RCA

Reference CCS Architecture

An initiative facilitated by the ERTMS Users Group and the EULYNX consortium

RCA Domain Knowledge

Preliminary issue

Document id: RCa.Doc.18

REVISION HISTORY

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1. INTRODUCTION

1.1. Release information

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RCA Domain Knowledge

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Disclaimer:

This issue is a preliminary version of this document. The content of this document reflects the current ongoing specification work of RCA. Formal requirements management and change management will be introduced in future iterations. The content may be unfinished, will likely contain errors and can be changed without prior notice. Unfinished work is be declared by using the ToDo label in this document.

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. Methodology conformance declaration

This RCA interface specification shall conform to the EULYNX Modelling Standard Baseline 3.0 (https://eulynx.eu/index.php/documents/documents-overview/baseline-set-3).

1.4. Purpose of the document

ToDo

1.5. References

The last delivered version of all RCA documents are available on Basecamp (https://3.basecamp.com/4168621/buckets/10801981/vaults/1592502777).

Every release includes a document plan with an overview of all available documents and their current version. Refer to RCA.Doc.6

Other referenced documents:

- CCS TSI ATO over ETCS SUBSET-126
- CCS TSI ATO over ETCS SUBSET-130
- CCS TSI ATO over ETCS SUBSET-131
- CCS TSI ATO over ETCS SUBSET-132
- CCS TSI ETCS SUBSET-026
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- EULYNX Eu.Doc.46

2. DOMAIN KNOWLEDGE

The aim of Domain Knowledge is to explain the underlying concepts used by RCA and to improve the comprehensibility of the RCA specification documents. Together with the glossary, the Domain Knowledge defines a common language used overall in RCA. The Domain Knowledge is not part of the formal interface specification.

The concepts defined in the Domain Knowledge will be realized by different RCA interfaces and subsystems. The concept may be realized by interfaces and subsystems differently; however the abstract concept shall remain the same. Domain Knowledge concepts are modelled as UML classes with the stereotype <<abstract>> associated. A <<realise>> relationship indicates that a certain class is implementing a certain concept.

The following example of a typical railway scenario provides an introduction to the different domains.

A journey through the Domain Knowledge

Let's consider a train run (GoA 2) for a passenger train. The journey starts at the Planning System. The train run has been ordered by an RU and has afterwards been planned in the Planning System. After the planning, the Planning System issues an Operational Plan (see section Operational Plan domain for details). Sys RCA is a consumer of that Operational Plan. At a defined point in time Sys RCA will start to execute the Operational Plan and with that produce the train run as ordered by the RU.

In order to produce this train run, Sys RCA requires a Railway Vehicle. Let's assume that a Railway Vehicle has been stabled and its On Board Unit shut down. The area where the Railway Vehicle is stabled is equipped with a Train Detection System, which reports to Sys RCA that the particular ContiguousTrackArea where the Railway Vehicle is located is occupied (see section Topology domain for details about the ContiguousTrackArea). Since the reason for that occupation is currently unknown to Sys RCA, it creates an Unresolved Trackbound Movable Object for the Railway Vehicle (see section Safety Logic domain for details on Movable Objects).

As the Train Driver enters start of mission on the On Board Unit of the Railway Vehicle, a connection between the On Board Unit and Sys RCA will be established. Sys RCA is now made aware of the reason for the occupation of the ContiguousTrackArea by the Railway Vehicle (Note: An occupation could be caused by one or multiple Railway Vehicles. In this example Sys RCA has not observed any other movement on the occupied ContiguousTrackArea and no changes in the length of the Railway Vehicle have been reported. Therefore, it is safe to deduce that the occupation was caused by this single Railway Vehicle). Sys RCA converts the Unresolved Trackbound Movable Object to a Resolved Trackbound Movable Object.

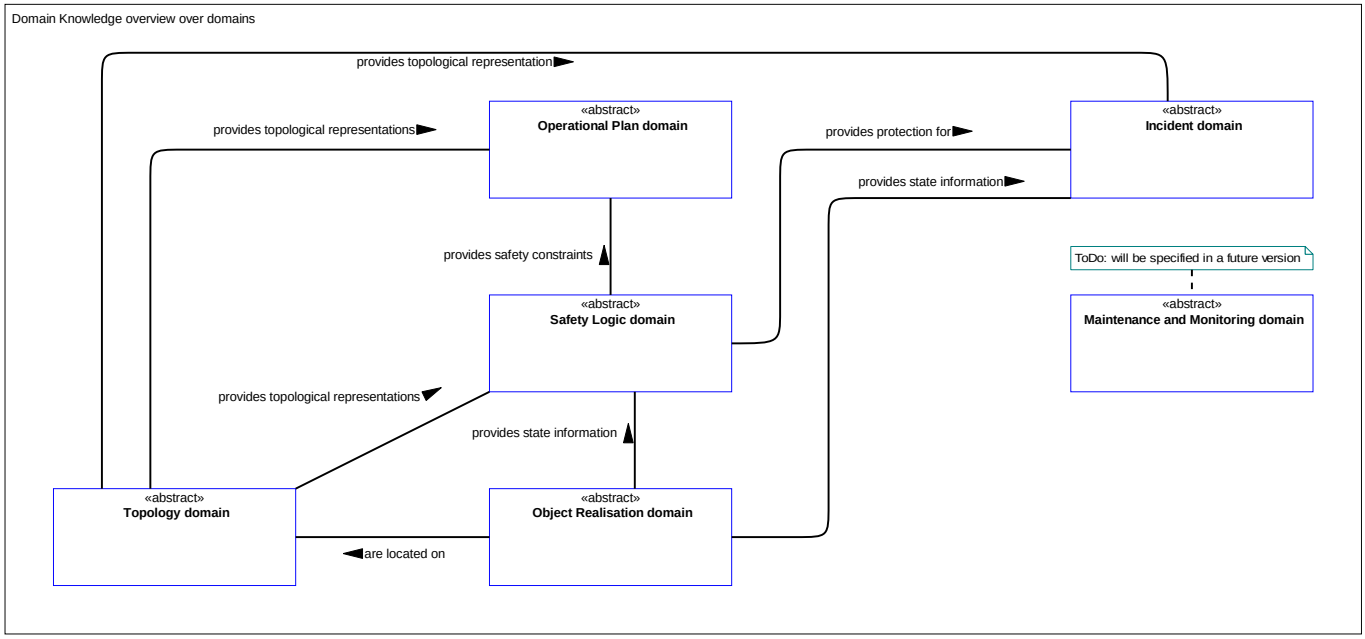
Once the time of the departure of the Railway Vehicle has been reached, Sys RCA provides the required track geometry for its journey by commanding Drive Protection Sections (see section Safety Logic domain for details on Drive Protection Sections). Drive Protection Sections abstract to several types of physical asset on the track, such as Points or Level Crossings. The translation between Drive Protection Section and physical asset is defined in the Object Realisation domain (see section Object Realisation domain for details).

After the Drive Protection Sections are in the state commanded by Sys RCA, Sys RCA grants a Movement Permission to the Resolved Trackbound Movable Object. The Object Realisation domain defines the translation from abstract representation to real world objects; in the case of our journey, it defines the translation from the abstract concept of a Movement Permission to a real world Movement Authority, required by the On Board Unit, and/or modification of the state of light signals (where implementation of light signals is needed). Once a Movement Authority is received by the On Board Unit, the Railway Vehicle may begin to move and begin its train run.

Once the train run begins, imagine that an unplanned movement of a Point along the commanded Drive Protection Section occurs. This problem will be reported as an Incident (see section Incident domain for more information). Based on the Incident, Sys RCA takes measures needed to ensure safe movements and rejects extensions of the Movement Permission. Sys RCA also reports the Incident and the halt of the execution of the Operational Plan to the Planning System. The Planning System based on this information recalculates all Operational Plans affected by this Incident and simultaneously initiates processes to restore the Point to its correct state.

As you can see with this simplified example, the objects defined in the Domain Knowledge interact with each other sequentially. This interaction is shown with relationships on the diagrams contained in this document. To separate different facets of the Domain Knowledge model, Domain Knowledge objects have been structured in different domains based on the grade of their content-wise cohesion. However, real data objects used in the Sys RCA specification can have attributes that realise objects from multiple domains in order to fulfill the required functionality of Sys RCA.

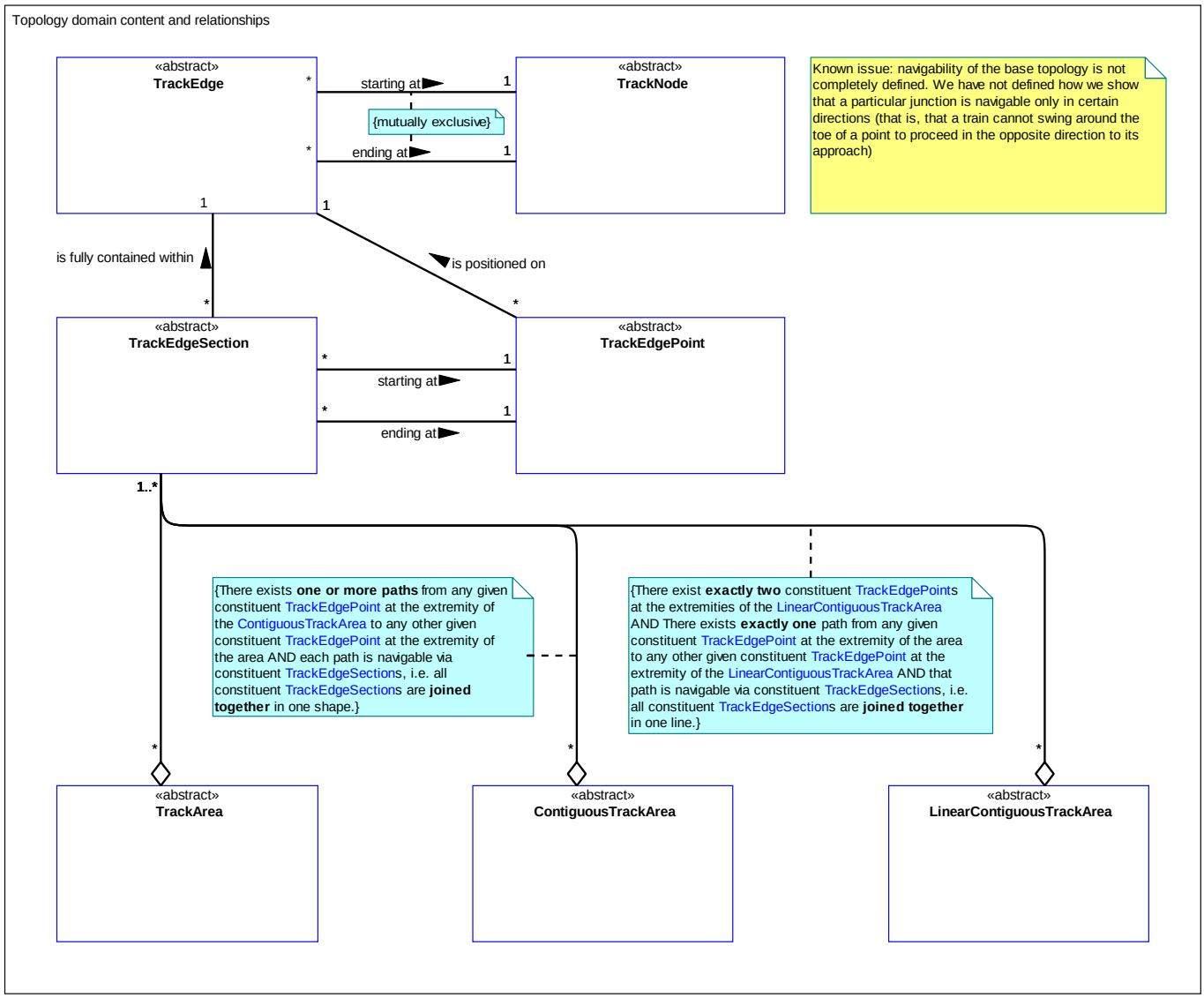
2.1. Overview



Description: Domain Knowledge is structured into distinct domains. The Domain Knowledge overview shows all existing domains in RCA. The diagram shows summarised the relationships between the different domains contained within the overall Domain Knowledge. A relationship between two domains means that there is at least one relationship between the concepts of those domains.

2.2. Domains

2.2.1. Topology

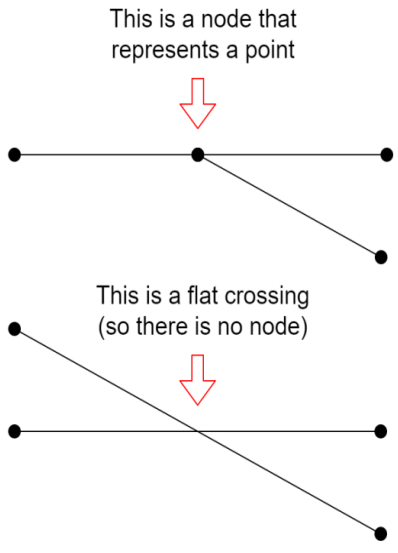


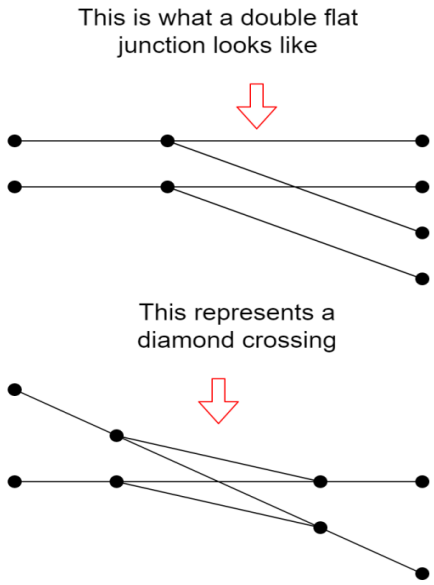
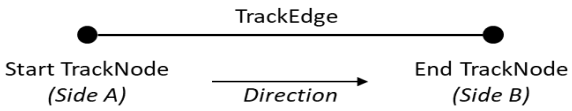
Description: This class diagram shows the relationships between the main topology concepts.

TrackEdges and TrackNodes represent the fundamental network topology of the railway which only changes when the infrastructure is physically changed. TrackEdgeSections, TrackEdgePoints and the three types of TrackArea provide a set of objects for representing the network topology of areas defined not by the physical connections on the track but by other constraints, such as the boundaries of station areas.

Note: Current discussion in RCA DataPrep and Topo4 may introduce changes to the Topology domain.

Name	Description

Name	Description
Topology domain	The Topology domain is a representation of the infrastructure facilities (points, tracks, stations, etc.) at different levels of abstraction (typically the track & line network).
TrackNode	A TrackNode is a position on the topological model of the track network where a TrackEdge begins or ends. There are several situations where a TrackEdge begins or ends, and all are modelled as TrackNode (list is not exhaustive): • Points - Note that even if you would typically say that at a point only one TrackEdge begins while another passes through the point, the TrackNode that represents the point splits the passing track into two TrackEdges • Buffer stops • System borders, e.g. the border between two infrastructure operators - Even if the physical track continues logically one track ends and another begins Examples showing TrackNodes and TrackEdges for describing certain topologies 

Name	Description
	
TrackEdge	An TrackEdge is a linear object that connects exactly two TrackNodes. One of these TrackNodes is defined as a Start TrackNode called Side A, the other is defined as an End TrackNode called Side B. TrackEdges are directed. Each route path between two TrackNodes is represented by a TrackEdge. 
TrackEdgePoint	A TrackEdgePoint is a generic construct used to describe a directed position on a TrackEdge. While TrackNodes are exclusively located at the begin or end of a TrackEdge, a TrackEdgePoint can be located at any position on a TrackEdge.
TrackEdgeSection	An TrackEdgeSection is a contiguous stretch of track within one single TrackEdge used to describe a specific property or state of the track on that stretch. TrackEdgeSections are used to define properties of tracks (like permitted speed, axle load) as well as states (like "allocated in a movement permission", "closed") or any other issues that can be projected to a stretch of track.
TrackArea	A TrackArea is an area that consists of one or more TrackEdgeSection. There are no restrictions whether those TrackEdgeSections are joined or not. Example of a TrackArea that consists of three TrackEdgeSections

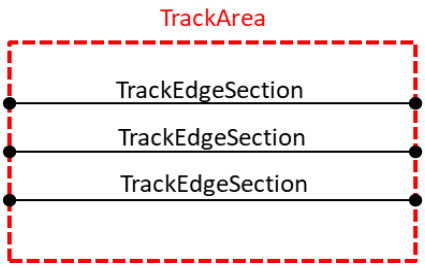
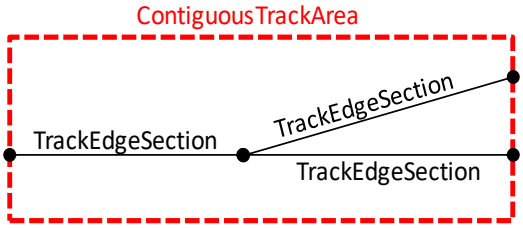
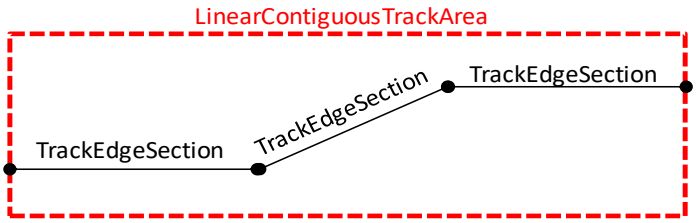
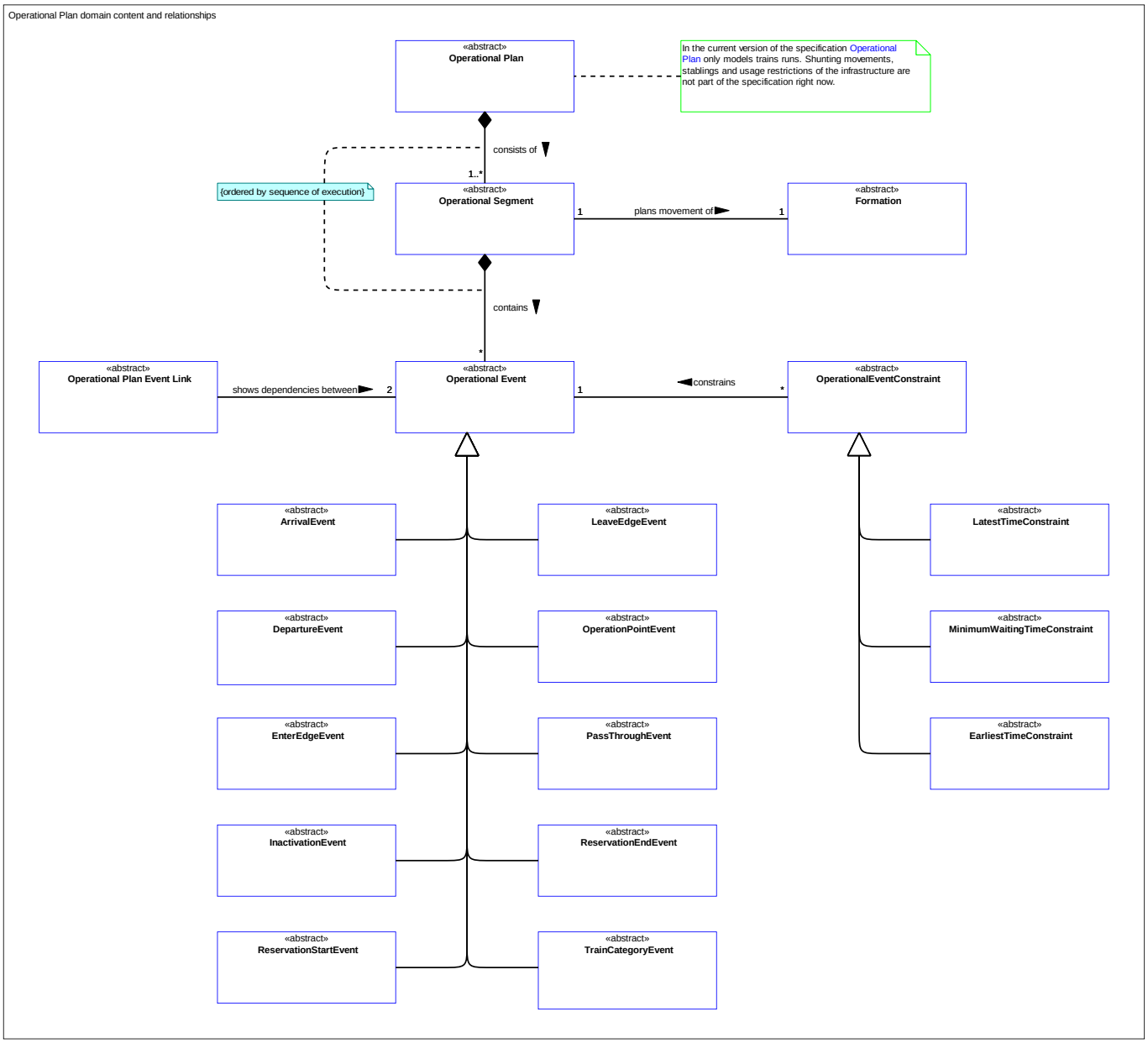
Name	Description
	
ContiguousTrackArea	A ContiguousTrackArea is an area which consists of one or more TrackEdgeSections joined together. Example of a ContiguousTrackArea that consists of three TrackEdgeSections: 
LinearContiguousTrackArea	A LinearContiguousTrackArea is an area that consists of one or more TrackEdgeSections joined together so that they represent one single path. Example of a LinearContiguousTrackArea that consists of three TrackEdgeSections: 

Table 1 Topology

2.2.2. Operational Plan

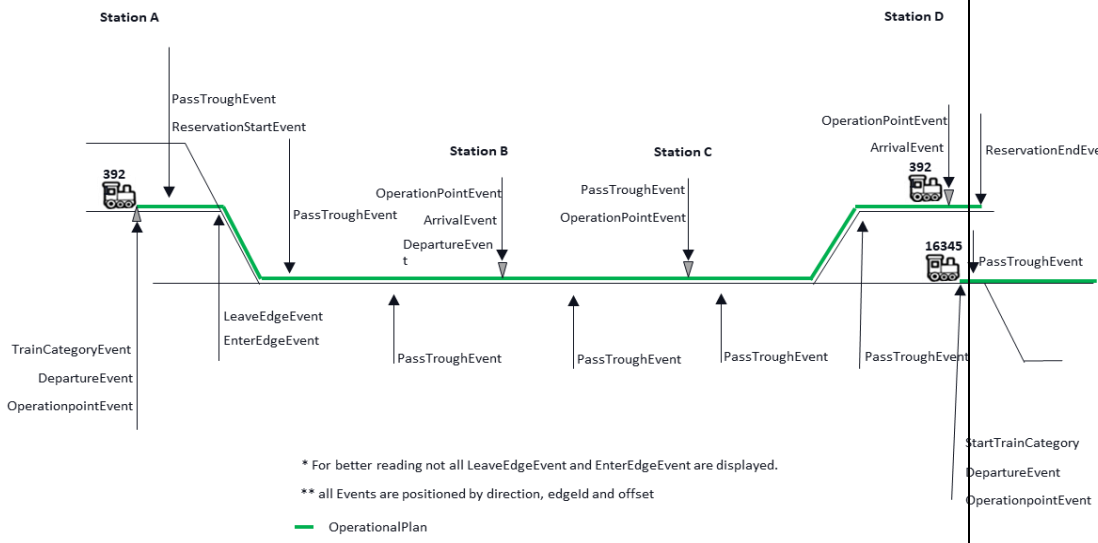


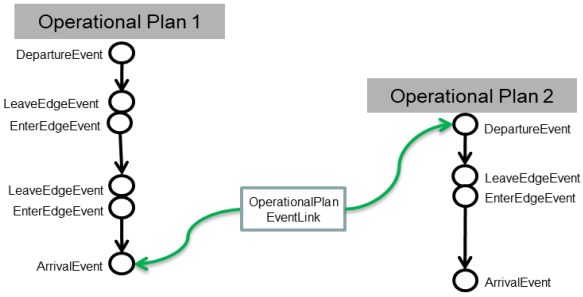
Description: This class diagrams shows the Operational Plan and its elements.

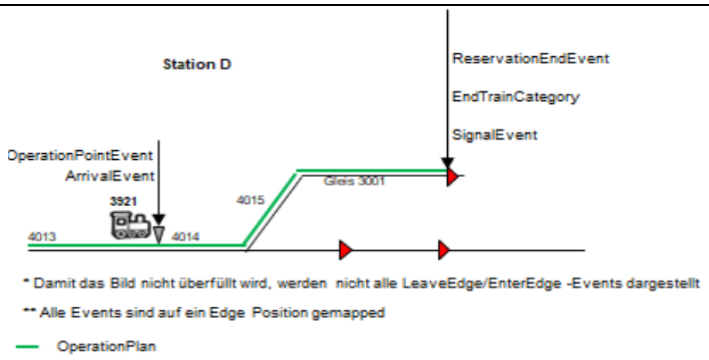
The Operational Plan is mainly a list of Operational Event, sorted by the order of execution, defining train runs, shunting movements, stablings and usage restrictions. An Operational Event defines an action to be taken at a certain location.

An introduction into the concept of Operational Plan can be found in the RCA.Doc.31, RCA Publication.

Name	Description
Operational Plan	All track usages are controlled with Operational Plans. The Operational Plan is issued for train runs, shunting movements, stablings and managing Usage Restriction Area (e.g. for construction and maintenance). Each train run is represented by a separate Operational Plan. The Operational Plan is the output

Name	Description
	of the planning process of Planning System. The Operational Plan is executed by SubSys PE. The following example shows an Operational Plan with a single Operational Segment and its Operational Events.  Note that currently only train runs are covered in this specification. Stabling, shunting movements and usage restrictions are not specified yet.
Operational Segment	The Operational Segment is the detailed plan that describes all track usage for exactly one Formation. Every Formation change will lead to new Operational Segment. A turnback is also considered a change in Formation due to the change of the direction of travel.
Operational Event	An Operational Event is a part of an Operational Plan. An Operational Event describes a planned action that should occur at a defined location on the track. EnterEdgeEvent and LeaveEdgeEvent are used to describe the route through the track network. Other Operational Events describe additional planned actions along this route (e.g. for defining departure and arrival times).
Operational Plan Event Link	A Operational Plan Event Link is a relationship between two Operational Events which are part of Operational Plans. The linked Operational Events can be part of the same or different Operational Plans. Operational Plan Event Links are used for describing circulation of a rolling stock (split, join, change of OperationId) and turnbacks. Example of an Operational Plan Event Link usage:

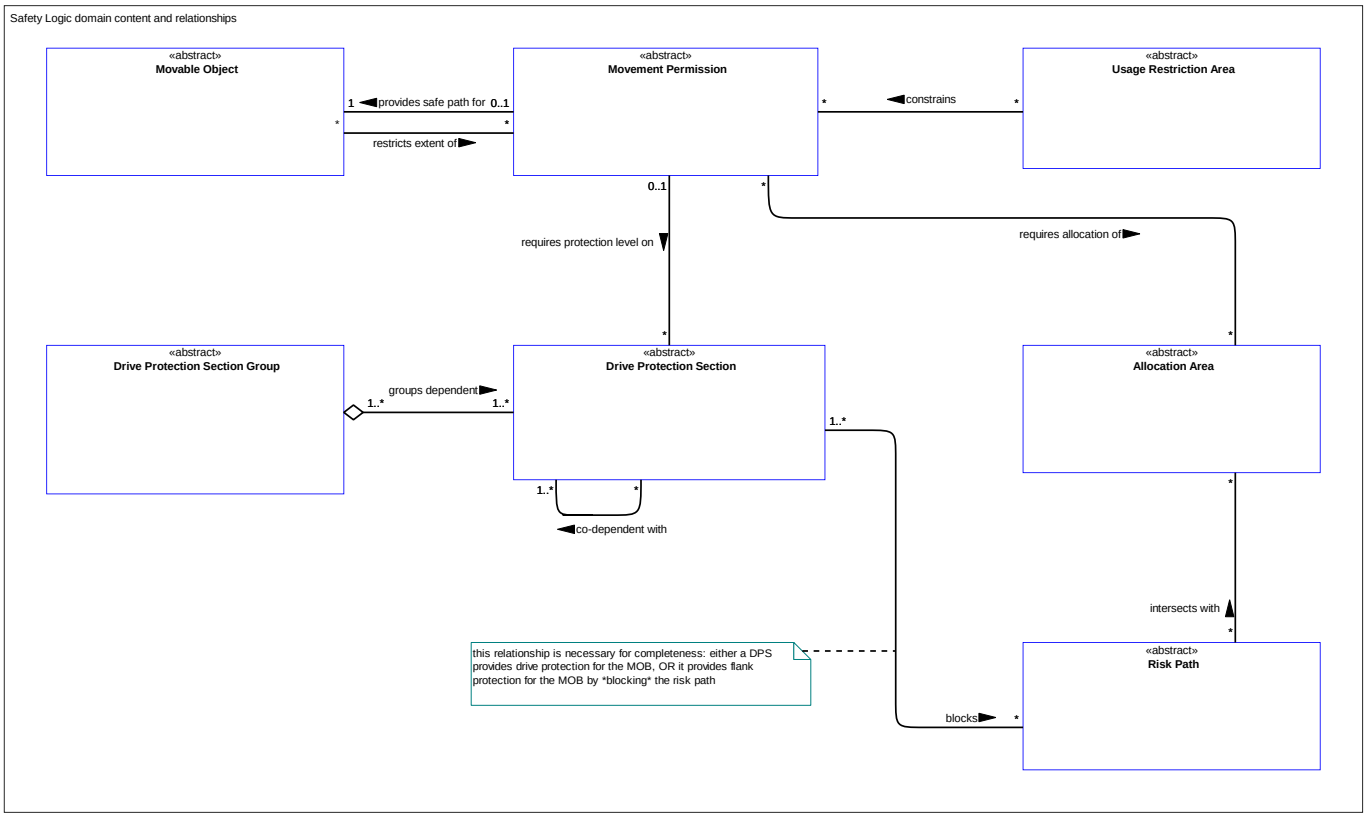
Name	Description
	
Formation	A Formation is an ordered sequence of Railway Vehicles in driving direction.
Operational Plan domain	The Operational Plan domain provides concepts for planned track usage and for reporting the real track usage and the plan execution progress. An Operational Plan is mainly a list of Operational Events sorted by order of execution, defining a planned train run, shunting movement, stabling or a usage restriction. An Operational Event defines actions to be taken at a certain location.
OperationPointEvent	OperationPointEvent represents and defines the Operation Points on a position of the track in the OperationalSegment. OperationPointEvent can have a MinimumWaitingTimeConstraint associated with it.
PassThroughEvent	PassThroughEvent represents a drive through of a train at a defined position on the track at a planned time.
TrainCategoryEvent	TrainCategoryEvent defines the TrainCategory and the position on the TrackEdge from which the newly specified train category becomes valid. Every OperationalSegment must contain a TrainCategoryEvent at the beginning, even if the TrainCategory is the same as on the previous OperationalSegment. The TrainCategory is effective until the next defined TrainCategoryEvent in the OperationalSegment appears.
ReservationEndEvent	ReservationEndEvent represents the end of an OperationalSegment route. The train should not reach this position, but this event is necessary to indicate the end of an OperationalSegment. It is especially important in places where the end of the path (target signal) is not unique. Example: The planned arrival for the train is on track 4014. Between ArrivalEvent and end of route is a point, so there are multiple ends possible. The ReservationEndEvent defines where the route for this movement ends.

Name	Description
	
ReservationStartEvent	ReservationStartEvent represents the beginning of an OperationalSegment route. An OperationalSegment must contain one ReservationStartEvent and one ReservationEndEvent. These two events define the reserved path for the OperationalPlan (e.g. train run). The ReservationStartEvent is located on the head of the train.
LeaveEdgeEvent	LeaveEdgeEvent represents the head of train leaving (position on track) the TrackEdge at its end. LeaveEdgeEvent is always immediately followed by an EnterEdgeEvent. This sequence of OperationalEvents describes the route path defined by the OperationalPlan.
EnterEdgeEvent	EnterEdgeEvent represents the head of the train reaching the beginning of a TrackEdge. EnterEdgeEvent usually follows a LeaveEdgeEvent. There is an exception to this rule: If an EnterEdgeEvent comes after an ArrivalEvent and the train will not pass the end of the TrackEdge. This sequence of Operational Events describes the route path defined by the Operational Plan.
InactivationEvent	InactivationEvent represents a point in the OperationalSegment, after which a train will not continue its journey on the planned route. It is used for trains with undetermined delay of the journey. The inactivation of the train ends, if after an update of the OperationalPlan this InactivationEvent is not present anymore in the OperationalSegment.
ArrivalEvent	ArrivalEvent represents the arrival (position on track) of the train in the operation point with a planned stop.
DepartureEvent	DepartureEvent represents the departure (position on track) of a train. It may follow after a planned ArrivalEvent or it may be the first departure in an OperationalPlan.
OperationalEventConstraint	OperationalEventConstraint is the superclass of all constraints that can be attached to an OperationalEvent. Such a constraint describes conditions that must be met before an OperationalEvent may be considered ready for production.

Name	Description
MinimumWaitingTimeConstraint	A MinimumWaitingTimeConstraint requires that its associated OperationPointEvent may not be passed before the specified time (period) after the most recent stop is elapsed. This constraint must be defined on the DepartureEvent.
LatestTimeConstraint	LatestTimeConstraint requires that its associated OperationalEvent is supposed to happen no later than the time specified in this constraint. It is used, for example, to specify the latest arrival time in an ArrivalEvent. This constraint can only be defined on ArrivalEvents.
EarliestTimeConstraint	An EarliestTimeConstraint requires that its associated OperationalEvent is supposed to happen no earlier than the time specified in this constraint. The EarliestTimeConstraint can be only be applied to DepartureEvent to define an earliest departure time.

Table 2 Operational Plan

2.2.3. Safety Logic

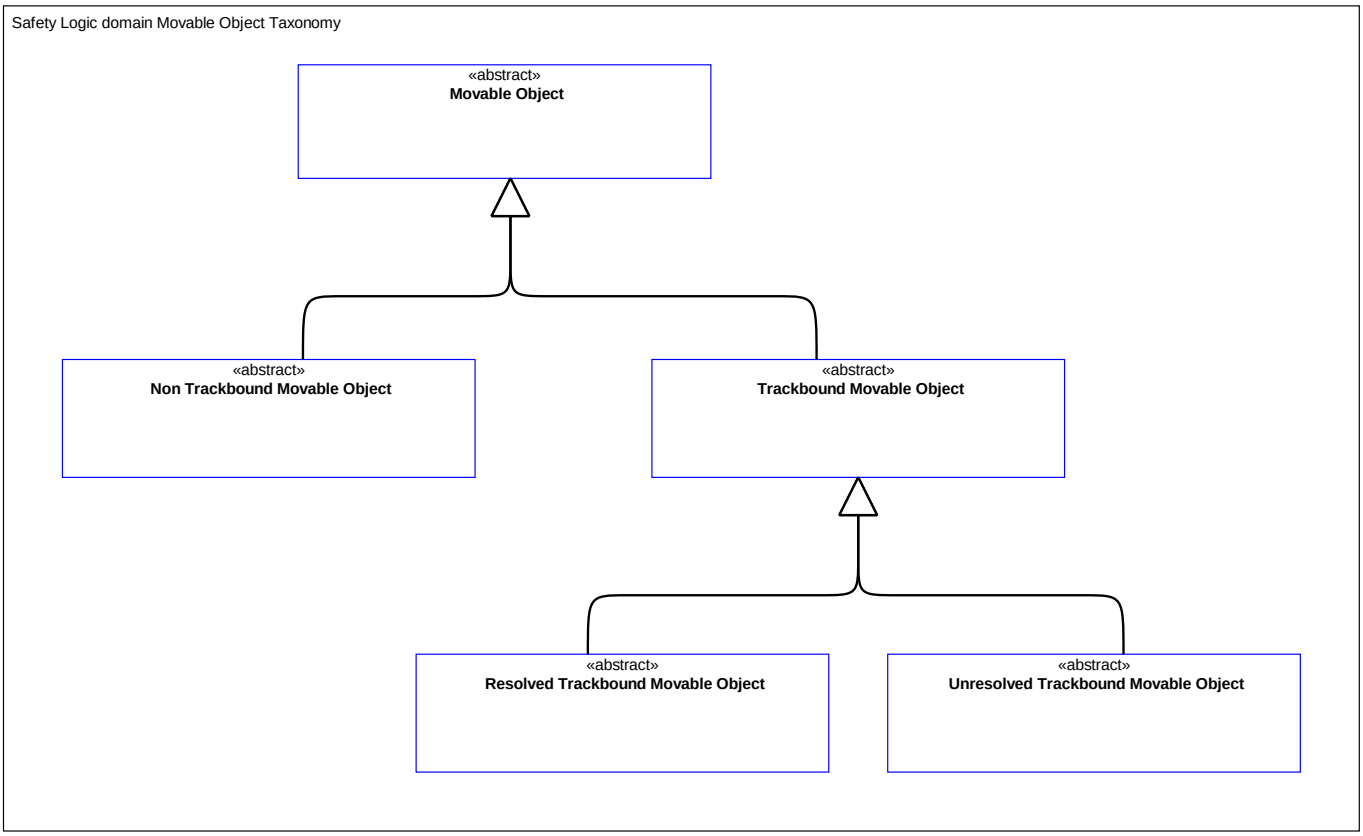


Description: This diagram shows the safety logic concepts applied in RCA.

Movement Permissions control the safe movement of Movable Objects. Drive Protection Sections ensure the needed drivability. If track usage must restricted, Usage Restriction Areas

are applied. The concept of Movable Objects has been further detailed in the diagram Movable Object Taxonomy content and relationships.

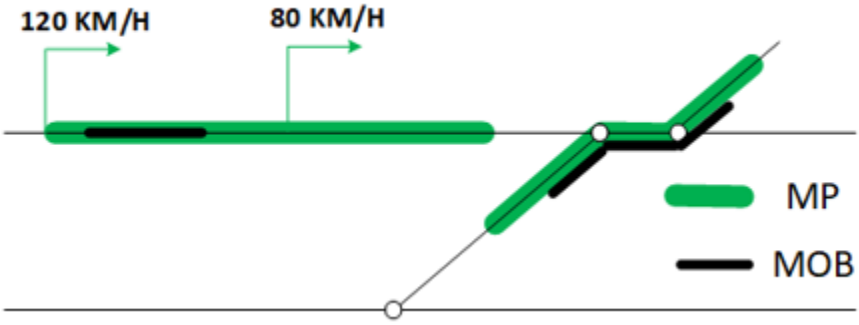
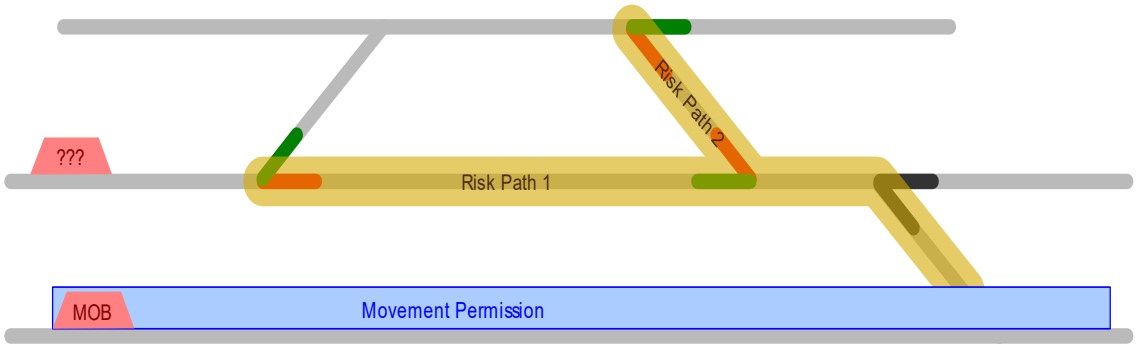
An introduction into the concept of safety logic can be found in the RCA.Doc.30, RCA Publication.

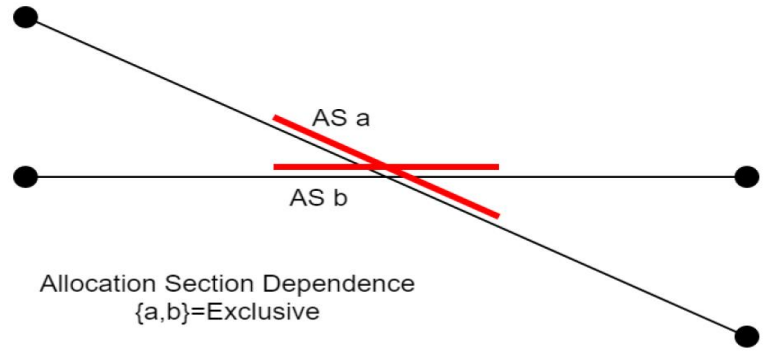
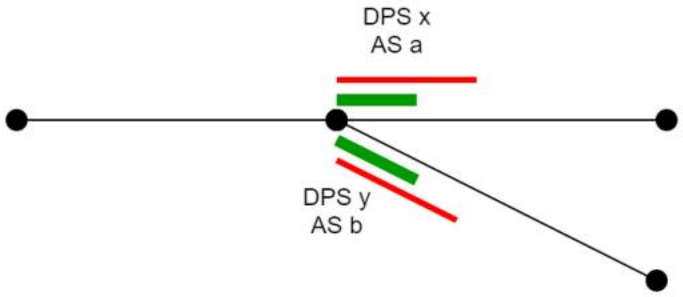
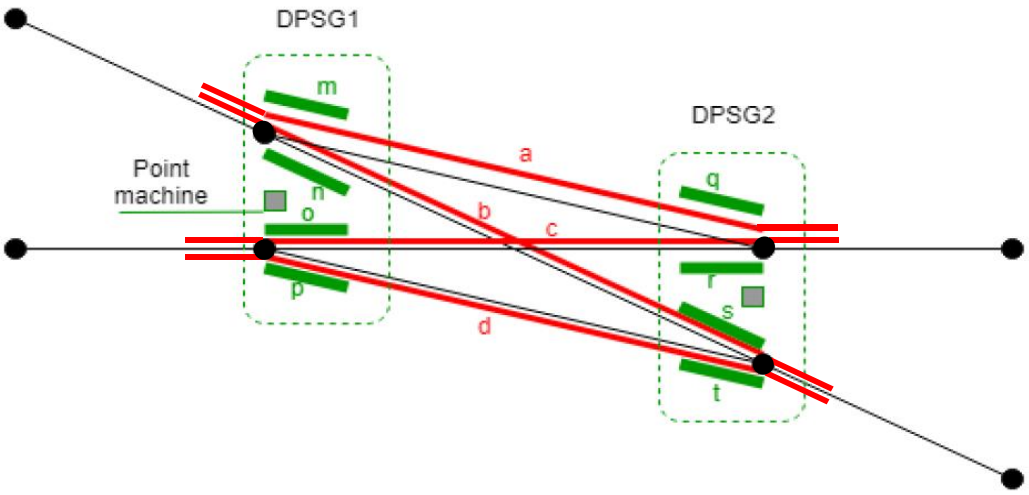


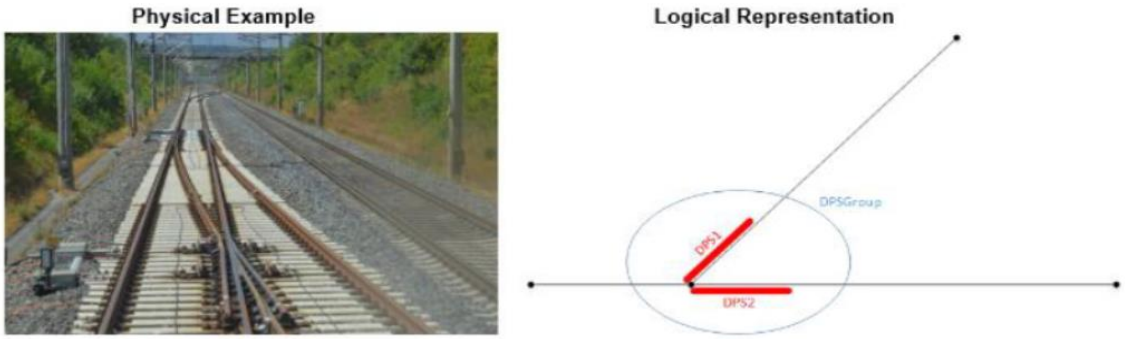
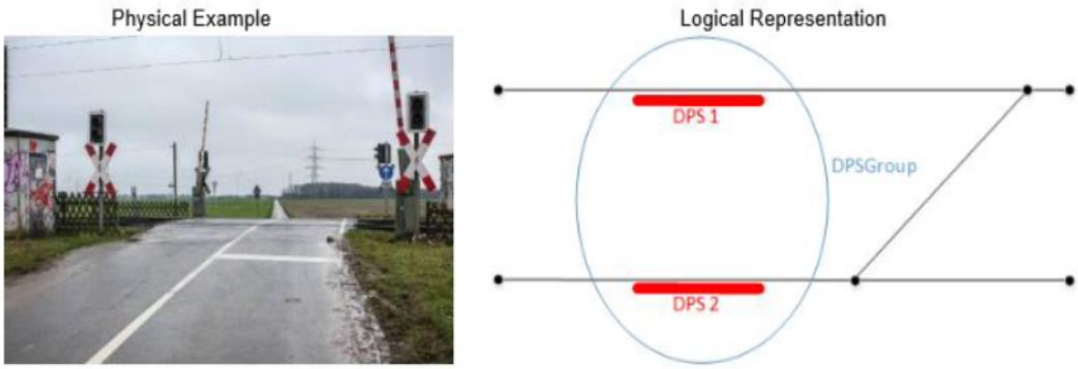
Description: This diagram shows the taxonomy of different Movable Object types.

Movable Objects can be distinguished in Non Trackbound Movable Objects (e.g. Trackside Person) and Trackbound Movable Objects (e.g. Railway Vehicle). If a Trackbound Movable Object is known by the Sys RCA, then it is a Resolved Trackbound Movable Object. If a Trackbound Movable Object is not known by the Sys RCA, it is a Unresolved Trackbound Movable Object. An example for such a Unresolved Trackbound Movable Object would be, if a Train Detection System reports a occupied TrackEdgeSection, but the Railway Vehicle causing that occupation has currently not been identified by the Sys RCA.

Name	Description
Movement Permission	A Movement Permission is an authorisation for a particular track bound Movable Object to move in a defined direction, with a defined speed, along a defined path (a contiguous stretch of TrackEdgeSections) on the track network. A Movement Permission includes all conditions under which the movement of the Movable Object can be performed safely. A Movement Permission always refers to exactly one Movable Object. Examples of Movement Permission:

Name	Description
	
Risk Path	The Risk Path is one potential path by which a non-permitted vehicle movement could result in a flank collision with a vehicle moving along a Movement Permission. Risk Path defines the track path from which another movement may endanger a Movable Object running in its Movement Permission (risk of flank collisions). The picture shows an example with two Risk Paths. A single Risk Path is defined on a LinearContiguousTrackArea where one end traverses an Allocation Area that is required by a requested Movement Permission, and the other end is defined on a buffer stop, end of a controlled vehicle, or a Drive Protection Section Group that can interrupt the flangeway of a Trackbound Movable Object travelling *towards* the Allocation Area. 
Allocation Area	An Allocation Area contains 1...n TrackEdgeSections in a TrackArea where the possibility of conflicting movements arises and therefore when a Movement Permission is granted on this section, it must become impossible to grant a Movement Permission on the conflicting path. Used where for geometric reasons two routes are mutually exclusive. A non-complete list of usages is: diamond crossings, single and double slips, turnouts and gauntlet tracks. The Allocation Area is foreseen for cases where the geometric exclusion is valid for all trains. Geometric exclusion by the features of a specific train unit, e.g. freight trains that exceed the regular loading gauge, is not solved with Allocation Areas. It is even possible to have multiple Allocation Areas for the same area bound to different classes of loading gauges, Example of a diamond crossing:

Name	Description
	 Example of a point:  Drive Protection Section Interdependence {x,y}=EXCLUSIVE Allocation Section Interdependence {a,b}=EXCLUSIVE Example of a double slip: The following diagram shows a double slip, where both points on each side of the crossing are controlled by one point machine. This creates symmetrical interdependencies. 

Name	Description
Drive Protection Section	A Drive Protection Section is defined through an extent on the track. It logically represents a part of a trackside asset that changes driveability. A Drive Protection Section comprises one or several TrackEdgeSections where, for Missions to pass safely, a controllable infrastructure element has to be set to and secured in a specific position. Note that the Drive Protection Section does not represent the controllable element itself but rather a single track that is passing through the element. Therefore one controllable element may affect several Drive Protection Sections. A simple turnout has two Drive Protection Sections for the two branching tracks and a level crossing has as many Drive Protection Section as tracks are passing through the level crossing. Common controllable infrastructure elements that require Drive Protection Sections are (non-complete list): Points, Level Crossings, derailers, movable bridges, gates, turntables. Example of using Drive Protection Section for a point: 
Drive Protection Section Group	A Drive Protection Section Group groups Drive Protection Sections that have interdependencies. Example of level crossing where a Drive Protection Section Group is used: 
Usage Restriction Area	A Usage Restriction Area limits or constrains movements on an area described by an overlapping free but not necessarily connected set of TrackEdgeSections. Under certain conditions, a Movement Permission may overlap a Usage Restriction Area (e.g. construction vehicle must enter a construction site). Usage Restriction Area are used for construction sites, speed restrictions, and exceptional situations (e.g. fire, landslide). Usage Restriction Areas can overlap, for example when

Name	Description
	multiple construction sites overlap. Usage Restriction Areas can be created according to an Operational Plan (example: "engineering trains only" area for scheduled construction site) or in response to an Incident (example: temporary speed restriction as a response to sighting of trespassers on the line).
Movable Object	A Movable Object is a representation of a real world movable object in the Operating State. Such Movable Objects can be trackbound (such as trains) or non-trackbound (such as workers). Any real Movable Object which is detected as such by a person or system with safety responsibility will be represented as a Movable Object in Sys RCA.
Safety Logic domain	The Safety Logic domain contains all important safety logic concepts needed in RCA to ensure safe movements of trackbound and non trackbound Movable Objects.
Trackbound Movable Object	A Movable Object whose movement is strictly bound to the paths defined by the railway network Topology domain (that is, a Movable Object that is guided by the rails). Trackbound Movable Objects are distinguished between Unresolved Trackbound Movable Objects and Resolved Trackbound Movable Objects. Design Rationale: Distinction between Unresolved Trackbound Movable Object and Resolved Trackbound Movable Object. Railway Vehicles because of different behaviours. a) There are Railway Vehicles that are identified and therefore known by Sys RCA. Identified means that there is a connection established between Sys RCA and the On Board Unit of the Railway Vehicle. This connection allows Sys RCA to localise and control the Railway Vehicle. This kind of Trackbound Movable Object is called a Resolved Trackbound Movable Object. b) However, there might be unidentified and therefore unknown Railway Vehicles on the tracks managed by Sys RCA. In this case, there is no connection established between their On Board Units and Sys RCA. Sys RCA is only informed about the occupation of the TrackEdgeSections in which these Railway Vehicles are located. The occupation has been most likely caused by Railway Vehicle(s), but since there is no connection, the Railway Vehicle(s) cannot be localised exactly. Their extents are unknown and the Railway Vehicle(s) cannot be controlled by Sys RCA. This kind of Trackbound Movable Object is called a Unresolved Trackbound Movable Object. The information authority of an Unresolved Trackbound Movable Object comes from the real world reported by Trackside Assets. On the other hand the information authority of Resolved Trackbound Movable Object lies with Sys RCA. The distinction between Non Trackbound Movable Object and Resolved Trackbound Movable Object allows for the different handling methods needed in these two distinct cases.
Non Trackbound Movable Object	Non Trackbound Movable Objects are identified, localised Movable Objects like Construction Equipment or Trackside Person, whose movement is not constrained along the paths defined in the railway network Topology domain.
Resolved Trackbound Movable	A Resolved Trackbound Movable Object is a Trackbound Movable Object whose front and rear end locations are fully resolved through aggregation of Train Position Reports and physical block occupation.

Name	Description
Object	
Unresolved Trackbound Movable Object	Represents a Trackbound Movable Object whose extent is defined by the limits of a Train Detection System (a role of Field Element). This occurs when a physical block is shown as occupied, but there are no Train Position Reports available for SubSys OA to resolve into a Resolved Trackbound Movable Object. An Unresolved Trackbound Movable Object may in reality represent several separate unregistered Railway Vehicles in the same physical block.

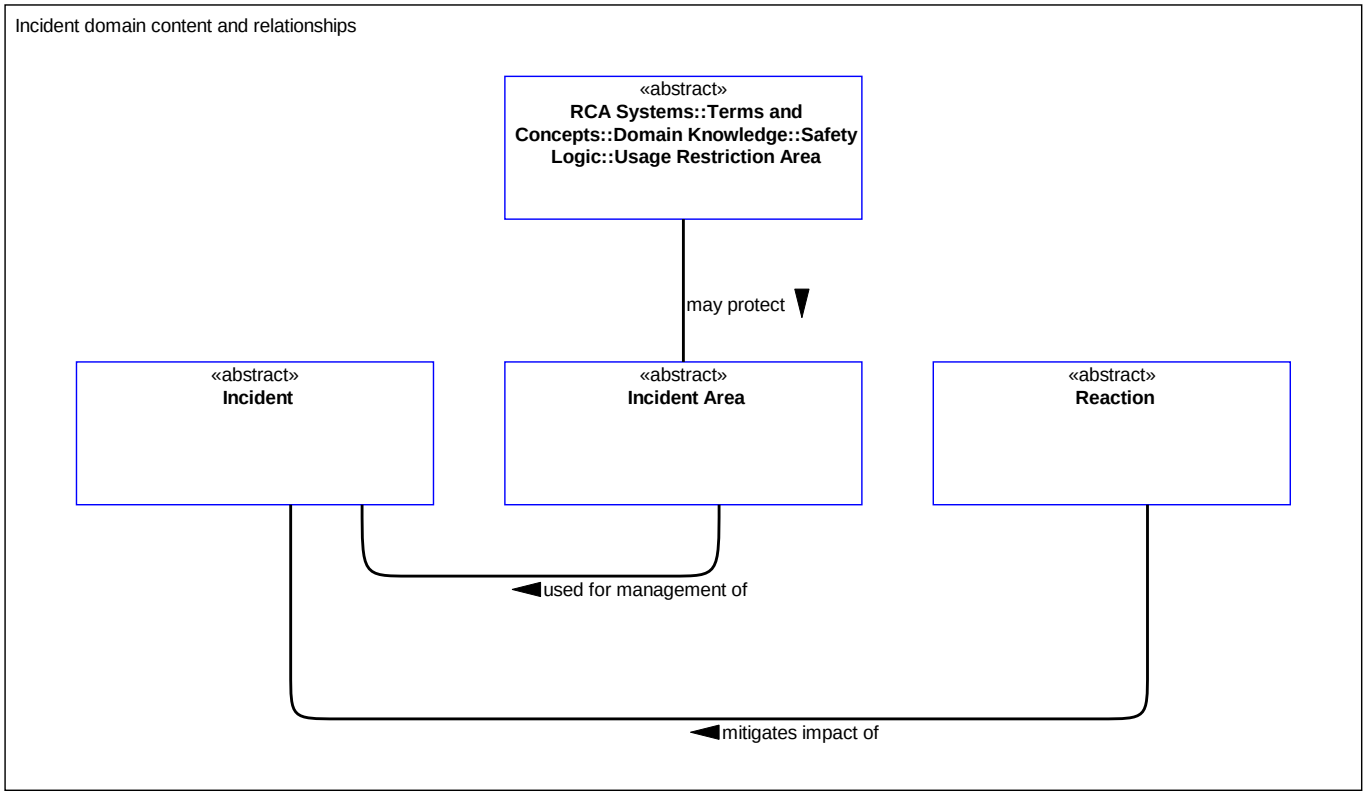
Table 3 Safety Logic

2.2.4. Maintenance and Monitoring

Name	Description
Maintenance and Monitoring domain	The Maintenance and Monitoring domain defines the concepts needed for the maintaining and monitoring systems of RCA.

Table 4 Maintenance and Monitoring

2.2.5. Incident

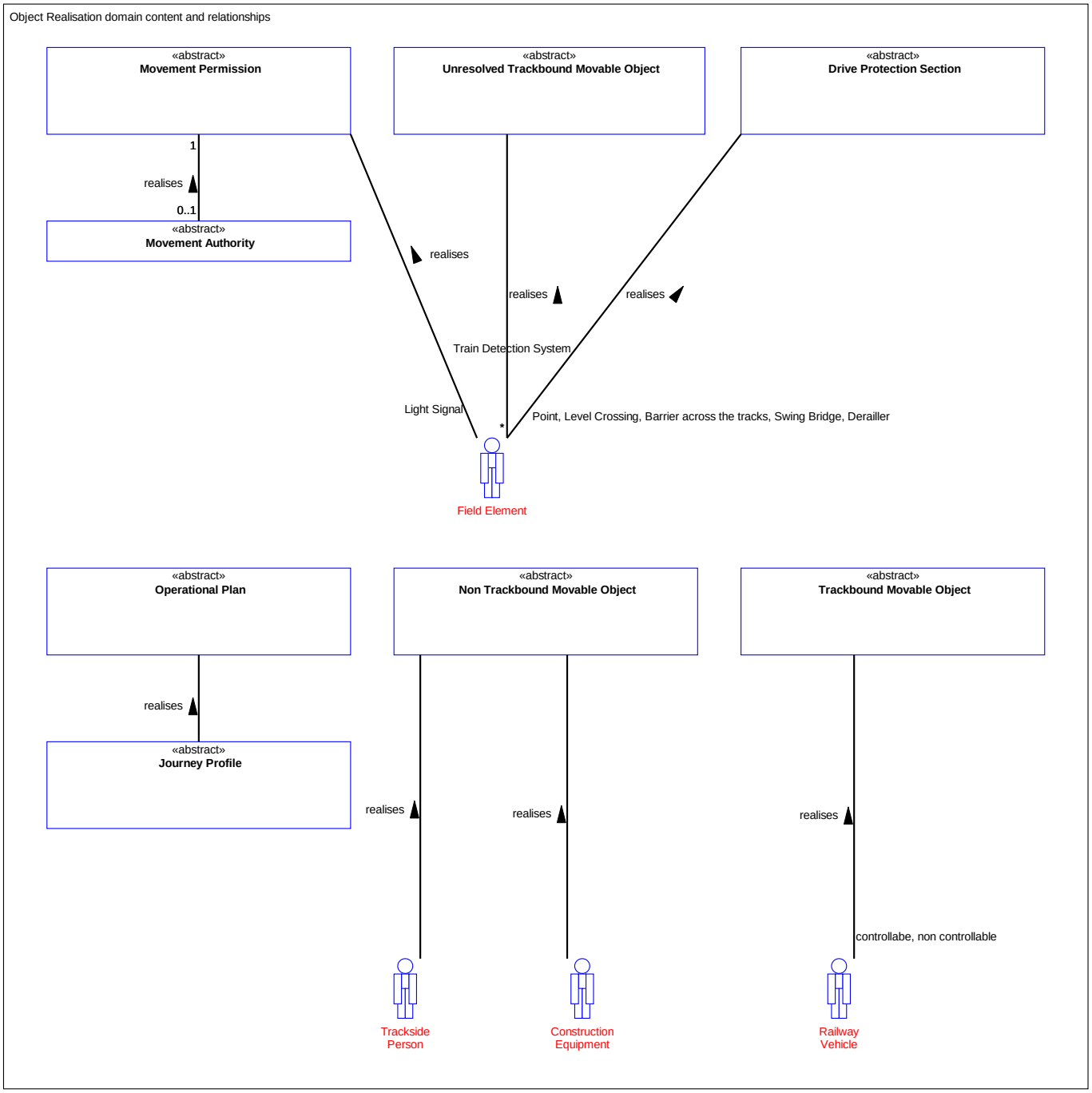


Description: This diagram shows the objects of the Incident domain and their relationships.

Name	Description
Incident domain	Incident domain provides concepts for the management of incident events in RCA.
Incident	An event that has an impact concerning safety, security or performance of the railway or CCS.
Incident Area	A specific area around an Incident to prevent or mitigate the potential impact of the Incident. An Incident Area is a 3-D spatial volume and is not limited to space near the track. For example, an Incident Area can be defined on a station platform or concourse, completely independently of the track.
Reaction	Measure to prevent or mitigate the impact of an Incident.

Table 5 Incident

2.2.6. Object Realisation



Description: This diagram gives an overview over the Object Realisation domain. It shows how real world objects are abstracted and represented in Sys RCA.

Name	Description
Object Realisation domain	The Object Realisation domain contains abstract representation of real world objects, such as Trackside Person, Railway Vehicle, etc.

Name	Description
Movement Authority	Permission for a train to run to a specific location within the constraints of the infrastructure. This concept is used in the ETCS Standard. Source: ETCS Specification SUBSET-023 v330
Journey Profile	The Journey Profile contains the set of dynamic infrastructure data and operational data required by the SubSys AV (called ATO-OB in the ETCS specification subset-126) in order to drive the train. The operational data contains the list of Timing Points to be traversed by the train along its journey. This list is defined in real time on the basis of the scheduled timetable and on-line traffic regulation. The Journey Profile may be updated during the journey. Source: ATO over ETCS Glossary, EUG Reference: 13E154, V1.6
Train	

Table 6 Object Realisation