IFC Rail Project

WP2 – Requirement Analysis Report

Overview and content of the business requirements from railway industry

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Contents

Executive Summary

The present document is a part of the official deliverables of the IFC Rail Project (Phase I), as shown in Figure 1 below. Please refer to the IFC Rail – Context & Approach document for further details.

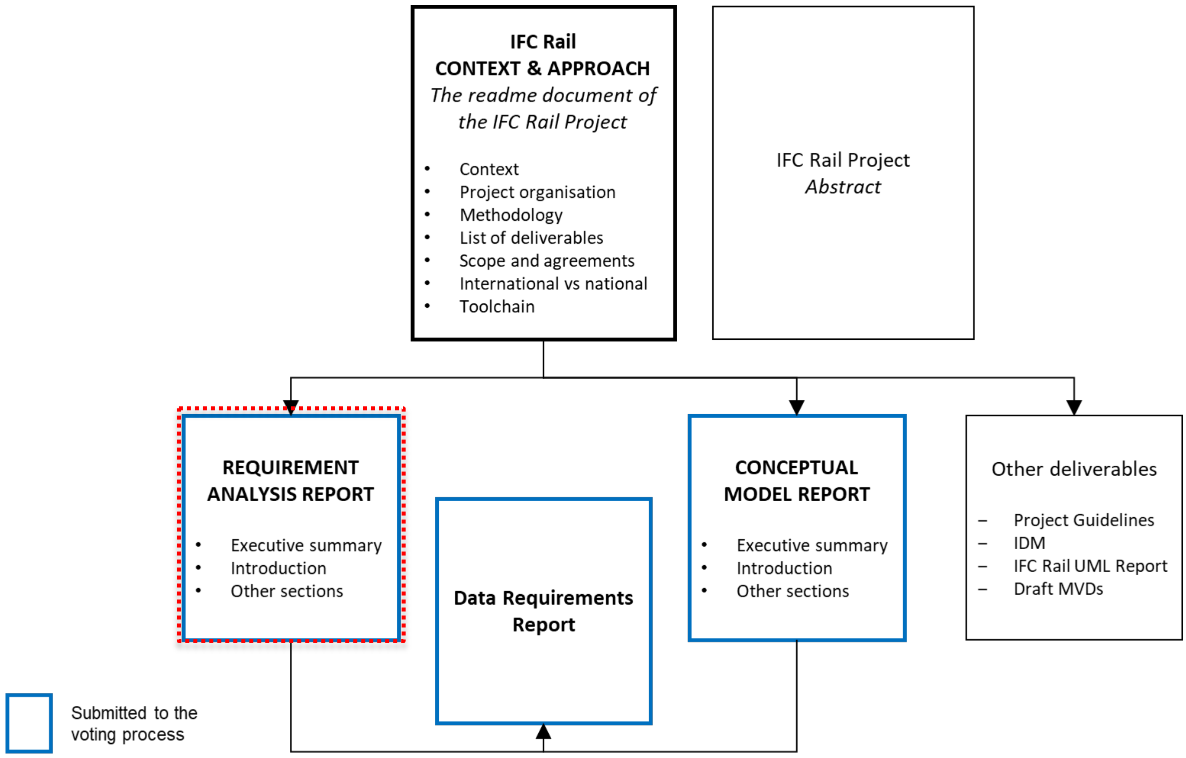

Figure 1 IFC Rail documents' structure

This document represents the first official deliverable of the IFC Rail project, and it contains the railway requirements for the extension of the IFC. The document contains the definition of the IFC Rail Reference Process Map (Chapter 2) , the IFC Rail use cases and their priority (Chapter 3), general requirements for modelling the railway infrastructure (Chapter from 4 to 8), such as alignment and spatial structure, and the estimated Model View Definitions (MVDs, in Chapter 9).

The IFC Rail Reference Process Map (also known as High-Level Reference Process Map, HLRP) is a BPMN diagram that contains a generalized description of data-driven activities for the management of infrastructure-assets throughout their lifecycle. The process is divided in 6 phases, from Planning to Dismiss, and it describes the interaction between 9 roles (e.g., Administration, Designer, and Builder). The IFC Rail Reference Process serves as a framework where use cases can be placed.

The project identifies 38 general railway use cases. Each case is defined by a name, a description, the phase it fits in, the roles involved in the use case, the general geometric representation and general semantic information needed to support it. Based on the analysis of the priority and complexity of each case, only the following use cases are faced by the project: Existing Condition Modeling, Railway Design Modeling, Interference and Coordination

Management, 3D Visualization, Quantity Take Off, and Handover from Builder to Maintainer. Except this last use case, which is allocated to the Build phase, all the other cases are detailed for the Planning and Intermediate Design phases.

The general requirements for modelling the railway infrastructure are related to the network specification, positioning, alignment, and spatial structure.

Most railway networks have traditionally grown nationally but are now strongly linked internationally. Common technical standards, e.g., track gauge, make cross-border traffic possible. These standards and regulations provide an important base for interoperability and fast and economical transport of goods and customers across national borders. These are high-level network requirements (e.g. axle load and design speeds) that shall be broken down into detailed requirements applied to the specific local infrastructure and its elements. The infrastructure manager can now define the necessary measures and technical requirements for planning and design as well as for construction, operation and maintenance.

The ability to position objects is a fundamental requirement throughout the infrastructure domain. In contrast to the building domain, in the railway domain objects are usually located along an axis. In the railway context an object could be positioned in the Cartesian reference system with Cartesian coordinates x,y and height, in a linear reference system with a reference of an axis (i.e. track centerline, catenary alignment), a distance along, a lateral and an elevation offset or in a local coordinate system used for practical reasons. Depending on the use case the positioning of objects is often done along a railway line or the centerline of a track. For the positioning of objects, it must be possible to use both, the railway line and the track centerline in combination, i.e. distance along from the railway line and the lateral offset from track centerline. Linearly referenced objects can be divided in point objects which have a single value along and Stretched objects which have a starting and an ending value along.

The topological network is divided into track sections between topological (nodal) points. As a parameterized space curve, each track section has the horizontal alignment (2D) with a sequence of horizontal elements, vertical alignment (2D) with a sequence of vertical elements, and cant (2D) with a sequence of cant elements. The following four geometry types need to be supported by IFC for the representation of the horizontal and vertical alignment: straight line, arc of a circle, transition curve, and horizontal/vertical bend. For the cant alignment, at least three geometry types are defined: constant cant (straight line), constant change of cant (straight ramp), curved cant (transition curve).

Spatial breakdown supports the breakdown of project-based 3D BIM models into smaller parts used for subproject management, data federation and detailed engineering. From this perspective, the railway line is broken down into the railway substructure, railway track structure, railway superstructure, and railway lineside structure, following the traditional way of building railways. The railway track structure is further decomposed into longitudinal sections: plain track superstructure, the turnout track, and the dilatation track. From the energy domain point of view, the railway superstructure is decomposed into the overhead line complex area, and the overhead line plain line area.

Finally, the estimated MVDs in this project are the Rail Reference View, the Alignment based Rail Reference View, the Rail Design Transfer View, and the Rail Asset Management View.

1 Introduction

The IFC Rail project aims at extending the IFC data model in order to support data exchange and use cases in the railway industry. It is a project governed by buildingSMART Railway Room.

WP2 of this project aims to define the scope of the project and requirements of IFC Rail for modeling. It is one of the official deliverables in the overall process of IFC Rail project (see Figure 2).

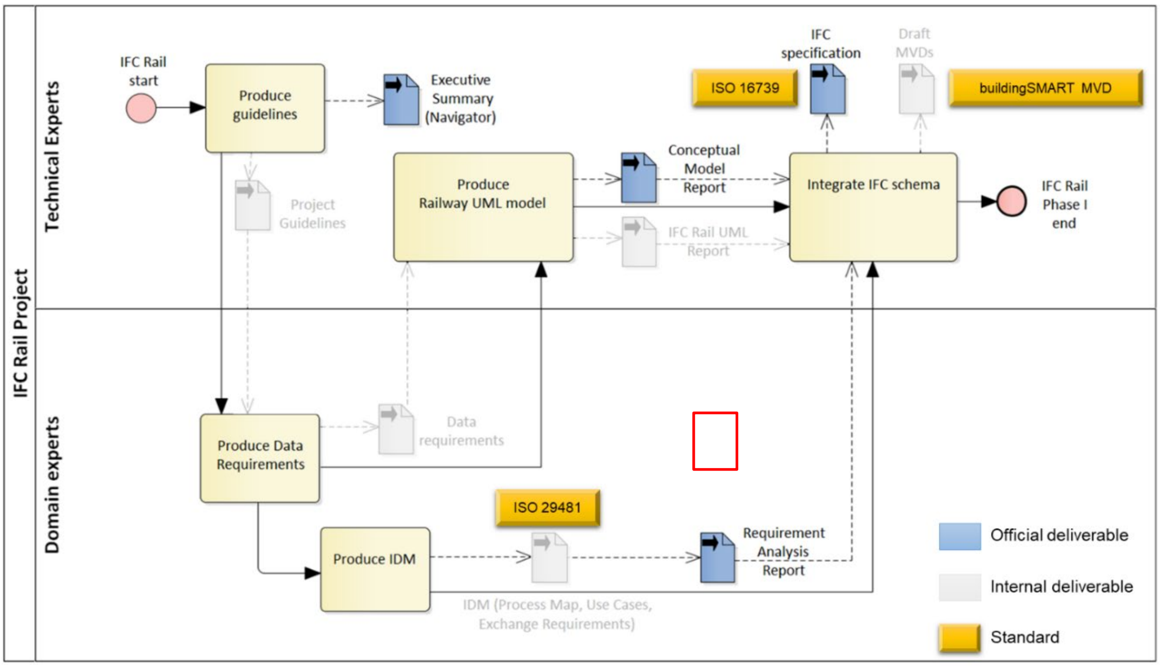

Figure 2 Overall process of IFC Rail Project (Phase I) and position of this document

Given the comprehensiveness of the railway industry, this project is organized into four domains as the general scope of the project: Track, Energy, Signalling and Level Crossing, and Telecommunication teamed up with domain experts from eight project stakeholders (see Figure 3) .

The requirement analysis of this project follows a combined methodology of domain-driven approach and use case-driven approach. Common railway requirements which are relevant for all railway domains including network specification, positioning, alignment and spatial structure are defined. These common requirements also contribute to the buildingSMART Common Schema project, which aims to specify a common foundation of modeling with other infrastructure domains including e.g. Bridge, Road, Tunnel. Besides, domain-specific data requirements are defined by experts from four domains.

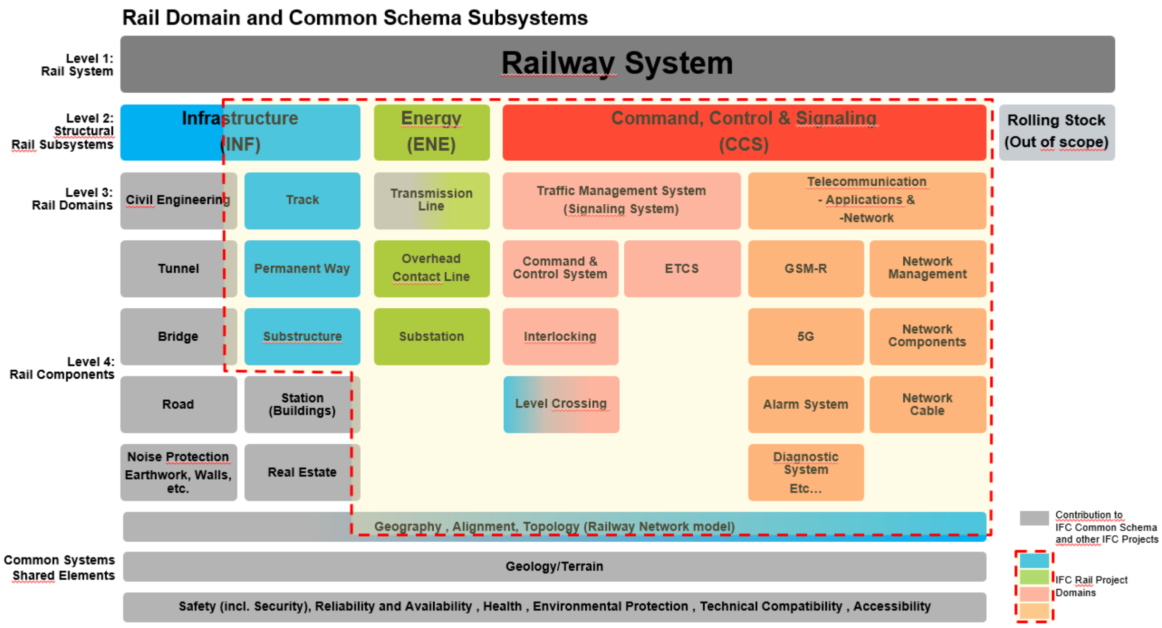

Figure 3 Scope of domains for analysing requirements in IFC Rail

In parallel of this process, use cases are defined following the IDM methodology. Given the restricted duration of this project, the most important use cases are defined to validate data requirements from domains. They are evaluated based on required semantic information and geometric representations. Based on this effort, the scope of planned Model View Definitions is estimated. Data requirements to define Model View Definitions.

2 Process map

The IFC Rail Data Requirements, and the subsequent IFC specification, depend on the use cases that need to be supported by IFC in the Rail context. The use cases describe when data are exchanged, for which purpose, and between which actors. The IFC Rail Reference Process Map (also known as High-Level Reference Process Map, HLRP) serves as a framework where use cases can be placed.

Given the specificities of each company and each country, process standardization is not only outside the scope of the project, but also impossible to achieve. Thus, the IFC Rail Reference Process Map is a high-level process in which each company can recognize, after mapping, its own specific processes and actors.

The IFC Rail Reference Process Map is a generalized description of data-driven activities for the management of infrastructure-assets throughout their lifecycle. It is described in a BPMN diagram, in which formality has been deprecated in favor of readability. The BPMN diagram is shown in Annex 1: IFC Rail Reference Process Map. The whole process is divided into 6 phases:

1) Planning

2) Intermediate Design

3) Detailed Design
4) Build
5) Operation and Maintenance
6) Dismiss

Also the process describes the interactions between 9 roles:

1) Administration
2) Project Manager
3) Owner
4) Designer (grouping all different disciplines and domains)
5) Coordination and Integration
6) Specialist
7) Builder
8) Infra Operator
9) Infra Maintainer

An organization can cover more than one role, and a role can be covered by more than one organization.

The arrows in the diagram are marked with a unique number: the hundreds digit of the number corresponds to the number of the phase where the arrow originates. Also, there are portions of process that recur several times during a lifetime of a project, at a different level of detail: evaluate existing conditions, design rail system, analyse design, and tendering. These recurrent portions are represented as sub-processes, defined only once in the grey background. Sub-processes are also used for readability purposes, as in the cases of manage maintenance and execute dismission plan.

- In the Planning phase (yellow background), design alternatives are generated and evaluated for feasibility, also according to the national strategy. This phase ends with one alternative being part of program and being financed.
- The goal of Intermediate Design (orange background) is to obtain the necessary authorizations and approvals from the project actors, before proceeding with the Detailed Design (red background). Design is based on the analysis of the requirements and of the existing conditions, and it explicitly includes the design of the alignment, of the civil works (infrastructure) and of the system solutions (superstructure). Design is then analysed through several points of view, such as safety, cost and environment. The process only includes analyses that are applicable to all the rail domains.

- The Detailed Design phase is similar to Intermediate Design phase, having a similar process with a different level of detail.
- The Build phase (green background) brings the construction plan into reality, and it ends with the handover of the assets. Once built, the infrastructure is tested and the specifications for operation and maintenance are produced.
- In the Operation and Maintenance phase (blue background), operation and maintenance are managed and monitored. The analysis of the failures, or the desire to renew/upgrade the infrastructure, imply a loop that brings the process back to design.
- The Dismiss phase (violet background) concludes the process: assets might be sold, stocked, refurbished, disposed, etc. Within this phase, the existing conditions of the railway are evaluated, a dismission strategy is formulated, and the dismission plan is executed.

3 Use cases

3.1 From use cases to exchange requirements and data requirements

Activities in the construction industry are driven by contracts that require more and more often BIM processes and data exchange based on IFC standards.

The ISO19650 standard, that is becoming widely accepted, is reported in the following Figure 4. It defines a framework for:

- information exchange/delivery in BIM projects;
- the content of the asset information model and the project information model.
- The IFC standard can support this framework.

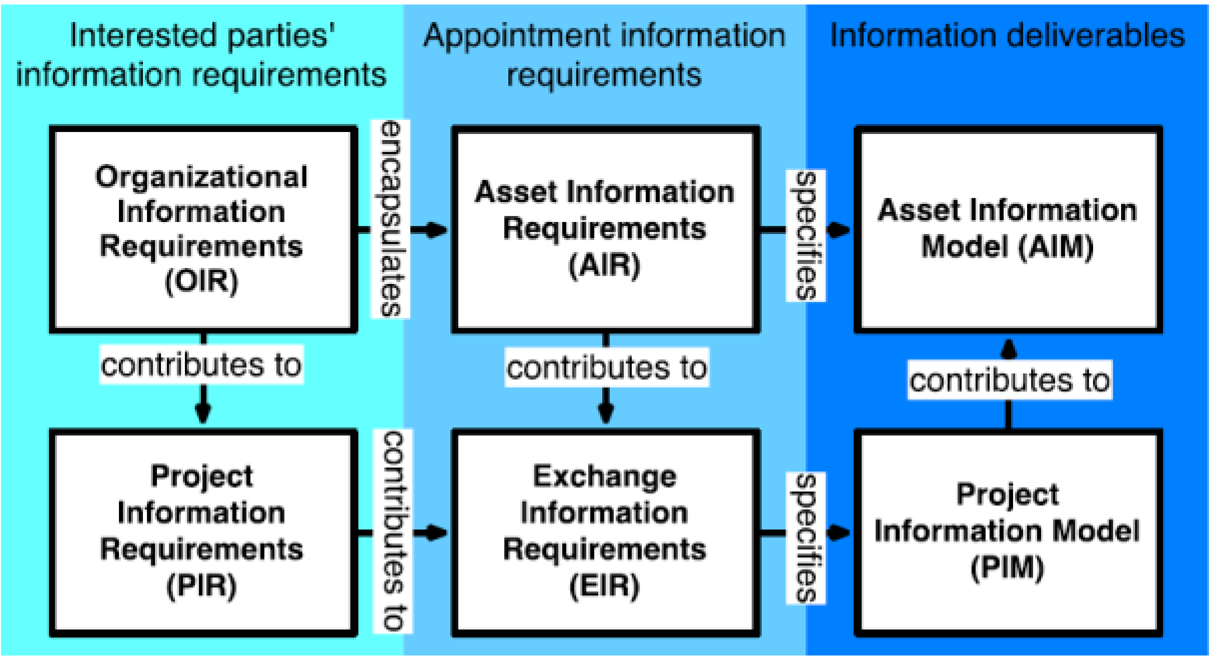

Figure 4 extract from ISO19650-Part 1

In order to explain what kind of information exchange may be enhanced by using IFC standards, the business experts working on data requirements, conceptual model and exchange requirements are asked to list and describe the general use cases (for data exchange) for their activities (see Figure 5).

Then the experts are asked to prioritize the general use cases that may be mostly supported by the data requirements and the conceptual model that are provided in the WP2 of the IFC Rail project.

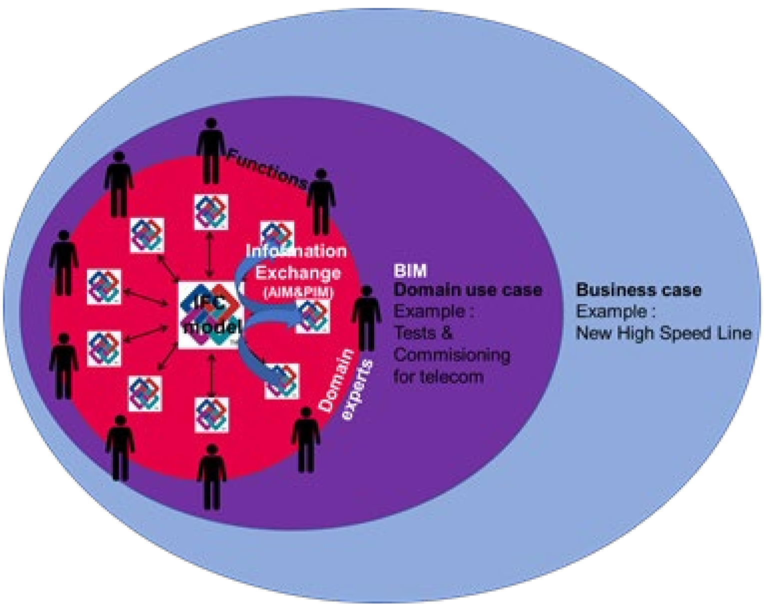

Figure 5 Use case context for the experts work on exchange and data requirements

3.2 Use case definition

Each use case has to be identified in order to define:

- Who provides
- Which information
- At what time (phase)
- In which format
- In which level of detail

In any project, some typical use cases are: inventory surveys, quantity take-off, cost estimation, tenders, visualizations, simulations, etc.

3.3 Use case methodology

The methodology to identify the general railway use cases was initiated by compiling and reviewing the existing use cases produced by other IFC infrastructure projects (e.g. IFC Bridge).

When common, they were kept as a common basis except when it was possible to group them on a common subjet (e.g. Project management includes contract, monitoring, scheduling, risk and cost management).

To identify the general railway use cases, we based our analysis on a railway project involving all domains in order to define the required actions to satisfy tasks to fulfill and achieve the project.

Some are important as key milestones or process steps to be carried out in order to:

a) Provide information, data and models such as the use case “Existing Condition Modelling” or other input

b) Compile, check and validate information, data and models such as the use case “Railway Models in Feasibility, Intermediate or Detailed Design”

c) Transfer or export information, data and models such as the use case “3D Visualization” or other output

The methodology is also to come from general use cases to Domain-specific use cases allocated in the IFC Rail Reference Process Map.

From each general use case according to the concerned project phase, all railway domains will detail and specify their exchange requirements.

3.4 General rail use cases

Each general use case is defined by specify information which were agreed before general use case Validation by CS/SE Group such as:

- Project Phases
- Project Functions
- Description and purpose
- General Geometric Representation
- General Semantic Information

The general use cases identified are:

1) Existing Condition Modeling
2) Tendering
3) Procurement
4) 2D Visualization
5) 3D Visualization
6) 2D/3D+time Visualization
7) Feasibility Studies for Railways (RW)
8) Alignment & Functional Railway Requirements (RW)
9) Project Monitoring
10) Change order management
11) Drawings & Documents Production
12) Quantity take off
13) Interference management
14) Domain analysis & simulations (RW)
15) Code & Functional Compliance
16) Infrastructure Design (all infrastructure domains)
17) Superstructure Design (all Superstructure domains)
18) Import Reference Model
19) Railway Intermediate Design Modeling (RW)
20) Railway Detailed Design Modeling (RW)
21) Project investigation and approval

22) Concertation and project acceptability
23) Management & Design for temporary situation
24) Construction Procedure Modeling & Scheduling
25) Staging & scheduling (design)
26) Railway Procurement & Construction Modeling (RW)
27) Data take off for construction machines (RW)
28) As-built vs.as-planned comparison
29) Testing & Commisionning (RW)
30) Functional & RAMS Demonstration (RW)
31) As built survey modeling
32) Railway as Maintained Modeling (RW)
33) Railway as Operated Modeling (RW)
34) Maintenance and operation planning
35) Training Model for Operation & Maintenance
36) From model to Register of Infrastructure
37) Pre-final acceptance
38) Disaster Planning / Emergency Preparedness

The complete list of all the details of defined general use cases are listed in Annex 2: Specification of general use cases. It was reviewed by the IFC Rail Common schema and Shared element group before the transfer to the domain group.

3.5 Use case priority and complexity

In order to develop the IFC Rail Standard and structure the IFC Rail production, it was decided to prioritize use cases based on several parameters.

When the use cases were determined, a specific review was carried out in order to identify:

1) The priority of all use cases defined by the Common Schema / Shared Elements Group: the objective is to specify the order of use cases to be taken by the modelling team based the most important and key use cases for a project (exchange requirements complexity, key step and data for a railway project, stakeholder expectations, etc.). The domains played an essentaile and important role in the priorization of the use case list by expressing their particular bussiness needs and primary issues.

2) The complexity of all use cases defined by the Technical Service Group: the objective is to specify the order of use cases due to the use case complexity and required efforts for modeling.

This cross check was made to ease making decisions to choose use cases for modelling.

3.6 Use case definition – Release 1

As decided by the Stakeholders at the buildingSMART Summit in Dusseldorf (March 2019), the use cases to be modelled for the next buildingSMART Summit in Beijing (October 2019) are:

1) Existing Condition Modeling

2) Railway Design Modeling (Feasibility Studies for Railway and Railway Intermediate Design Modeling)

3) Interference and Coordination Management (Physical Interface, 3D coordinationand clash detection, Signal Visibility Checking)

4) 3D Visualization

5) Quantity Take Off

They will be detailed for 2 following phases: Planning and Intermediate Design. If finished, Track and Signalling Domain can work on Detailed Design phase for the use case Railway Design Modeling.

Another prioritized use case is 6) Handover from Builder to Maintainer (also known as Information needed for maintenance perspective), which is allocated in the Build Phase (see Table 1).

Use case	**Planning**	**Intermediate Design**	**Detailed Design**	**Build Phase**	**Operate and Maintenance**
Existing Condition Modeling	ECM-PL; 103	ECM-ID; 204, 205			
Railway Design Modeling					
Feasibility Studies for Railway	FSR-PL; 105				
Railway Intermediate Design Modeling		RIDM-ID; 223			
Railway Detailed Design Modeling			RDDM-DD; 323		
Interference and Coordination Management		ICM-ID; 212			

3D Visualization	3DV-PL; 105	3DV-ID; 209, 210, 211, 214			
Quantity Take Off	QTO-PL; 115	QTO-ID; 215	QTO-DD, track only; 315		
Handover from Builder to Maintainer (Information needed for maintenance perspective)				INMP-BP; 421	

Table 1 IFC Rail priority use cases with associations with project phases and exchange scenario numbers in IFC Rail Reference Process Map

These use cases are good examples of data exchange and can be an example of full exercise with Input / Output Data Transfer, Data Model / Compilation, Data Checking / Coordination (see Table 2):

Use Case	**Input Data Transfer**	**Data Model / Compilation**	**Data Checking / Coordination**	**Output Data Transfer**
Existing Condition Modeling	X	X		
Railway Design Modeling	X	X		
Interference Management			X	
3D visualization				X
Quantity take off				X
Handover from Builder to Maintainer		X		X

Table 2 Purposes of priority use cases

The data requiments and the conceptual models delivered by the IFC Rail project are supposed to support the exchange requirements needed for the use cases short listed in the Table 1 but it is important to notice that they may also support a large amount of concepts needed for many other use cases, by adding specific properties to some concepts or by breakdowning. A Business Storyline was implemented in order to clarify use cases (railway view, identification of stakeholders) as a concrete example and allow all Rail Domains to detail and specify their exchange requirements based on the story line. The aim of this storyline is listed as follows.

- To help Rail domains to focus on a business context in order to clarify the use cases data set;
- To qualify the exchange requirements on a common realistic situation and be able to get non-theorical discussion on requirements or expectations from domains or modelers;
- To provide a better understanding and communications;
- To define the scope for the modelling works;
- To facilitate domain validation at the end.

4 Railway Network and Line Specifications

4.1 Characteristic of a railway network

Most railway networks have traditionally grown nationally but are now strongly linked internationally. Common technical standards like track gauge make cross-border traffic possible. These standards and regulations provide an important base for interoperability and fast and economical transport of goods and customers across national borders, especially in freight traffic and long-distance passenger services.

International regulations are drawn up from specific national guidelines, for both the rail infrastructure and the rolling stock. These form the backbone of international transport. This is known as interoperability in technical jargon. Committees that define these together with representatives of the railways are, for example, UIC, ERA, UNIFER, etc. Figure 6 shows the findings of Working Group IFC Rail.

The area of application of these standards should be defined within the national context. They should be defined on the level of traffic flows for the national railways and subsystems. They can therefore vary nationally or even per railway company.

Examples of high-level usage parameters (network characteristics) are:

- Traffic use (freight traffic, passenger traffic, high speed trains, etc.)
- Track gauge
- Maximum axle load
- Operational speed
- Safety rules
- Clearance gauge
- Alignment guidelines
- Type of electrification (none / diesel, voltage, third rail, Alternating Current, Direct Current)
- Train lengths
- Platform heights
- Necessary elements of train protection (e.g. ETCS)
- Valid languages for communication during operation
- Ownership
- Etc.

These minimal applicable standards must be determined and designed. They form the requirements for the railway infrastructure from the overall perspective of network utilization. Once they have been defined, it is difficult and time-consuming to adjust them again. Basically, these aspects include fundamental technical requirements for the equipment and operation of the rolling stock.

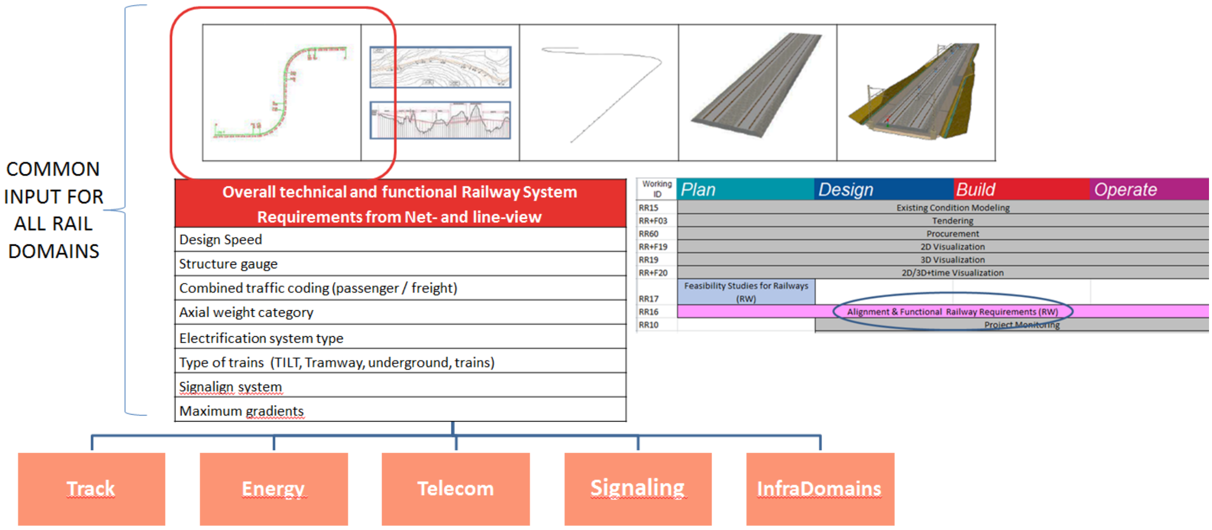

Figure 6 Findings of Working group IFC Rail (SBB, RFI, SNCF), slides of IFC Rail, spring 2019

These parameters are determined internationally and defined with guidelines and threshold values. They provide the infrastructure manager with important criteria for the construction and maintenance of its assets. In the case of planned changes of utilization of the rail infrastructure, they are the criteria to guarantee the relevant standards (e.g. 4m corner height for truck transport). Since it costs a lot of money to implement and comply to these standards. and is usually accompanied by increased maintenance costs, they don't need to be implemented throughout the entire network. For this purpose, so-called "corridors" are defined in an international agreement.

4.2 Corridors and routes

In order to determine and guarantee the traffic demand between two regions, so-called corridors are defined. These corridors are agreed upon either nationally or internationally, sometimes even defined by a rail company alone. This can be as simple as a single connection with a track between two locations. Normally, however, we start speaking of a corridor when it reaches a certain dimension. Corridors can also be agreed upon and jointly managed between railways or countries.

In Europe, Trans-European Networks (TEN corridors) are the most significant examples (see Figure 7). Intercontinental, the Silk Road or the Trans-Siberian Route are the best-known examples. From a global perspective the Silk Road or the Trans-Siberian Route can be named.

A railway corridor is normally defined by the following characteristics, which should be constant within the same corridor (selection):

- Region of origin and destination
- Continuous trafficability
- Main utilization
- Capacity targets

Common defined "usage characteristics" of the railway network (e.g. track gauge, loading gauge, axle load) according to Chapter 4.1

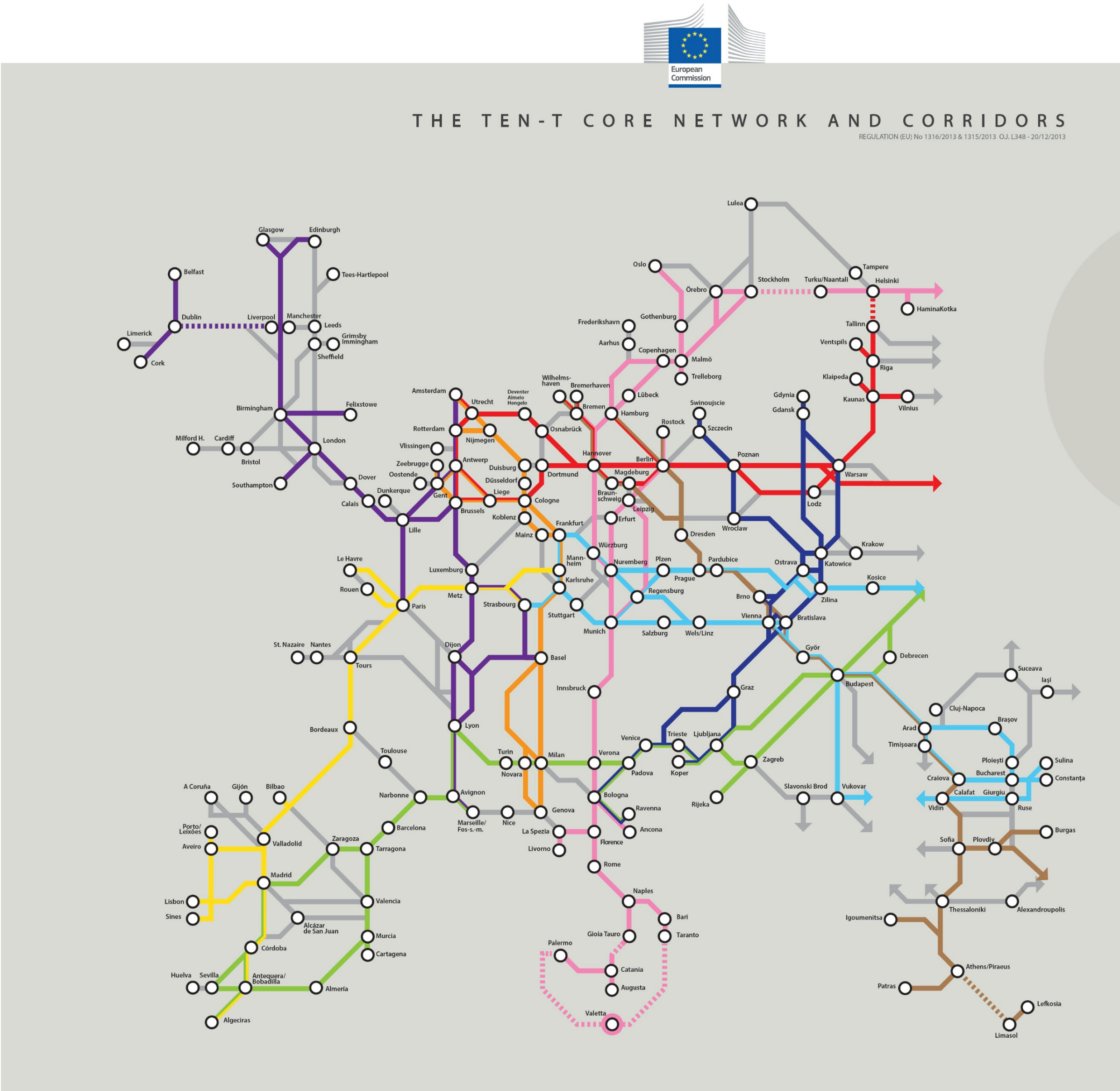

Figure 7 Scheme of TEN-Corridors (Source TENtec European Commission, Trans-European Transport Network (TEN-T), https://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/index_en.htm

The aim of a corridor is to provide a defined minimum transport capacity for the corridor related traffic. Rough capacity planning is carried out early on with a target number of timetable paths. These are already provided with the most important parameters for path planning (e.g. minimum train speed and traction, train length, etc.).

Within a corridor there are often different routes to get from origin to destination. These must be taken into account in the definition of the corridor and explicitly designated as part of a transport corridor. These different routes are essential for the desired performance and reliability on the corridor. The effect on the various corridor-specific routes should also be taken into account for closures and construction sites. In the "Rhine-Alpine" corridor, for example, there are two different routes leading from Genoa via Milan - Lugano to Basel (Gotthard) or from Genoa via Novara - Brig - Bern to Basel.

It is obvious that the properties defined above for a given corridor should ideally apply to all routes in the corridor. This provides the greatest possible flexibility for planning, scheduling and operation. This will not be fully possible in all cases (e.g. train lengths, traction and hook loads and speeds). In order to describe these routes more precisely, the term "Railway Lines" is used.

And not only for European corridor but for any railway project in general. Once Net specs are defined it is costly and difficult to change them later, also because from these specs all the choices and objects are made. That's why is so important to find a way to associate them to the BIM model and make possible to check them during the design phases and model validation.

4.3 Railway line and operating point

In order to break down the high-level railway network specifications into the actual railway networks and to specify the requirements more precisely, the term "Railway Line" is used. This is infrastructure-related and must not be mixed up with "commercial lines" of the railway companies (e.g. Intercity number 1 or S-Bahn line number 4).

For most railways such a line related perspective currently already exists. It is often used in the common language usage. In combination with station names, it is often sufficient to determine a rough location. A line can have its own kilometers with hectometer plates, which are clearly visible to the operating personnel on the train board.

Several lines can even run parallel to each other in the outdoor layout; their local boundaries are in many cases not visible. Often lines are already classified by the individual infrastructure managers according to their relevance in the network or traffic load (e.g. main line, secondary line).

Typical properties of a line are:

- Origin and destination. Usually a passenger station or a freight terminal (in the form of an operating point, see below).
- Continuous trafficability
- Own Kilometrage of the line
- If required: basic line geometry in planar space (2D)
- Normally common and defined "usage parameters" of the railway network (e.g. track gauge, clearance gauge, axle load, electrification system) in accordance with Chapter 4.1.
- Categorization / Importance
- In addition, the information about a possible corridor assignment must be known. It's possible, that there are requirements from several corridors.
- Basic information on actual or future traffic usage can also be provided: e.g. train numbers, train mix, effective traffic load.

Figure 8 shows some basic examples of line specific properties.

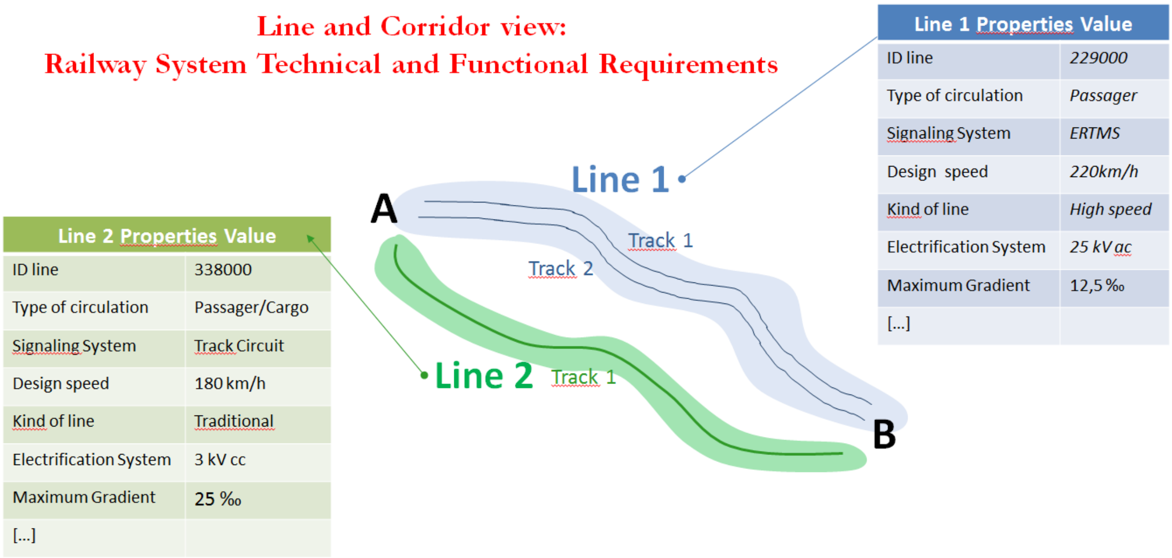

Figure 8 Findings of Working group IFC Rail (SBB, RFI, SNCF), slides of IFC Rail, spring 2019

In addition, a line is usually linked with a structure of operating points. These are locations or zones that are of importance to the infrastructure manager or the transport company. They are normally used for planning, scheduling and operation in a service-oriented network (e.g. stations, junctions, commercial accounting points, technical (e.g. interlocking) or operational (depot) locations.

An operating point may be assigned to several lines if its "practical function" justifies it. An operating point can in principle be assigned any meaningful attributes. Particularly in the case of stations, these can be used to describe specific local properties. These can be used, for example, for statistical evaluations.

Typical properties of an operating point are:

- Purpose (e.g. commercial operating point for passenger or freight traffic, junction, substation, accounting boundary, national boundary, etc.) Usually a passenger station or freight terminal in the form of an operating point Continuous trafficability
- Position in X, Y, Z Coordinates
- Reference to the kilometrage of the line
- Categorization / Importance
- In addition, the information about a possible corridor assignment must be known. It's possible that there are requirements from several corridors.
- Basic information on actual or future traffic usage can also be provided: e.g. Passenger numbers, number of platforms, existing freight loading infrastructure, train lengths, disabled accessibility
- Optional information on condition and technology: construction activities, restrictions
- Specific requirements for operation and technology such as signal boxes

With the terms of railway network, corridor, route, line and operating point introduced so far, only the continuous trafficability is represented. No statement has yet been made about the actual track layout itself. As a precondition for the application of the BIM method in a railway system, the network of all the particular tracks and turnouts must first be modelled in such a way that the inventoried objects can be precisely positioned. This is especially the case for linear referencing.

This requires the so-called "track topology" as well as the alignment (see Chapter 6).

4.4 Track topology

The track network of a railway is topologically structured and must be modelled accordingly. The track network is key for various services of railway operation outside the BIM-methodology and this has to be represented in a trustworthy way.

There are only two topological elements "track edges" and "track nodes" which represent the track network and the trafficability according to predefined rules. This also aims to define the relationships between neighbouring elements. The topology can be displayed in a planar space. This then shows each track and each turnout (see Figure 9). Since a topological representation is often only a schematic representation of the track system, the track topology does not necessarily have to be true to the length.

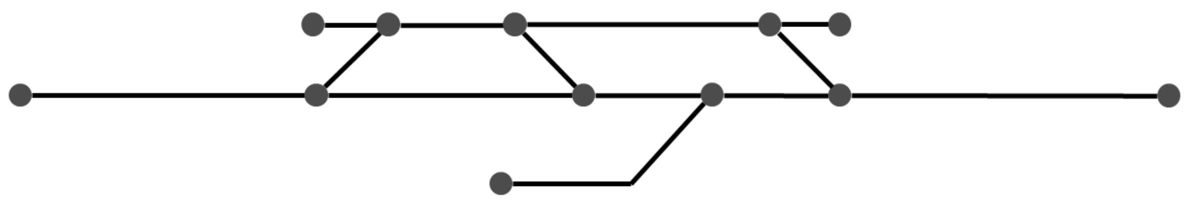

Figure 9 Topological illustration of a railway station with track junctions and track edges

The two topological elements are described below.

4.4.1 Track Node

A track node can be either a junction or a track end. A junction is a position in a turnout where there is a choice of two directions ("left or right"), so a simple turnout has just one junction. More complicated junctions such as three-way junctions or double intersection points are provided with several subsystems each with an option for two directions. The tip of the blade is regarded as the appropriate location of the track node. A derailment device is therefore also a special form of a track node. A track intersection does not correspond to a track node, as there is no possibility to choose the route (see Figure 10).

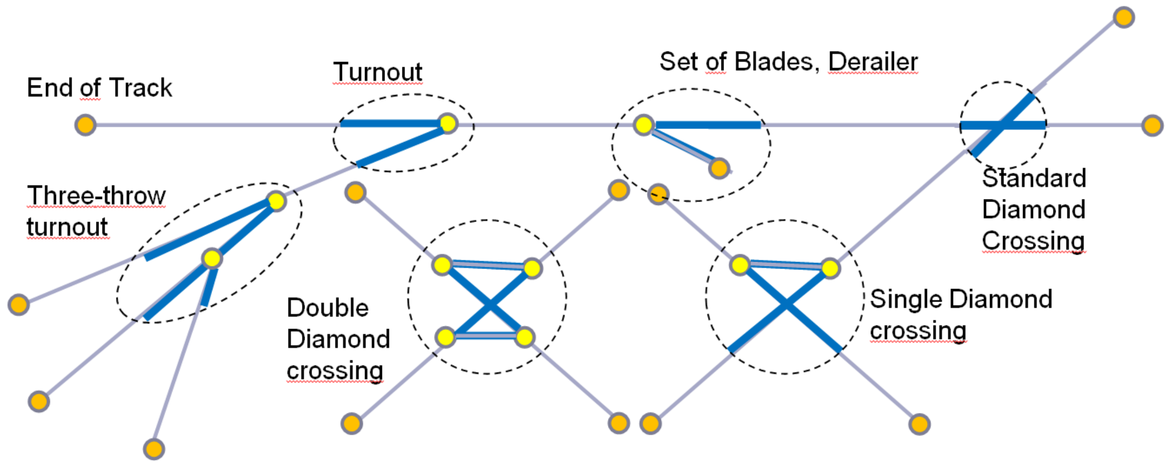

Figure 10 Conceptual illustration of different track components as track nodes and track edges (illustration by SBB, BNT Study)

Definition of a track node:

- Is a point without physical dimension (length zero)
- Can be clearly fixed in space with x,y,z coordinates. But no positioning is necessary for a conceptual application.
- Is linked to ONE (1) track edge when the track ends at this location (or is not further modeled). A typical object at the end of the track is a buffer stop.
- Or is linked to THREE (3) track edges and thus represents a junction (as a topological element). This also includes a derailment device.
- Is never connected with only two (2), four or more track edges (exceptions possible like turntables)
- in case of a junction is defined as the position of the tip of the blade (start of the blade device) during a soak/branch. Does not correspond to the switch center (intersection of the tangents) but can be calculated from the geometry data of a switch/branch (basis: installation plan).
- Shows only a theoretical geometric trafficability with three adjacent track edges.
- Can also be calculated in addition to a direct x,y,z referencing from a coordinate system in the linear sequence from the track edges.
- Attributes of the track node always refer to the corresponding turnout grid with its objects, but not to the track grids (if the attribute does not also exist on the track panel).

4.4.2 Track Edge

A track edge is a simple railway track (panel) that can be traversed in both directions according to defined rules. There is no other way than to run from start to end. A track edge always connects two (and only two) track nodes. Therefore, at the beginning or at the end a track node is always inserted in the topological system.

Definition of a track edge:

- Always starts at one certain Track Node

- Always ends at one certain track node
- Has a defined direction (orientation)
- Has a length sequence "u" (m) that increases with the direction of orientation and always has a positive value.
- For a purely topological, schematic diagram: Information for the length dimension is not required.
- Attributes of the track edge always refer to the corresponding track panel with its objects (the corresponding track panel), but not to the turnout panel (if the attribute does not also exist on the turnout panel).

Relationships from track node and track edge to track axis and alignment:

- A track node always lies on the track axis, which by definition is positioned in geometrical center of the distance between the upper edge of the two rails.
- A track edge has a reference to the track axis, which by definition is positioned in geometrical center of the distance between the upper edge of the two rails.
- The track axis carries the information about the track geometries defined in the "Alignment".
- In a scaled representation, the length of the track axis corresponds to the effective sequence of all the geometry elements according to the alignment.

Based on the above definitions, the entire track system can now be modelled as a railway network. On a topological layer, numerous parameters regarding capacity calculation (e.g. headways, design speeds), operation (e.g. positions of turnouts and signals) and technical requirements (e.g. train protection, platform lengths) will be defined at an early planning stage. These must be derived from the higher-level requirements of the network, the corridor and line-specific aspects and from local requirements.

RailTopoModel (RTM) and simulation software for capacity calculation and specification of the technical requirements for the railway system and the specific layout are based on this.

4.5 Transformation of the network requirements

In this chapter the two core elements for a cost-benefit-optimized project definition and an asset management for a successful and traffic needs are outlined:

1. Determination of the requirements from the higher needs of the railway network, corridors and lines.
2. Existing or planned track network in topological configuration

It is clear that the overall requirements cannot be transferred 1:1 to each topological element. In the railway network, not every track or turnout has to meet all higher-level requirements. For example, secondary tracks in stations may have lower allowed axle loads than defined in the corridor requirements. Other tracks are may not electrified.

Nevertheless, in accordance with the above definition, it must be ensured that the continuous trafficability can be guaranteed while complying with the overriding requirements. These are formulated for each domain and often provide requirements for different domains (e.g. Design speed).

The infrastructure manager must therefore know the track nodes and track edges and define whether or not they have to meet the higher-level requirement. Once this definition has been completed, the infrastructure manager knows the detailed actual or future requirements for his assets and can act accordingly. All railway-specific assets (Track, Signalling, Energy, Telecom, Bridges, Tunnels, etc.) therefore need a reference to the topology. This can be achieved a direct topological reference via a calculated allocation.

4.5.1 Properties of Track nodes and Track edges

A possible solution is to add a requirement attribute group to the Track node and Track edge objects in addition to the already existing properties. These properties contain the information whether the track node or edge must fulfill a higher-level requirement or not. The simplest possibility is to compile the overall requirements as properties of track edge and tack node with a corresponding Enum (Standards) or Boolean (has to fulfil yes/no) (see Table 3).

	Property Track-edge		**Description**	**Format**	**Example**
Req	Axle Load		Does the track-edge meet the requirements from network view? - yes -> 25 t / axle, no -> local specification.	boolean	Yes 25t/axle
Req	Catenary		Does the track-edge meet de requirement from network view? Yes = Overhead catenary with specified supply No = local specified, no catenary needed	boolean	No – without over head wires
Req					
Req					

Table 3 Properties of Track edge

With this structure of properties for track nodes and track edges it is possible in a first step to define the fulfilment of the defined network standards for each asset of the Railway system.

The infrastructure manager can now define the necessary measures and technical requirements for planning and design as well as for construction, operation and maintenance. This procedure enables a cost-benefit-optimized asset management under the aspect of BIM for railway infrastructure.

5 Positioning

5.1 Introduction

The ability to position objects is a fundamental requirement throughout the infrastructure domain. In contrast to the construction domain, in the railway domain objects are usually located along an axis. Railway and road belong to the so-called linear infrastructures. This chapter is to be seen from the business point of view of railways. It defines the requirements that must be fulfilled for positioning of objects in IFC Rail.

5.2 Reference systems

5.2.1 Cartesian reference system

A Cartesian reference system consists of a reference frame, an associated coordinate system and an elevation system.

For IFC Rail a 3D Cartesian coordinate system can be used to locate a point in a three-dimensional space, e.g. in a national coordinate system after a map projection is used to convert the geodetic coordinates to plane coordinates on a map. It projects the datum ellipsoidal coordinates and national heights onto a map (see Figure 11).

Note that the distances derived from such coordinates are affected with a scale. In a widespread railway system, it may not be sufficient to take the scale as a constant.

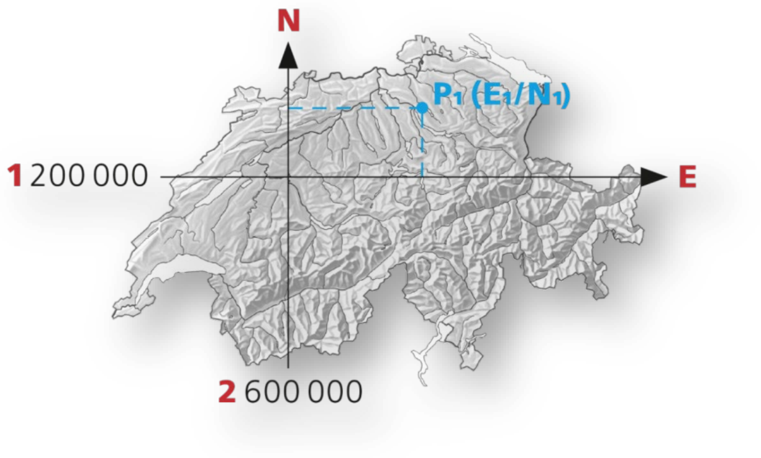

Figure 11 Reference system of Switzerland (source National Survey Switzerland)

An object is positioned in the Cartesian reference system with the following properties in Table 4:

Property	Type	Description
Northing	double	Cartesian Y-coordinate
Easting	double	Cartesian X-coordinate
Elevation	double	Cartesian Z-coordinate (Height)

Table 4 Properties for positioning of objects in spatial reference system

5.2.2 Linear reference system

A Linear Reference System (LRS) is a linear coordinate system that is bound to a reference axis which can be a curved line with its origin, its scale and its orientation (i.e. track centerline, road axis, …). It allows positioning of objects that are on or near an axis (see Figure 12).

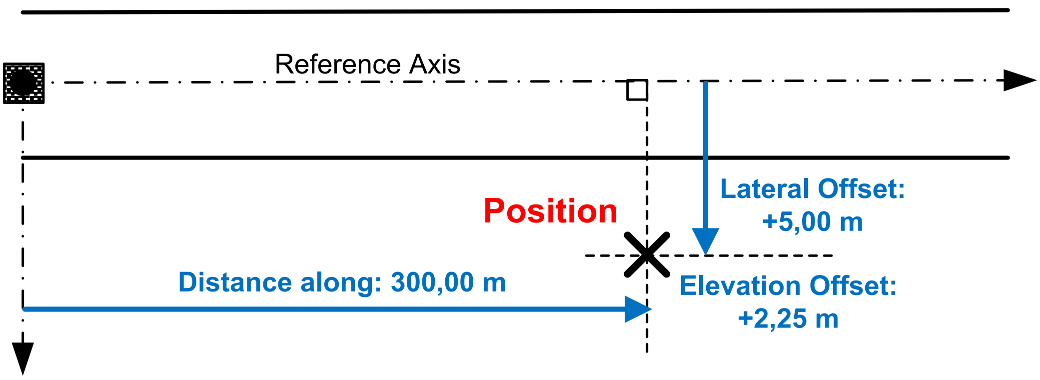

Figure 12 Linear reference system showing a point with coordinates (300; 5; 2,25)

An object is positioned in the linear reference system with at least the following properties in Table 5:

Property	Type	Description
Axis	ID	Reference Axis
Distance along	Double	Position along the reference axis defined by the odometric distance measured from the beginning of the reference axis to the perpendicularly projected position of the object onto the axis.
Lateral offset	Double	Position perpendicular to the defined axis (e.g. track axis, outer rail).
Elevation offset	Double	Position of the object measured from the lateral offset on a defined vertical axis (not represented in Figure 12).

Table 5 Properties for positioning of objects in linear spatial reference system

5.2.3 Local reference systems

For practical reasons certain assets have their own local coordinate systems where their components are "locally" positioned. This means that a local reference system is available within the asset. Examples of application for local reference systems are the track turnout components which should be locally referenced inside the track turnout panel or the positioning of Electrical and telecom systems inside a building.

The transformation of the coordinates of such an object into the global coordinate system requires an insertion point with its distance along, lateral offset, height offset and 3D rotation (Figure 13).

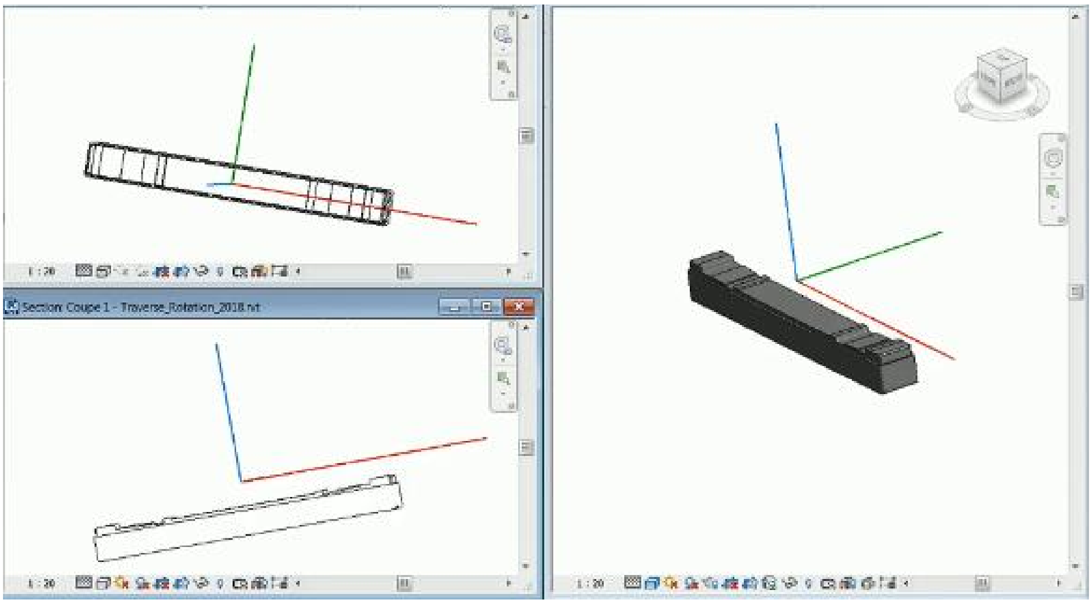

Figure 13 Insertion point for a sleeper is represented by the origin of the local coordinate system

5.3 Reference axis for IFC Rail

Depending on the use case the positioning of objects is done along a railway line or the centerline of a track (see also the Chapter 4). This means that different reference axes (railway line, track centerline, catenary etc) must be offered as the reference axis for the LRS (see Figure 14).

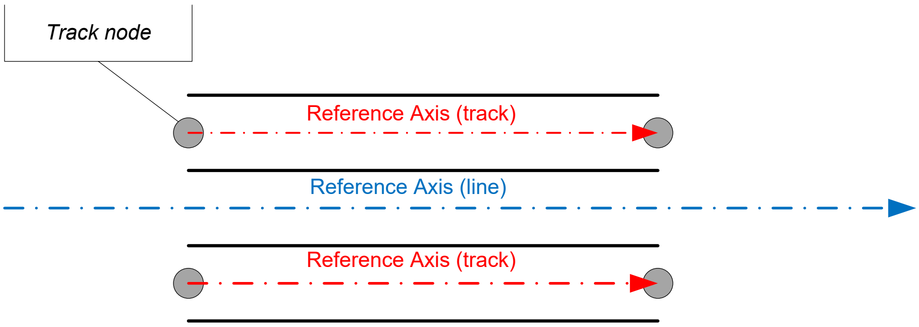

Figure 14 Different reference axis for object positioning used in railway

For the positioning of objects, it must be possible to use both, the railway line and the track centerline in combination, i.e. distance along from the railway line and the lateral offset from track centerline.

5.4 Type of objects and their positioning in LRS

From the collected requirements for the positioning of the objects, two types of objects or properties could be identified:

1. "Point objects" which have a single value along
2. "Stretched objects" which have a starting and an ending value along

Consequently we need two types of properties for the positioning as shown in Table 6:

Type of objects and their LRS properties	
Point object	Stretched object
Reference axis	Reference axis
Starting point	Starting point Ending point
Lateral offset	Starting lateral offset Ending lateral offset
Elevation offset	Starting elevation offset Ending elevation offset

Table 6 Type of objects and their LRS properties

5.5 Detailed requirements for object positioning

The requirements for the positioning of the objects on object type level, per domain, are shown in excel files: [Detailed requirements.]()

6 Alignment

This Chapter defines the requirements on alignment for track geometry and for linear referencing systems.

6.1 Track Geometry

6.1.1 Alignment

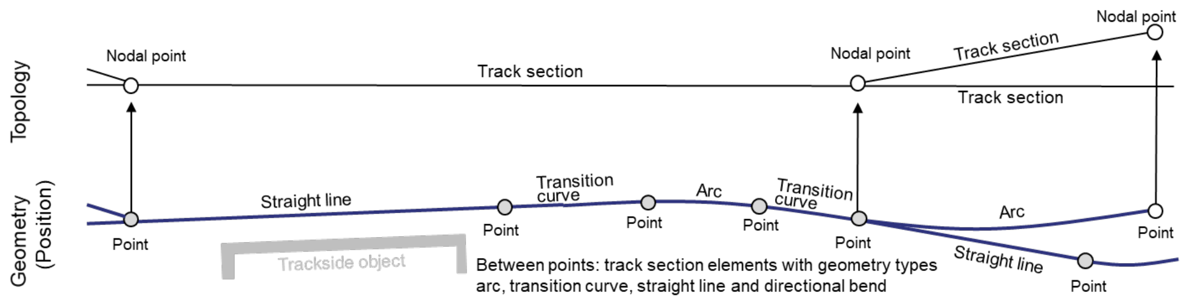

Figure 15 Alignment and relationship with topology

The topological network is divided into track sections between topological (nodal) points, see Figure 15.

Each track section is a separate entity in the sense that projections (= modifications) can be undertaken within a section of this kind. The nodal points (= topological points = facing ends of a turnout or ends of tracks) mark the ends of these track sections.

As a parameterised space curve, each track section has the following three alignments (= layouts), which are to be regarded as independent:

- Horizontal alignment with a sequence of horizontal elements

- Vertical alignment with a sequence of vertical elements
- Cant (= superelevation) with a sequence of cant elements

Each of these three alignments contains a sequence of ordered geometric track center elements comprising various geometry types that are linked together in a chain provided that predefined thresholds hold (e.g. at SBB 30 cc difference in angle, 1 mm difference length- or crosswise). The linkage of the elements as a chain is essential as each element within the track section dependents on the one in front.

6.1.2 Required Geometry Types

The following three geometry types are required:

- Straight line

  The straight line is defined based on coordinates for the starting point, direction (azimuth) and length. The initial and final radii are not defined.

- Arc of a circle

The arc is defined based on coordinates for the starting point, direction (azimuth), radius and length.

Negative radius	=	leftward curve in the direction of continuously increasing chainage / line kilometers
Positive radius	=	rightward curve in the direction of continuously increasing chainage / line kilometers

- Transition curve

The transition curve is defined based on coordinates for the starting point, direction (azimuth), length and initial and final radii as well as the type of transition curve. In addition to the clothoid (= Euler spiral) other types of transition curves can be used, such as transition curves with a sigmoid curvature or the Bloss transition curve.

6.1.3 Required Layouts

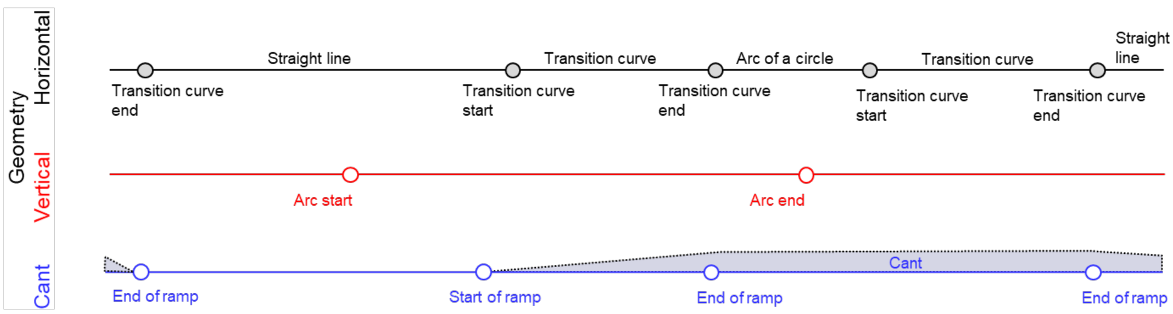

Figure 16 Schematic sketch of the three track layouts as a parameterised space curve. Note that the cant normally follows the horizontal layout, but there can be exceptions as shown in this figure.

The track geometry is divided into the following the three layouts, see also Figure 16:

- Horizontal alignment:

The horizontal alignment permits all three geometry types: straight line, arc of a circle and transition curve.

The tolerance limits for lengthwise, crosswise and angle errors must be kept. Otherwise the chain will not be deemed to be linked together. The horizontal coordinates of the starting point, the length and the initial angle (= azimuth) are entered for each geometric element. If no absolute coordinates are known, the initial coordinates of the geometric elements are entered as (0,0) or using less precise coordinates (graphical coordinates) in the geodetic reference system. Coordinate values can have standard deviations when appropriate. The type of geodetic reference system and/or the map projection must be given. The measurement respectively the calculation date must be stated.

- Vertical Alignment (= gradient):

The vertical alignment defines at least three different geometry types:

- Straight line (= constant gradient)
- Arc of a circle
- Transition curves

The tolerance limits for the vertical offset and angle errors (= abrupt change of the gradient) must be kept to, otherwise the chain will be deemed to be broken. The vertical alignment always follows the center axis (SBB) or the lower rail (DB, ÖBB).

An exception is the transition between a positive cant into a negative cant which is the case in the vicinity of a reverse curve without interposed straight line. Here, the vertical layout is identical with the low line (DB, ÖBB), see Figure 17.

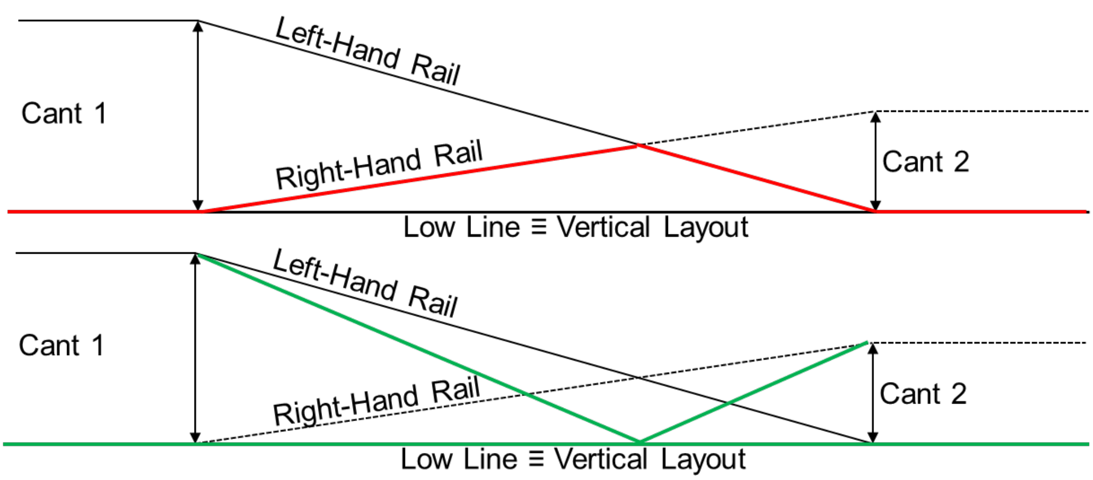

Figure 17 Vertical layout with altering sign of the cant. Top: airplane propeller (most often), bottom: lower rail (recommended).

- Cant:

The cant is defined as the difference between the height of the left rail minus the height of the right rail when looking into the defined direction. To obtain a vertical alignment which is independent from the cant, the model must distinguish between the case where the vertical alignment follows the track axis and the case where it follows the lower rail. Therefore, the left and the right rail cant are given explicitly, see Figure 18.

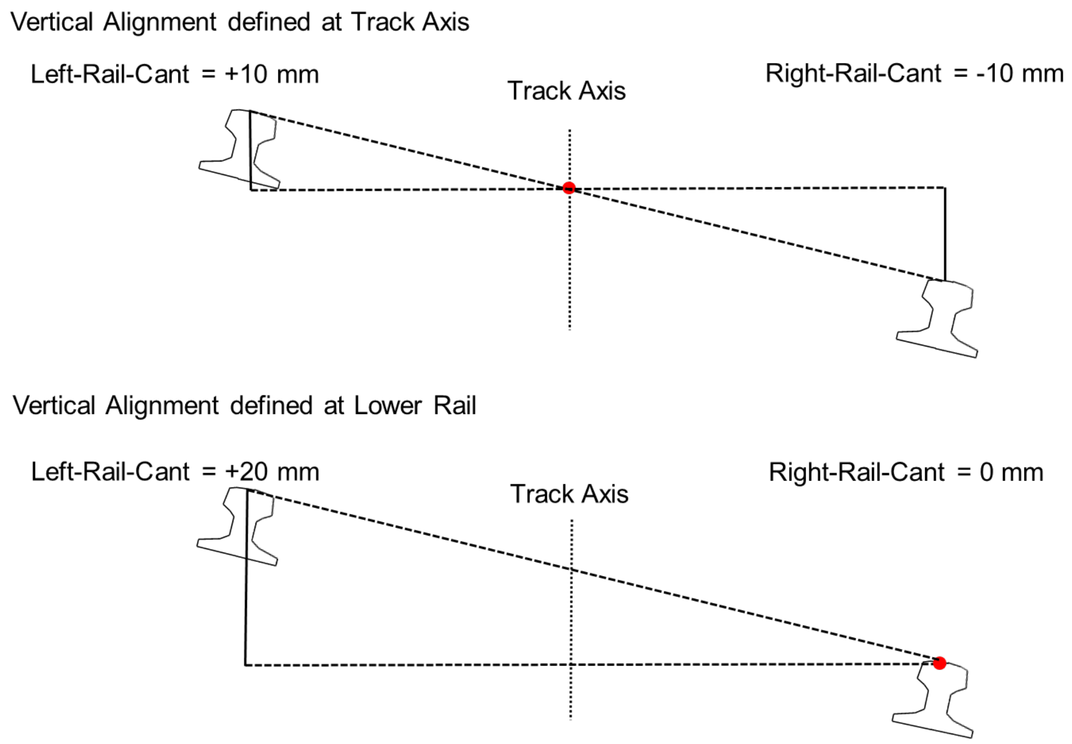

Figure 18 Top: Vertical Alignment follows the track axis. Below: Vertical Alignment follows the lower rail. In both cases the cant of the track is Left-Rail-Cant – Right-Rail-Cant = +20 mm.

At least three geometry types for the cant elements are defined in the cant layout:

- Constant cant (straight line)
- Constant change of cant (straight ramp)
- Curved cant (transition curve)

The tolerance limit for a sudden difference in cant must be kept to.

6.1.4 Alternative Representation of Track Geometry

As an alternative to the parameterised model using horizontal, vertical and cant profiles, a track section can also be represented as a sequence of straight lines between supporting points along the track axis (3D polyline / Spline). In this case, the density chosen for the points must ensure that any deviations between the discretised and the parameterised model are sufficiently small for the task at hand.

Advantage: complex curves can be incorporated into the model without the need for parameterising.

Disadvantage: a large volume of data may potentially be generated.

6.1.5 Diagram of the Alignment Data

Figure 19 shows the three geometry types (straight line, arc, transition curve) and their relation to the three layouts (horizontal-, vertical layout and cant). The required parameters are listed for each layout.

	Track Section Element	**Trackside Object**
Parameterised	Horizontal Alignment + Vertical Alignment + Cant	Horizontal Alignment + Vertical Alignment
Discretised	Supporting Points Along Track (=Ordered Sequence of Points)	Point

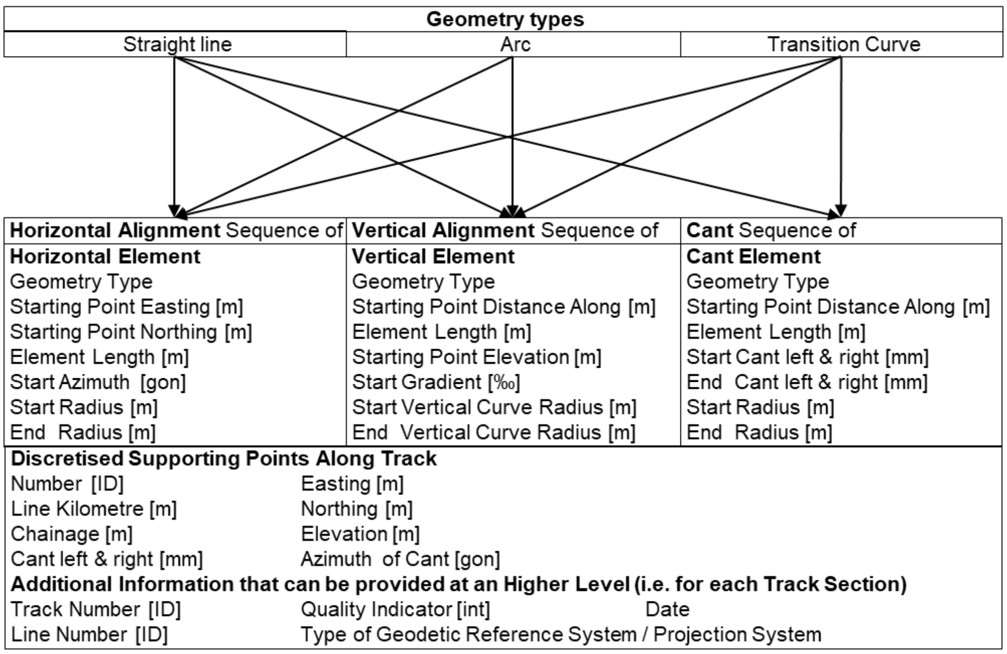

Figure 19 Data structure describing the geometry of the track section

6.2 Linear Referencing Systems

The linear referencing can be done at line and track level. Several terms have been used to express linear referencing, e.g. line kilometers, chainage, chainage system, stationing. The following definitions are made for the development of IFC Rail.

6.2.1 Chainage System

A path that either exactly represents a track axis or follows roughly a railway line is used to define a Linear Reference System (LRS). It is also known as “line Kilometers”. The chainage system serves to provide location details (information) for any railway installations. Every horizontal alignment usually contains a chainage system which has a similar data structure as the horizontal alignment itself.

The chainage system is composed of different segments. Within a chainage segment, the chainage value increases or decreases continuously. The chainage value can have jumps between the chainage segments. The chainage system must be mappable.

The required attributes for the broken chainage are shown in the following Table 7 .

Index	Name	Description
1	Prefix	Prefix string at the ahead of the chainage.
2	PrevNominalChainage	Chainage value at the end point of the previous segment.
3	SuccNominalChainage	Chainage value at the start point of the succeed segment
4	PrevDescription	Text description at the end of the previous segment.
5	SuccDescription	Text description at the end of the succeed segment.

Table 7 Broken chainage data

Although the path for the line kilometers must have certain elevation values in the 3D model, these values cannot be used as an elevation reference. The two values for positioning a point in the chainage system are:

- the distance between the to-be-referenced point and its foot of the perpendicular to the track axis or outer rail.
- the distance along of the foot of the perpendicular to the chainage system in meters.

Any point in the horizontal plane can be transformed without loss in both directions between a grid-system (x, y) and a chainage system.

6.2.2 Stationing Along Track

The precise position within a track section along the horizontal alignment is called stationing, ensuring that distances are mapped correctly to scale. Stationing requires only one value to define points on the track axis and it cannot be broken, i.e. the values along track cannot have jumps.

6.3 General Aspects Related to Alignment

6.3.1 Geodetic Reference System

All coordinates are geocentric 3D coordinates in the national geodetic reference system or are alternatively mapped into 2D in the respective national grid using a map projection, e.g. LV95 (SBB), Gauss-Krüger coordinates in DB_REF2016 (DB) or Gauss-Krüger coordinates in MGI M28-M31-M34 (ÖBB). In addition to the projection errors there are also the distortions caused by choosing a physical elevation reference system. For large railroad networks, the elevation and the mapping cause varying distortions of scale, which must be considered to obtain true-to-scale BIM models required for structures (bridges, tunnels, turnouts).

6.3.2 Trackside Objects

Although trackside objects do not form part of the alignment, they will have a determinative influence on it if they:

- are considered to be forced points along a track, e.g. at bridges without a ballast, turnouts or level crossings.
- exert an influence on the structure gauge or might exert an influence for an impending change in the alignment, e.g. at edges of platforms.
- exert or could exert an influence on the safety clearance required under accident prevention regulations.

Trackside objects are represented by points that have been measured or projected. As these objects are relevant to the track layout, it must be possible to store these objects in the BIM-alignment-model with sufficient positional accuracy using the matching geodetic reference system.

6.3.3 Turnouts

Geometrical elements and attributes of turnouts should be shared with other rail domains (e.g. radius, deviation of the deviated track, position of inherent points of turnouts – e.g. the point of the switch blades).

6.3.4 Additional properties

Some additional properties have to be included somewhere in the IFC. Examples:

- Structure gauge clearance
- Fouling point
- speed, cant deficiency and other dynamic parameters

6.4 Proposals for Expanding IFC Alignment 1.1

As a basic principle, IFC Alignment 1.1 forms a sound basis for the representation of the track layout at DB, ÖBB and SBB. The fact that the standard IFC also offers the option of mapping the alignment as a polyline with supporting points along a track fits with the mapping methods used by the three railway companies. Representing the alignment as a 3D polyline allows any number of transitional curves to be mapped. It must be possible to take the special vertical layout of reverse curves into account.

Main changes being proposed:

The cant (superelevation) profile is missing. It must be possible to have the cant as the third layout in addition to the horizontal and vertical alignment.

The network is not yet divided into track sections demarcated by topological points.

The “Continuity” attribute in the IFC reflects the criterion that the final coordinates of the preceding element match the initial coordinates of the subsequent elements within predefined tolerance limits. The “tangentialContinuity” attribute in the IFC reflects the criterion that the preceding element must be tangent to the subsequent element within a predefined tolerance limit. In respect of element ends of two successive elements, there must be a way to define tolerance limits within the coordinates/tangents would still be classified as being connected. A flag for “connectedness” is needed between the elements in the “Horizontal Alignment”, the “Vertical Alignment” and the “Cant”.

7 Spatial Structure

Spatial Structure is a gross, high-level decomposition of space to help and ease physical (product) breakdown structure used in IFC (Figure 20). It supports to breakdown project-based 3D BIM models into smaller parts used for subproject management, data federation and detailing. The spatial breakdown also organises the communally named locations for human activity. It can be used to indicate where an element is e.g. a signal is located in relation to a particular railway turnout. Spatial Structure is conceptually independent from positioning (precise geometric location in mathematical sense) of elements, which is in infrastructure domains is typically managed by linear placement according to alignment (see Chapter 5). From IFC point of view, spatial structure breakdown is project-based and must be organized in a strict hierarchy.

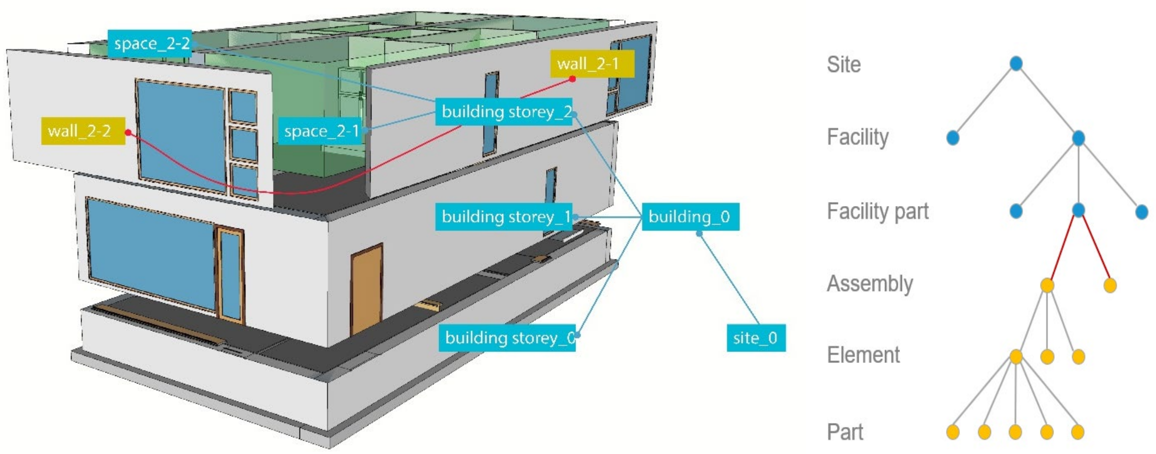

Figure 20 Spatial Structure concepts illustrated in conventional IFC using building domain as an example. Blue nodes are spatial structure elements, while yellow ones are physical elements

In the most upper level, the spatial structures in railway projects can be defined as Railway Line and Railway Facility. In a railway project, a railway line is the upper level spatial structure which contains all the track-side and line-side elements. A railway facility can be a shelter or energy facility, which can belong to a railway line when it is at line-side, or independent with it if it is remotely located.

Like the building domain, not all spatial structure elements are necessary for a railway project. It is up to the project team to decide in the beginning about proper spatial breakdown, i.e. (1) whether macro level longitudinal breakdown is needed; (2) proper spatial structure elements to be used and breakdown level (some project may want to stop at railway line level); (3) spatial structure can change depending on project phases.

7.1 Shared spatial structure

As a linear asset, it is logical that a railway line can be broken down into sections along the line. It is indeed possible to breakdown a railway line into multiple line sections in the macro level for management reasons e.g. a railway line across multiple countries or specific project requirements e.g. detailed design that cannot handle the full-scale 3D model of a railway line. However, when it comes to the level of organizing railway elements, there are no concepts that can be used to clearly breakdown a railway project across all the railway domains from longitudinal point of view. Therefore, it is suggested that a railway line can be broken down firstly from vertical and lateral point of view, unless it is necessary to be broken down longitudinally in the macro level for afore-mentioned reasons.

The shared spatial structure concepts are defined as follows. The vertical and lateral spatial breakdown of a railway line is shown in Figure 21.

- Railway line
    - Railway substructure
    - Railway track structure
    - Railway superstructure
    - Railway lineside structure
- Railway facility

The reasons for breaking down a railway line in this way are specified as follows:

- It is the main way the railway infrastructure is build. Earthwork as substructure is built firstly in order to organize building track elements in track structure. Railway superstructure containing supporters and overhead contact lines are built afterwards. This spatial breakdown structure can more easily federate data according to this logic.
- Domain groups have greater consensus on this vertical and lateral decomposition.
- Further longitudinal breakdown can still be made in domain-specific level (see Chapter 7.2) or with Zones (see Chapter 7.3);

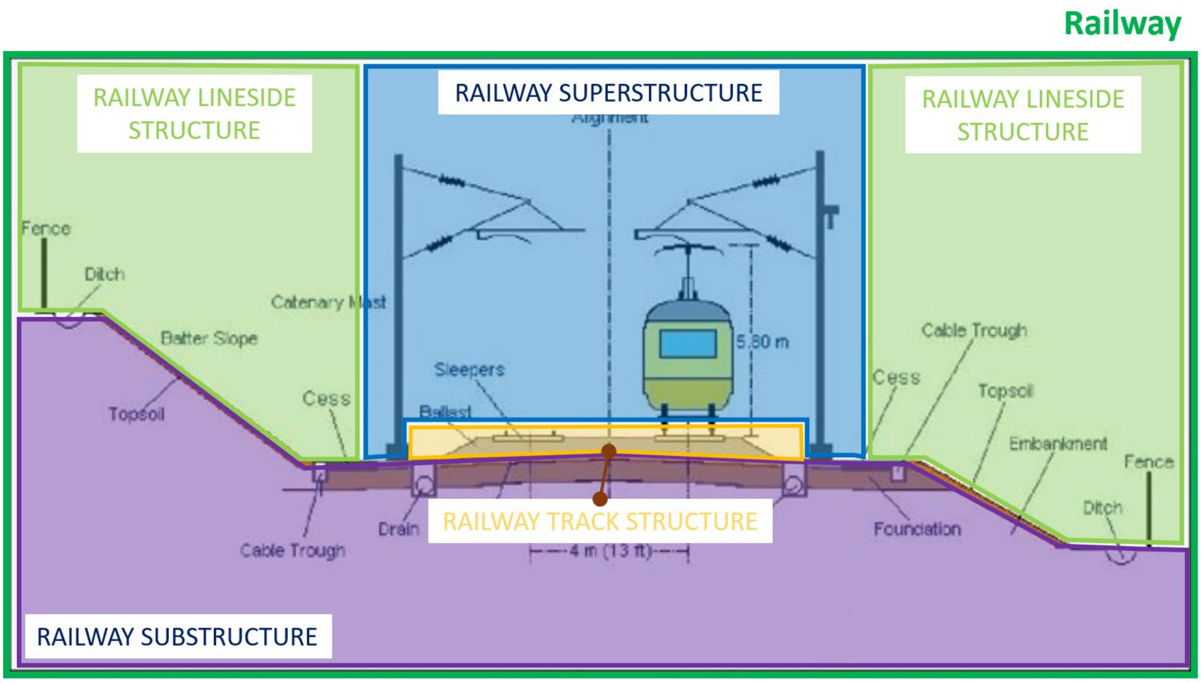

Figure 21 Vertical and lateral spatial structure breakdown of a railway line

A railway facility can be located at line side and thus belongs to the railway line e.g. a shelter located as line-side. It can also be independent with railway line as a standalone project per se e.g. a power supply substation. The way how to organize it with the railway line depends on specific requirements of a project.

7.2 Domain-specific spatial structure

The requirements of further breaking down shared spatial structure elements come from Track and Energy domains.

The shared spatial structure element Track structure can be further broken down as follows. These structures can be used for providing detailed location information for elements.

- Railway track structure
  - Plain track superstructure
  - Turnout track
  - Dilatation track

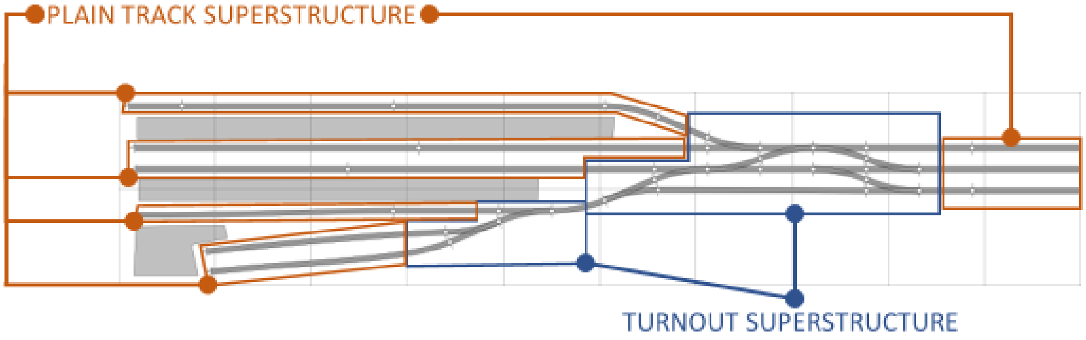

Figure 22 Proposed possible track spatial structure breakdown

The energy spatial structure can be overhead line structure, which is a part of Railway superstructure and railway energy facility, which is considered as a subtype of railway facility. The overhead contact line structure is managed by tensioning section, which contains overhead line, mooring and supporters.

- Railway superstructure
  - Tensioning section, Length of the overhead contact line between two terminating points (Around 1,5 KM)

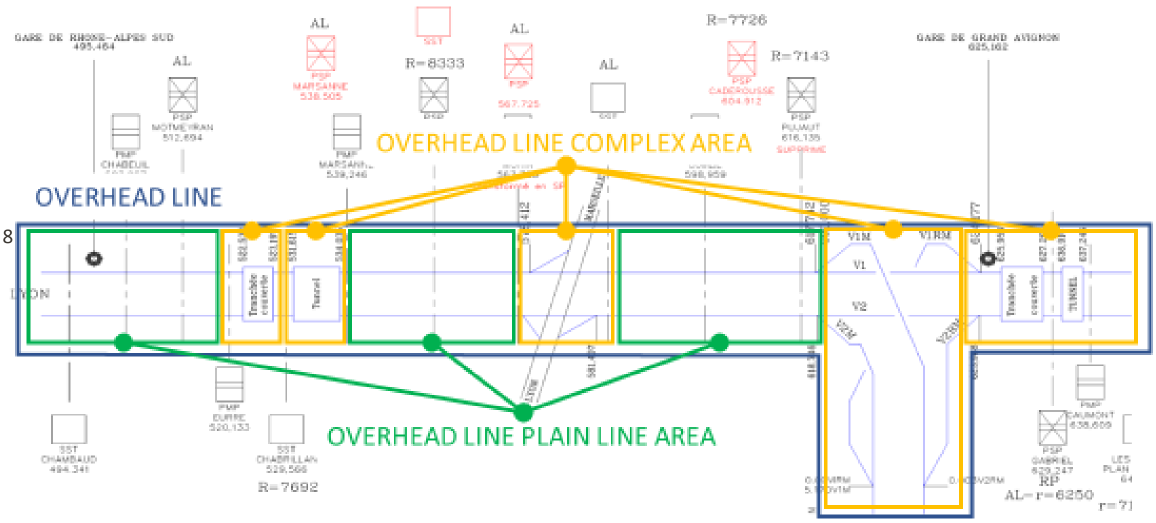

Figure 23 Tensioning section in energy overhead line structure in Railway superstructure

7.3 Spatial structures and zones

In the IFC context, spatial zones can also contain physical elements but are more flexible than spatial structural concepts: spatial zones do not have to be organized in a strict hierarchical structure. In Telecom, Signalling and Energy domains, spatial zones can be defined to further organize physical elements if defined spatial structure concepts do not fulfil domain requirements.

7.4 Relationship with other infrastructure domains

The railway infrastructure has close interactions with other infrastructure domains like bridge, tunnel and road. As stated in Chapter 1, these subjects are defined in separate projects governed in buildingSMART InfraRoom. The next step of Spatial Structure is to harmonize Railway spatial structure with those defined by Bridge, Tunnel and Road projects. Figure 24 and Figure 25 show the railway vertical breakdown structure in tunnel and on bridge.

To reduce the complexity, it is better to keep spatial structure of these infrastructure domains more independent with each other. The IFC Road has proposed four different reference relationships between infrastructure domains: Passes Under, Passes Over, Passes Through, Crosses. They need to be evaluated with cases in IFC harmonization work.

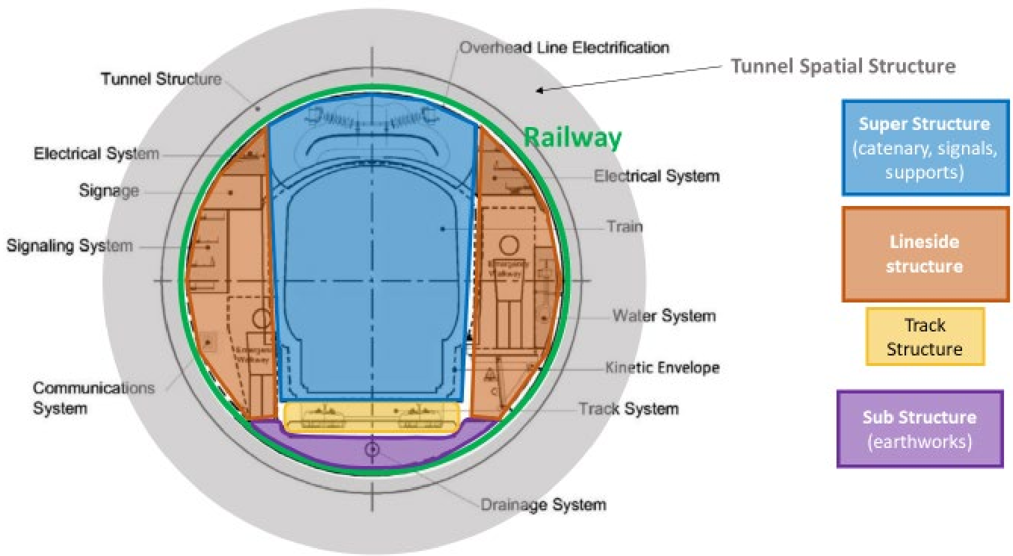

Figure 24 Railway spatial structure example with tunnel

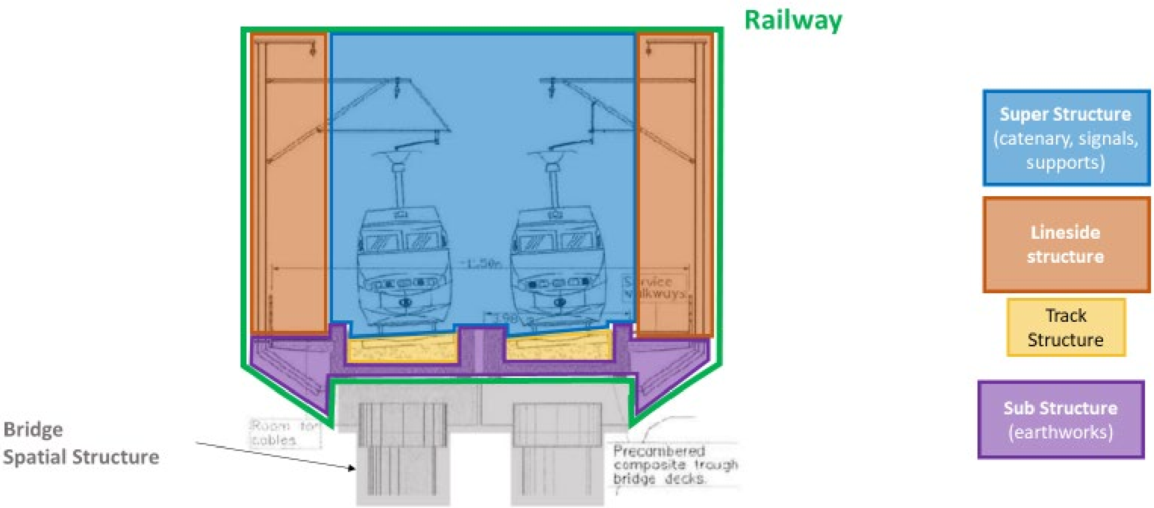

Figure 25 Railway spatial structure example with bridge

8 Geometric representations

Geometric information is fundamental for BIM processes. Since IFC has defined a rich library of geometric representations, in this project the method for defining proper geometric representations is to evaluate which existing geometric representation items in IFC can fulfil requirements of prioritized use cases and whether they need to be extended.

There are in general two kinds of geometric representations: 1) Explicit representations e.g. boundary representation; 2) Parametric representations e.g. Swept Solid, Constructed Solid Geometry (CSG). IFC is a data model for exchanging information between different systems and applications. The receiving application requires proper geometric representations to either analyze data to derive required information or edit them for further design and data exchange processes.

Explicit geometric representations like tessellated face set are required to implement 3D Visualization, which is basic for all use cases. In IFC, tessellated face set can be used to instantiate 3D solid objects (closed surface) or 3D surfaces (open surface). The former one can be used to model physical products, while the later one can be used to model objects which have a surface feature, e.g. geometry of terrains. Tessellated face sets are commonly supported by 3D geometry kernels to efficiently visualize 3D geometry. They can also be used to compute information to facilitate use cases like Quantity Take-Off and Interference Management. Swept Solid Geometry is commonly required for Quantity Take-Off. It is a parametric representation that enables creating a 3D object by sweeping a 2D profile along a segment or a directrix. They can be used to derive dimensional information of elements.

Same with other infrastructure domains, alignment lies in the foundation of geometry information in railway infrastructure. In current IFC, the geometry of alignment is defined by *IfcAlignmentCurve*, which can be parametrically defined by horizontal alignment and vertical alignment. As stated in Chapter 6, railway cant must be defined as another parameterized item for defining railway alignment. With such information, the IFC model should be able to parametrically create track geometry or other 3D elements by sweeping a profile along track axis or computing other 3D shapes like loading gauge. As stated in Chapter 3, alignment is important for Existing Condition Modeling and Railway Design Modeling. The discretized point sets require further investigation to decide whether new geometric representations should be introduced into IFC.

In general, the more parametric representations there are the more possibilities to define editable geometry objects. In the use case Railway Design Modeling, editable geometric representations should be required. At this stage of the project, except cant alignment, there are no requirements identified to define additional parametric representations.

Before bSI Beijing Summit in October 2019, it is estimated that IFC Rail project will extend cant alignment based on existing IFC geometric representations.

9 Model View Definitions

A Model View Definition (MVD) is a subset of the IFC data model, which defines a complete set of required entities, attributes, properties and constraints to support one or more particular information exchange scenarios as use cases. MVDs are especially important for implementation of IFC, as most software vendors usually choose proper MVDs instead of the entire IFC to implement. BuildingSMART provides certification service for standardized MVDs to ensure quality of implementations. An MVD can be represented using mvdXML, which is a bSI standard developed to document MVDs. Similar with an IFC standard, an MVD specification mainly consists of an MVD schema (primarily captured in EXPRESS) and reference data, referred to as property sets and quantity sets.

The scopes of MVDs in this project are defined with following considerations: 1) prioritized use cases (see Chapter 3) and required geometric representations (see Chapter 7); 2) to align with existing MVDs in buildingSMART and planned MVDs in IFC Infra projects (Bridge, Road).

The estimated MVDs in this project are as follows.

- Rail Reference View (RV)
- Alignment based Rail Reference View (ARV)
- Rail Design Transfer View (DTV)
- Rail Asset Management View

Table 8 shows their associations with prioritized use cases defined in Chapter 3. In the context of IFC, the purpose of Reference View is to provide a simplified basic suit of geometric representations and relationships of spatial and physical elements. It is used for the purpose of design coordination among different domains. With Reference View, the receiving applications can take the imported IFC data as reference to design and coordinate models. Two Reference View MVDs are planned to be defined in this project, with the difference that whether railway alignment is included or not. As shown in Chapter 3, for the use cases such as Existing Condition Modeling and Railway Model Design, alignment is essential for data exchanges and coordination among railway domains. It is hence suggested to define a Rail Reference View with Alignment for these use cases. The use case Interference Management may also require Alignment for some specific cases like computing loading gauge or signal visibility checking.

A Reference View without alignment is also planned. With this simplification, this MVD can be more supported by exiting IFC implementations to support use cases like 3D Visualization and Quantity Take-Off, in which alignment information is not necessary.

An MVD Rail Asset Management View is planned to support the use case Handover from Builder to Maintainer. For maintenance, the required geometric representations are not essentially different from those in Alignment Reference View, but asset management requires additional relations and attributes from a different perspective of thinking. Conventionally information which are important for maintenance like access to assets, dependency of assets, network topology, detailed location information, condition of elements, linear reference information is typically not explicit in IFC data. This MVD requires more investigation to define proper data structure and constraints.

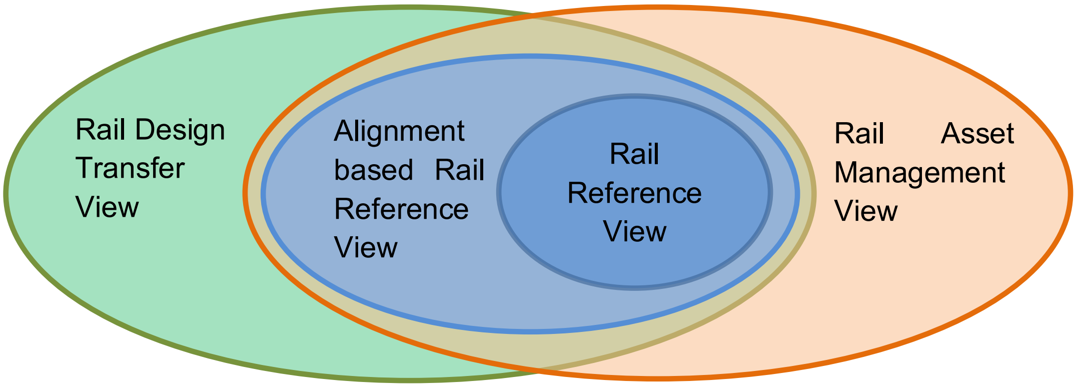

Figure 26 Scopes of estimated MVDs in IFC Rail

All the MVDs in this project will be defined according to Exchange Requirements finalized from Domain groups. They need to be prioritized according to project planning next steps. They also require further integration and harmonization with other IFC infra projects.

ID	Use Case	MVD
ECM	Existing Condition Modelling	Railway Reference View with Alignment
FSR	Feasibility Study for Railway	Railway Reference View with Alignment
RIDM	Railway Intermediate Design Modelling	Railway Reference View with Alignment / Railway Design Transfer View
RDDM	Railway Detailed Design Modelling	Railway Reference View with Alignment / Railway Design Transfer View
ICM	Interference and Coordination Management	Railway Reference View with Alignment

3DV	3D Visualization	Railway Reference View
QTO	Quantity Take-Off	Railway Reference View
INMP	Handover from Builder to Maintainer (Information Needed for Maintenance Perspective)	Railway Asset Management View

Table 8 Prioritized use cases and associated MVDs

				IFC4 RV	Bridge RV	Bridge ARV	Rail RV	Rail ARV	IFC 4 DTV	Bridge DTV	Rail DTV
IfcSolidModel				x	x	x	x	x	x	x	x
	IfcCsgSolid								x	x	x
	IfcManifoldSolidBrep								x	x	x
		IfcAdvancedBRep							x		x
			IfcAdvancedBRepWithVoids								
		IfcFacetedBrep							x		x
			IfcFacetedBrepWithVoids								
	IfcSweptAreaSolid			x	x	x	x	x	x	x	x
		IfcExtrudedAreaSolid		x	x	x	x	x	x	x	x
			IfcExtrudedAreaSolidTapered							x	
		IfcFixedReferenceSweptAreaSolid							x		x
		IfcRevolvedAreaSolid		x	x	x	x	x	x	x	x
			IfcRevolvedAreaSolidTapered							x	
		IfcCurveSweptAreaSolid							x		x
	IfcSweptDiskSolid			x	x	x	x	x	x	x	x
		IfcSweptDiskSolidPolygonal									
	IfcSectionedSolid					x		x		x	x
		IfcSectionedSolidHorizontal				x		x		x	x
IfcTesselatedItem				x	x	x	x	x	x	x	x
	IfcTesselatedFaceSet			x	x	x	x	x	x	x	x
		IfcTriangulatedFaceSet		x	x	x	x	x	x	x	x
			IfcTriangulatedIrregularNetwork								
		IfcPolygonalFaceSet		x	x	x	x	x	x	x	x
	IfcIndexedPolygonalFace										
		IfcIndexedPolygonalFaceWithVoids									
IfcCurve				x	x	x	x	x	x	x	x
	IfcBoundedCurve			x	x	x	x	x	x	x	x
		IfcAlignmentCurve				x		x		x	x
	IfcOffsetCurve							x		x	x

IfcOffsetCurveByDistances					x		x	x
IfcDistanceExpression			x		x		x	x
IfcOrientationExpression			x		x		x	x
IfcLinearPlacement			x		x		x	x
IfcAlignment2DHorizontal			x		x		x	x
IfcAlignment2DVertical			x		x		x	x
Alignment Cant*					x			x
IfcAlignment2DSegment			x		x		x	x
IfcAlignment2DVerticalSegment			x		x		x	x
IfcAlignment2DHorizonalSegment			x		x		x	x
Alignment 2D Cant Segment*					x			x

Table 9 Specification of required geometric representations of Rail MVDs (is an expected new representation item in IFC)*

10 Future work

In the conceptual modeling phase or IFC modeling phase, some requirements still need to be defined and clarified. Common and shared fields like cabling, station access and functional requirements need to be defined in the future. Additional requirements of spatial structure and geometric representations can be consolidated in the modeling phase of the project.

If the Release 1 of priority use cases are finished, this project can plan to have next round of prioritization of use cases. This will require another round of defining scopes of MVDs, common and domain-specific requirements.

The following topics are proposed to be covered in the IFC Rail project Phase 2:

- The Interoperability of the IFC Infrastructure Schemas (Road, Tunnel, etc.)
  These are generally concerned with linear infrastructure and are in various stages of completion.
- Collaboration with Common Schema | Project Definition, Organization and Funding
- Further use cases especially directed to Asset Management
- Final Model View Definitions
- IFC Implementation in Software and certifications
- Unique Rail Data Dictionary Evaluation and Definition, depending on the other Infrastructure Rooms decisions)
- Interfaces or collaboration to other Standards:
  Shift2Rail, RTM, GS1 unique object identifier
- Further cooperation with EULYNX and bSI in the Signalling domain
  (EULYNX working mode is for another 3 years)

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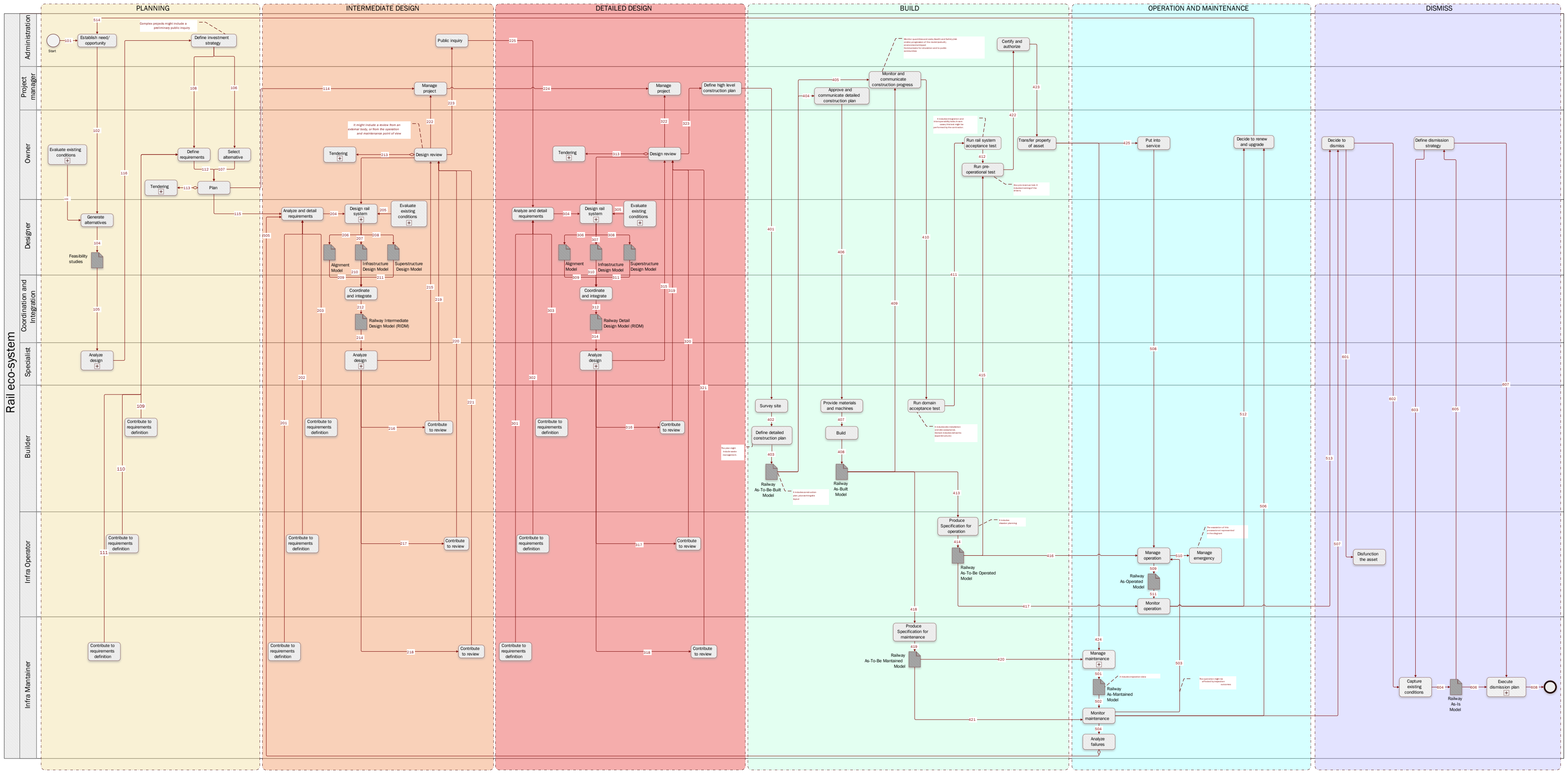
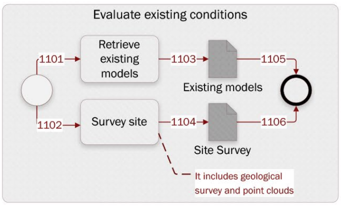
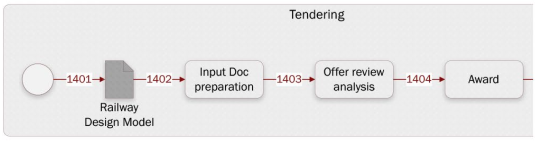
Annex 1: IFC Rail Reference Process Map

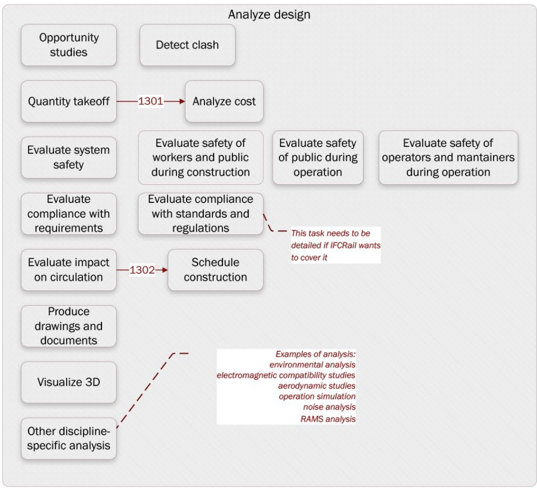
Annex 1.1: Reference Process Map

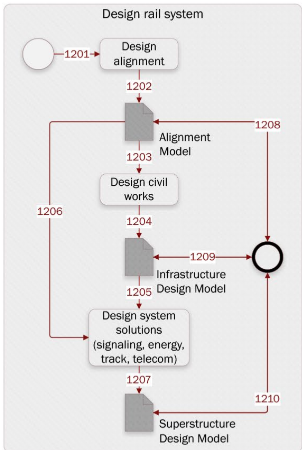


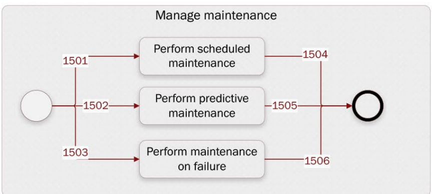
Annex 1.2: Subprocess Maps











Annex 2: Specification of general use cases

<table>
<tr><th>Plan</th><th>Design</th><th>Build</th><th>Operate</th><th>Dismiss</th></tr>
<tr><td colspan="4">Existing Condition Modeling</td><td></td></tr>
<tr><td colspan="4">Tendering</td><td></td></tr>
<tr><td colspan="4">Procurement</td><td></td></tr>
<tr><td colspan="4">2D Visualization</td><td></td></tr>
<tr><td colspan="4">3D Visualization</td><td></td></tr>
<tr><td colspan="4">2D/3D+time Visualization</td><td></td></tr>
<tr><td>Feasibility Studies for Railways (RW)</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Alignment & Functional Railway Requirements (RW)</td><td></td></tr>
<tr><td></td><td colspan="3">Project Monitoring</td><td></td></tr>
<tr><td></td><td colspan="3">Change order management</td><td></td></tr>
<tr><td></td><td colspan="3">Drawings & Documents Production</td><td></td></tr>
<tr><td></td><td colspan="3">Quantity take off</td><td></td></tr>
<tr><td></td><td colspan="3">Interference management</td><td></td></tr>
<tr><td></td><td colspan="3">Domain analysis & simulations (RW)</td><td></td></tr>
<tr><td></td><td colspan="3">Code & Functional Compliance</td><td></td></tr>
<tr><td></td><td colspan="3">Infrastructure Design (all infrastructure domains) (IN)</td><td></td></tr>
<tr><td></td><td colspan="3">Superstructure Design (all superstructure domains) (SS)</td><td></td></tr>
<tr><td></td><td>Import Reference Model</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Railway Intermediate Design Modeling (RW)</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Railway Detailled Design Modeling (RW)</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Project investigation and approval</td><td></td><td></td><td></td></tr>
<tr><td></td><td>Concertation and project acceptability</td><td></td><td></td><td></td></tr>
<tr><td></td><td colspan="3">Management & Design for temporary situation</td><td></td></tr>
<tr><td></td><td colspan="3">Construction Procedure Modeling & Scheduling</td><td></td></tr>
<tr><td></td><td colspan="2">Staging & scheduling</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Railway Procurement & Construction Modeling (RW)</td><td></td><td></td></tr>
<tr><td></td><td></td><td>Data take off for construction machines (RW)</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">As-built vs.as-planned comparison</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">Testing & Commisionning (RW)</td><td></td></tr>
<tr><td></td><td colspan="3">Functional & RAMS Demonstration (RW)</td><td></td></tr>
<tr><td></td><td></td><td colspan="2">As built survey modeling</td><td></td></tr>
</table>

			Railway as Maintained Modeling (RW)	
			Railway as Operated Modeling (RW)	
			Maintenance and operation planning (RW)	
			Training Model for Operation & Maintenance (RW)	
			From model to RINF (RW)	
			Pre final acceptance (RW)	
			Disaster Planning / Emergency Preparedness	

Table 10 general use cases and covered phases

Id	Name	Description	Required geometry representation	Required semantic information	Exchange Scenario in Process Map	Prior.	Comple x.
ECM (RR15)	Existing Condition Modelling	Made to compile all existing data from library works, survey, digital files, data listing, standard or functional key data etc...	Swept Solid Geometry; Tessellated Brep or Face set; Alignment	Site survey data: topology, geotechnics, any network data in interference with the project (gas / water pipelines, HV/LV lines, roads) and specify geospatial constraints as national parks limits, heritage constraints for building…	103;204;205;304;305;323;402	High	Medium
TEN (RR+F 03)	Tendering	Include in the model the information about allotment of the contracts for the design phase, the surveys and construction phase. Generate some tender documentation by extracting information from the model. Analyse the compliance of some features of the bid by using the model. Evaluate & compare the bids for some criteria by using the model.	Triangulated Face set if visualization if required		113;213;313;403;406	Medium	Low
PRO (RR60)	Procurement	Procurement sequence modelling and procurement strategy analysis. It includes material/system acceptance testing documents and homologation test of new products.	None	Product data required for construction	na	Medium	Low
2DV (RR+F 19)	2D Visualization	Transfer model from design/Operation and Maintenance application to 2D visualization application	2D representations	Existing and domains' data to visualize project into its environment		Medium	High
3DV (RR19)	3D Visualization	Transfer model from design/Operation and Maintenance application to 3D visualization application	Triangulated Face set	Existing and domains' data to visualize project into its environment		High	Low

TIM (RR+F 20)	2D/3D+time Visualization	Transfer model from design/Operation and Maintenance application to 3D+time visualization application	Triangulated Face set	Existing and domains' data to visualize project into its environment		Medium	Low
RWM1 (RR17)	Feasibility Studies for Railways (RW)	It's an analysis and evaluation of a proposed project to determine if it (1) is technically feasible, (2) can be realized in time and within the estimated cost and (3) will be profitable. Called also concept design, feasibility study or feasibility design.	Tessellated Boundary Representations or Face set; Alignment	Data from existing, domains, transverse activities (environment, local constraints…) to enable domains definition, data transfer to simulations, doc generation, various scenarios presentation…	105	High	Medium
AFR (RR16)	Alignment & Functional Railway Requirements (RW)	Data collection and transfer compiled Railway requirements or localisation	Alignment	Alignment / Land perimeter / Project functional req. as speed, station Number or position….	104;209;309;323	Medium	Low
PMO (RR10)	Project Monitoring	Include key activities relative to Project Management: risk, contract following-up, planning/scheduling, phase progress and performance, cost control, doc control, resources, etc…	Triangulated Face set if visualization if required	key elements related to PM monitoring such as design deliverable progress, procurement and on-site work completion progress, cost, etc…	114;222;322;405	Medium	Low
PMC (RR+F 09)	Change order management	Allocate changes to parts of the model. Allocate changes of functionnal requirements to parts of the model. Allocate new constraints to parts of the model.	Triangulated Face set if visualization if required		na	Medium	Low
DWG (RR45)	Drawings & Documents Production	Transfer model from Design/Build/Operate application to allow generation of drawings and doc such as table via specific application	2D representations	Technical data from domains	105;209;210;211;214;309;310;311;314;404;413;418	Medium	High

QTO (RR46)	Quantity Take Off	Derive quantities from (count, volume, area) from the model	Facet Brep or Tessellated Face set; Swept Solid;	Technical data from domains	115;215;315;406	High	Low
ICM (RR40)	Interference management	Transfer and compile models from multiple sub-systems of Infra (civil works...) and Superstructure (track, signalling, energy), detect clashes/collision/interference and communicate issues to be solved	Tessellated Face set or Boundary representation; Alignment depending on specific applications.	Data from existing, Infra+superstructures...	212;312;403	High	Medium
DAS (RR18)	Domain analysis & simulations (RW)	Transfer from design application to structural or other system/subject analysis application as operation simulations, noise simulations or vibration analysis, passenger traffic & flow simulations, travel time calculations, fire/aerodynamics simulations….	Swept Solid, CSG or other parametric representations; Analytic representations may be required	Track layout with curves, distance from buildings, types of CW structures…according to simulation tools required	105;215;315;418	Low	Medium
CFC (RR41)	Code & Functional Compliance	Transfer model from Design/Build/Operate application to demonstrate compliance to standards/codes or functional req. via specific application. For example, Product quality check (in each phase).	All kinds of parametric representations including Alignment or new representations	technical data from domains such as standards req., product definition etc…	102;219;319;408	Medium	Medium
IDD (RR20)	Infrastructure Design (all infrastructure domains)	- Import data from infra / civil work domains and specific requirements for bridge, tunnel to Railway modeling system. It includes Environmental & administrative procedures + Work Site requirements	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid. May require other parametric representations.	Civil work / infrastructure data and specific domain requirements	104;207;307;323	High	Medium

SDD (RR30)	Superstructure Design (all Superstructure domains)	- Import data from superstructure domains and specific requirements for systems to Railway modeling system. Safety procedures	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid	Railway systems data and specific domain requirements	104;208;308;323	High	Medium
IRM (RR+C 03)	Import Reference Model	Import initial reference model (terrain, soil, building, civil, aligment etc.) from GIS or other, to design application. As the reference for the domain model.	Tessellated Brep or Face set; Alignment		na	Medium	Low
RWM2 (RR01)	Railway Intermediate Design Modeling (RW)	Made for the Intermediate Design Phase, this use case is a Design-to-Design (reference model); it contains: - site conditions (should be in RR17) - key functional requirements and standards data - Public, political, financial and Owner requirements - technical Domains data	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid. May require other parametric representations.	Data from existing, domains, transverse activities to enable coordination reviews, data transfer to simulations, doc generation, public enquiry, optimization/variantes presentation…	223	High	Low
RWM3 (RR02)	Railway Detailed Design Modelling (RW)	Made for the detailled Design Phase, this use case is a Design-to-Design; it contains: - updated site conditions - key functional requirements and standards data - Public, political, financial and Owner requirements - technical Domains dataMade for the detailed Design Phase, this use case is a Design-to-Design; it contains: - updated site conditions - key functional requirements and standards data - Public, political, financial and Owner requirements - technical Domains data	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid. May require other parametric representations.	Data from existing, domains, transverse activities to enable coordination reviews, data transfer to simulations, doc generation, procurement or work package contract…	323	High	Medium

PIA (RR+F 01)	Project investigation and approval	Generate and transfer views extracted from the digital as proofs of evidence to justify which requirements are met or not. The requirements can be operational, functional, physical, imposed by the program, regulations, codes, standards, decisions during the development of the project, ... whatever the phase (design, build, commissioning, operation).	Tessellated Brep or Face set; Alignment; 2D representations		115;223;323;413;423	Medium	Medium
CPA (RR+F 02)	Concertation and project acceptability	Generate and transfer views extracted from the digital to present and explain to the public, during the design phase or the construction phase : - the features of the project : operational, functional or physical - the constraints - how they meet the requirements defined by the program, regulations, codes, standards, decisions during the development of the project, ...	Tessellated Brep or Face set;		225	Medium	Low
DSS (RR51)	Management & Design for temporary situation	Design for temporary situation modelling and constructability analysis (method and site requirements)	2D representations	temporary data from domains and Construction work process and method	401	Medium	High
CPM (RR50)	Construction Procedure Modelling & Scheduling	Construction sequence modelling and constructability analysis (method and site requirements)	Facet Brep or Tessellated Face set; Swept Solid; Alignment	All domains data and Construction work process and method	401	Medium	Medium
SSD (RR+F 07)	Staging & scheduling (design)	Describe all the works stages to end up to the final design, including temporary, provisory and complementary works and equipments. May change the final design.	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid. May require other parametric representations.		401	Medium	Medium

RPC (RR03)	Railway Procurement & Construction Modeling (RW)	Made for the Build Phase (inc. Procurement, Construction and Commissionning), this use case is a Design-to-construction; it contains : - final updated site conditions - technical Domains data for construction (shop drawings ; documentation issued for construction)	Tessellated Brep or Face set; Swept Solid; Alignment; Sectioned Solid. May require other parametric representations.	Data from existing, domains, transverse activities to enable work and supervision / coordination reviews, data transfer to simulations, doc generation as well as data from work package contracts	404;409	Medium	Medium
DTO (RR+F 13)	Data take off for construction machines (RW)	Generate from the model instructions to pilot automated construction machines. Real-time control of interferences with the existing conditions. Construction machine positioning.	Tessellated Brep or Face set; Alignment;		406	Medium	Medium
ASB (RR71)	As-built vs.as-planned comparison	Compare as-built vs as-planned and enable as output the production of As-Built design	Facet BRep or Tessellated Face set, Swept Solid.	As-built data (for example, from contractors) vs as-planned data (from designer) …for all domains	409	Medium	Medium
T&C (RR70)	Testing & Commisionning (RW)	Testing and commissionning sequence modelling and system integration process	None	Sub-system and system T&C process and data required for validation	411	Medium	Medium
FRD (RR42)	Functional & RAMS Demonstration (RW)	Transfer model from Design/Build/Operate application to demonstrate compliance to RAMS (Reliability, Availability, Maintainability, and Safety) requirements and for Performance Monitoring via specific application	None	technical data from domains such as functional and performance required and definition etc…	115;215;315;409	Medium	High
ASM (RR+F 18)	As built survey modeling	Collect information on site. Update the digital twin with the information collected. Manage the history of the updates. Manage different types of informations.	Facet BRep or Tessellated Face set, Swept Solid, Alignment. May require other geometric representations		na	High	Medium

RMM (RR05)	Railway as Maintained Modelling (RW)	Made for the Operation Phase, this use case is a Construction-to-Maintenance & Asset management; it will be handed over to the owner and the maintainer and contains : - technical Domains construction data for maintenance (maintenance documentation as manuals)	Facet BRep or Tessellated Face set, Swept Solid, Alignment	Data from existing, domains, transverse activities to enable maintenance	421	High	Medium
ROM (RR04)	Railway as Operated Modelling (RW)	Made for the Operation Phase, this use case is a Construction-to-Operation; it will be handed over to operator (GIS) and contains : - technical Domains construction data for operation (operation documentation as manuals, safety consignes, ...)Made for the Operation Phase, this use case is a Construction-to-Operation; it will be handed over to operator (GIS) and contains : - technical Domains construction data for operation (operation documentation as manuals, safety consigns, ...)	Facet BRep or Tessellated Face set, Swept Solid, Alignment, Analytical representations	Data from existing, domains, transverse activities to enable operation	417	Medium	Medium
MOP (RR80)	Maintenance and operation planning	Transfer Construction data to either operation or maintenance. For example, Management and maintenance planning (asset management)	Facet BRep or Tessellated Face set, Swept Solid, Alignment	Construction data for operation and/or maintenance	418;413	Medium	Medium
MOM (RR81)	Training Model for Operation & Maintenance	Transfer Construction data to train operators or maintainers	Facet BRep or Tessellated Face set, Swept Solid, Alignment	Construction data for operation and/or maintenance	412	Low	Medium
MRI (RR+I0 1)	From model to Register of Infrastructure	Extract from digital model the information for compile the RINF (Register of Infrastrucutre) database (provided for in article 35 of Directive 2008/57/EC). For example: name of track/point, TEN classification, category of Line, load capability, maximum speed permitted,	None		423	Low	Low

		interoperable/multinational/national gauge, etc. (see file attach for example of a list of information)					
PFA (RR+I03)	Pre final acceptance	Tool for MTBF (Mean time between failure) monitoring of each signalling equipment. Extract and permit to verify the MTBF of each component.			422	Low	
RR+C04	Disaster Planning / Emergency Preparedness	A process in which emergency responders would have access to critical building information in the form of model and information system. The BIM would provide critical building information to the responders, that would improve the efficiency of the response and, more importantly, minimize the safety risks. The dynamic building information would be provided by a building automation system (BAS), while the static building information, such as floor plans and equipment schematics, would reside in a BIM model. These two systems would be integrated via a wireless connection and emergency responders would be linked to an overall system. The BIM coupled with the BAS would be able to clearly display where the emergency was located within the building, possible routes to the area, and any other harmful locations within the building.				Low	

Table 11 Specification of defined general use cases

Annex 3: List of figures

Annex 4: List of tables