3.2 is selected, so RCA PREP systems and operational Systems are using the same reference model, which minimizes transformation efforts and ambiguities.

7.1 Next Steps

Based on the decision regarding the reference model the following next steps are proposed:

- Presumed a decision for the (plain) BNT model to be introduced into RCA, the class diagrams of the RTM-conformant approach should be used as a starting point for a document describing the transformation between RTM and BNT (by exchanging the realization links between BNT and RTM classes with a “transforms to” association).

8 References

The following documents provide related references:

[1] RCA System Architecture [RCA.Doc.35]

[2] RCA Glossary [RCA.Doc.14]

[3] RCA Domain Knowledge [RCA.Doc.18]

[4] RCA Methods and Tooling [RCA.Doc.33]

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

[6] Rail Topo Model (RTM) standard IRS.30100:2016. https://uic.org/rail-system/railtopomodel (2021-03-18)

[7] EULYNX PREP, snapshot model provided on https://eulynx.eu/index.php/dataprep (2021-03-18)

[8] railML3, schema provided on https://www.railml.org/files/download/schemas/3.1/documentation/railML3.html (2021-03-18)

[9] Rail System Model (RSM) Release 1.2_alpha, http://ijzerweg.nl/

[10] RCA Digital Map – Object Catalogue – not published yet

[11] OGC Standard, https://www.ogc.org/standards/sfa (22.03.2021)

[12] RCA Digital Map Concept [RCA.Doc.35]

9 Annex A: Example topology definition

Based on a reference topology the actual modelling according to the selected BNT approach is shown, in order to give more clarity to the actual implementation.

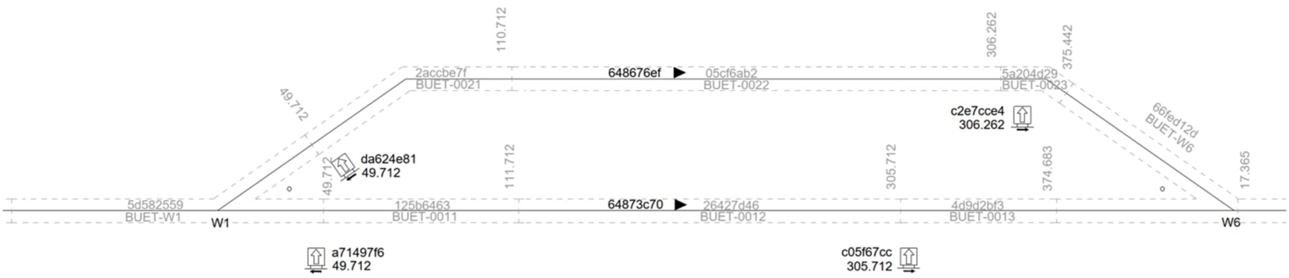


Figure 18: Infrastructure example

9.1 BNT

9.1.1 TrackNodes (Switches)

```
"trackNodes": [
	{
		"id": "e2af0b92-889b-11eb-8dcd-0242ac130003",
		"name": "BUET-1",
		"type": "POINT",
	},
	{
		"id": "e2af0f0c-889b-11eb-8dcd-0242ac130003",
		"name": "BUET-6",

		"type": "POINT",
	}
]
```

9.1.2 TrackEdges (Track Sections)

```
"trackEdges": [
	{
		"id": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
		"name": "LUET.w7.Left_BUET.w1.Top",
		"length": 2568.27,
		"startNode": " ac74b488-88b8-11eb-8dcd-0242ac130003",
		"endNode": " e2af0b92-889b-11eb-8dcd-0242ac130003"
	},
	{
		"id": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
		"name": "BUET.w1.Right_BUET.w6.Left",
		"length": 424.865,
		"startNode": "e2af0b92-889b-11eb-8dcd-0242ac130003",
		"endNode": "e2af0f0c-889b-11eb-8dcd-0242ac130003"
	},
	{
		"id": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
		"name": "BUET.w1.Left_BUET.w6.Right",
		"length": 425.233,
		"startNode": "e2af0b92-889b-11eb-8dcd-0242ac130003",
		"endNode": "e2af0f0c-889b-11eb-8dcd-0242ac130003"
	},
	{
		"id": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
```

```
            "name": "BUET.w6.Top_LSG.w5.Left",
            "length": 4247.44,
            "startNode": "e2af0f0c-889b-11eb-8dcd-0242ac130003",
            "endNode": "3e25be7c-88b9-11eb-8dcd-0242ac130003"
        }
]
```

9.1.3 Navigabilities

```
"navigabilities": [
        {
            "id": "9cc4a874-1180-4e05-86a5-60ca6ee3a896",
            "name": "LUET.w7.Left_BUET.w1.Top-BUET.w1.Right_BUET.w6.Left",
            "fromEdgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "TARGET",
            "toEdgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "START"
        },
        {
            "id": "431497a6-fe06-422c-901e-17595165e8c1",
            "name": "BUET.w1.Right_BUET.w6.Left-LUET.w7.Left_BUET.w1.Top",
            "fromEdgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "START",
            "toEdgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "TARGET"
        },
        {
            "id": "13b958bc-33ec-4550-b5ce-5d9c3ebf3cad",
            "name": "LUET.w7.Left_BUET.w1.Top-BUET.w1.Left_BUET.w6.Right",
            "fromEdgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "TARGET",
            "toEdgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "START"
        },
        {
            "id": "d56b748c-c448-44fd-817b-898c0bc42e12",
            "name": "BUET.w1.Left_BUET.w6.Right-LUET.w7.Left_BUET.w1.Top",
            "fromEdgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "START",
            "toEdgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "TARGET"
        },
        {
            "id": "0a70c15b-ba12-4ba3-be28-54564030496f",
            "name": "BUET.w6.Top_LSG.w5.Left-BUET.w1.Right_BUET.w6.Left",
            "fromEdgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "START",
            "toEdgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "TARGET"
        },
        {
            "id": "e02b5afd-8d9e-473a-a23d-fa64f26553f6",
            "name": "BUET.w1.Right_BUET.w6.Left-BUET.w6.Top_LSG.w5.Left",
            "fromEdgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "TARGET",
            "toEdgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "START"
        },
        {
            "id": "91eda633-d467-46c9-9c78-c114960c9cd2",
            "name": "BUET.w6.Top_LSG.w5.Left-BUET.w1.Left_BUET.w6.Right",
            "fromEdgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
            "fromEdgeSide": "START",
            "toEdgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
            "toEdgeSide": "TARGET"
        },
```

```
	{
		"id": "42740e0a-cb99-465b-ba26-77d76ff733f5",
		"name": "BUET.w1.Left_BUET.w6.Right-BUET.w6.Top_LSG.w5.Left",
		"fromEdgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
		"fromEdgeSide": "TARGET",
		"toEdgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
		"toEdgeSide": "START"
	}
]
```

9.1.4 MpTargetMarker (ETCS Stop-Marker Boards)

```
"mpTargetMarkers": [
	{
		"id": "a71497f6-f6f2-483d-b67f-4c66272ff0fd",
		"name": "BUET-B1",
		"trackEdgePoint": {
			"edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
			"offset": 49.712,
			"direction": "TARGET_TO_START",
		},
		"type": "MONITORED_BY_OCS",
		"releaseSpeed": 20
	},
	{
		"id": "da624e81-6333-4fce-94de-11569552c5f3",
		"name": "BUET-B2",
		"trackEdgePoint": {
			"edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
			"offset": 49.712,
			"direction": "TARGET_TO_START",
		},
		"type": "MONITORED_BY_OCS",
		"releaseSpeed": 20
	},
	{
		"id": "c05f67cc-f13b-4d6b-9c18-61645b70be1d",
		"name": "BUET-C1",
		"trackEdgePoint": {
			"edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
			"offset": 305.712,
			"direction": "START_TO_TARGET",
		},
		"type": "MONITORED_BY_OCS",
		"releaseSpeed": 20
	},
	{
		"id": "c2e7cce4-b839-4a42-96f3-b61222321171",
		"name": "BUET-C2",
		"trackEdgePoint": {
			"edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
			"offset": 306.262,
			"direction": "START_TO_TARGET",
		},
		"type": "MONITORED_BY_OCS",
		"releaseSpeed": 20
	}
]
```

9.1.5 Occupancy Sections (TDS)

```
"occupancySections": [
	{
		"id": "5d582559-c67c-49af-a932-5c31deb370e6",
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```
        "name": "BUET-W1",
        "contiguousTrackArea": [
            {
                "trackEdgeSection": {
                    "trackEdgePointFrom": {
                        "edgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 2539.287
                    },
                    "trackEdgePointTo": {
                        "edgeId": "648abd2e-78a9-11e8-8277-7fb03fe0dd72",
                        "offsetTo": 2568.270
                    }
                }
            },
            {
                "trackEdgeSection": {
                    "trackEdgePointFrom": {
                        "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 0.000,
                    },
                    "trackEdgePointTo": {
                        "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 59.712
                    }
                }
            },
            {
                "trackEdgeSection": {
                    "trackEdgePointFrom": {
                        "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 0.000,
                    },
                    "trackEdgePointTo": {
                        "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 59.712
                    }
                }
            }
        ]
    },
    {
        "id": "125b6463-2e58-41b0-878f-cd25d86f8a73",
        "name": "BUET-0011",
        "contiguousTrackArea": [
            {
                "trackEdgeSection": {
                    "trackEdgePointFrom": {
                        "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 49.712,
                    },
                    "trackEdgePointTo": {
                        "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 111.712
                    }
                }
            }
        ]
    },
    {
        "id": "26427d46-db36-4327-8d41-2204e5516835",
        "name": "BUET-0012",
        "contiguousTrackArea": [
            {
                "trackEdgeSection": {
                    "trackEdgePointFrom": {
                        "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                        "offset": 101.712,
                    },
```

```
                        "trackEdgePointTo": {
                              "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 305.712
                        }
                  }
            }
      ]
},
{
      "id": "4d9d2bf3-bfe7-40a1-89b7-ae671dd5d262",
      "name": "BUET-0013",
      "contiguousTrackArea": [
            {
                  "trackEdgeSection": {
                        "trackEdgePointFrom": {
                              "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 295.712,
                        },
                        "trackEdgePointTo": {
                              "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 374.683
                        }
                  }
            }
      ]
},
{
      "id": "2accbe7f-a3c2-4d4b-8872-0d31e3d9b1af",
      "name": "BUET-0021",
      "contiguousTrackArea": [
            {
                  "trackEdgeSection": {
                        "trackEdgePointFrom": {
                              "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 49.712,
                        },
                        "trackEdgePointTo": {
                              "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 110.712
                        }
                  }
            }
      ]
},
{
      "id": "05cf6ab2-4931-44ef-9722-09d1177aa541",
      "name": "BUET-0022",
      "contiguousTrackArea": [
            {
                  "trackEdgeSection": {
                        "trackEdgePointFrom": {
                              "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 100.712,
                        },
                        "trackEdgePointTo": {
                              "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                              "offset": 306.262
                        }
                  }
            }
      ]
},
{
      "id": "5a204d29-62f0-4774-9fd6-ca3b9362d63c",
      "name": "BUET-0023",
      "contiguousTrackArea": [
            {
                  "trackEdgeSection": {
```

```
                        "trackEdgePointFrom": {
                            "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 296.262,
                        },
                        "trackEdgePointTo": {
                            "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 375.442
                        }
                    }
                }
            ]
        },
        {
            "id": "66fed12d-27fe-4502-8476-8e7274b82674",
            "name": "BUET-W6",
            "contiguousTrackArea": [
                {
                    "trackEdgeSection": {
                        "trackEdgePointFrom": {
                            "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 364.683,
                        },
                        "trackEdgePointTo": {
                            "edgeId": "64873c70-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 424.865
                        }
                    }
                },
                {
                    "trackEdgeSection": {
                        "trackEdgePointFrom": {
                            "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 365.442,
                        },
                        "trackEdgePointTo": {
                            "edgeId": "648676ef-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 425.233
                        }
                    }
                },
                {
                    "trackEdgeSection": {
                        "trackEdgePointFrom": {
                            "edgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 0.000,
                        },
                        "trackEdgePointTo": {
                            "edgeId": "648676ee-78a9-11e8-8277-7fb03fe0dd72",
                            "offset": 27.365
                        }
                    }
                }
            ]
        }
    ]
```