# EU Rail Knowledge Graph (ERA KG)

**Sesame-MISTEA** Meeting Montpellier |
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Photo: Adobe Stock / by Tarasylo

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# Agenda
- ERA in a Nutshell
- ERA Journey towards Data centric organization
- A little semantics goes a long ~~way~~ rail...
    - ERA Ontology
    - ERA Knowledge Graph
- Demo Applications
- Challenges
- Future Work
- Q/A Session

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# ERA in a Nutshell

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# ERA organization



### Recommendations to the Commission
- Technical Specifications for Interoperability (TSIs)
- Common Safety Methods (CSMs)
- Registers (Infrastructure, Vehicles, National Rules, ...)

### Technical development in Railway Safety
- Risk management and safety management systems
- Monitoring
- Safety culture and safety leadership
- Human and organisational factors
- Accident investigation methodologies

### Assistance to Member States and the European Commission
Dissemination on railway safety and interoperability
Training courses
Interface between NSA Supervision and Agency Authorisations and Certifications
Other support activities on request of the stakeholders
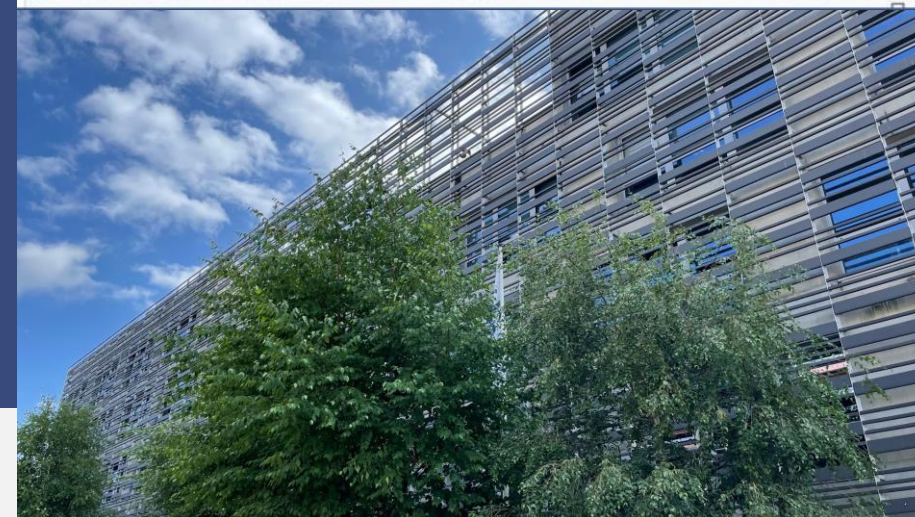
**Legal Framework**: Agency Regulation (Regulation (EU) 2016/796 of the European Parliament and of the Council of 11 May 2016 on the European Union Agency for Railways)

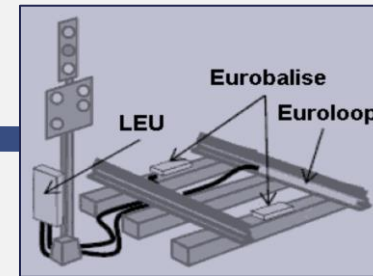EUROPEAN
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# The railway system
(simplified)

Infrastructure
& Energy

Rolling stock

Signalling

Humans

- Infrastructure managers
- Railway undertaking
- Entities in Charge of maintenance
- Keepers
- National Safety Authorities
- National Investigation Bodies
- Others, pls see Article 4(4) of the Directive 798/2016 for the full list

# Legal background

| Agency regulation | Interoperability directive | Safety directive |
|---|---|---|
| Regulation (EU) 2016/796 | Directive (EU) 2016/797 | Directive (EU) 2016/798 |

Implementing decisions → era.europa.eu/Registers

# Registers @ERA

| System | Full name | Accessiblity | Technical scope | Data owners |
|---|---|:---:|:---:|---|
| RINF | European Register of Infrastructure | **Public** | Infrastructure, energy and control-command signalling subsystem | Infrastructure managers (IMs ) |
| ECVVR/NVR | European Centralised Virtual Vehicle Register & National Registers | Restricted | The rolling stock subsystem | Keepers + National Registration Entities (NRE) |
| EVR | European Vehicle Register | Restricted | The rolling stock subsystem | Successor of ECVVR/NVR |
| ERADIS | European Railway Agency Database of Interoperability and Safety | **Public** | Safety and interoperability documents | Railway Undertakings (RUs), National Safety Authorities (NSAs) |
| ERATV | European Register of Authorised Types of Vehicles | **Public** | The rolling stock subsystem | NSAs, ERA |
| OCR | Organisation Code Register | **Public** | EU rail Organisations data | Organisations, ERA |
| RDD | Reference Document Database | **Public** | National rules | Member States (MS), ERA |
| SRD | Single Rules Database | **Public** | Regulatory framework, limited to operational and fixed installation | Member States (MS) |
| SAIT- (SIS) | Safety Alert IT tool – Safety Information System | Restricted | Technical equipment | Railway players, ERA |
| VKMR | Vehicle Keeper Marking Register | **Public** | Vehicle Marking | Keepers - OTIF |

# Towards Data Centric Organisation

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# Data Centricity Essential

**STOP** to data models hidden in the application layer => an inflation of similar, yet different data models created by IT providers
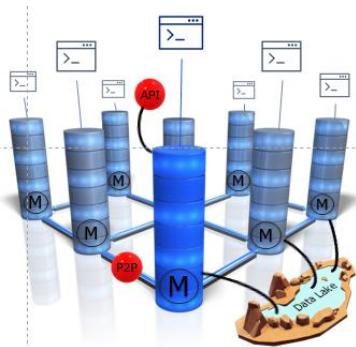
**YES** to data models which are "freed" from the code and can be shared and linked with the knowledge graph = Ontology + data values
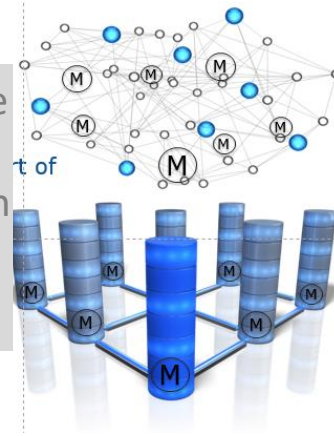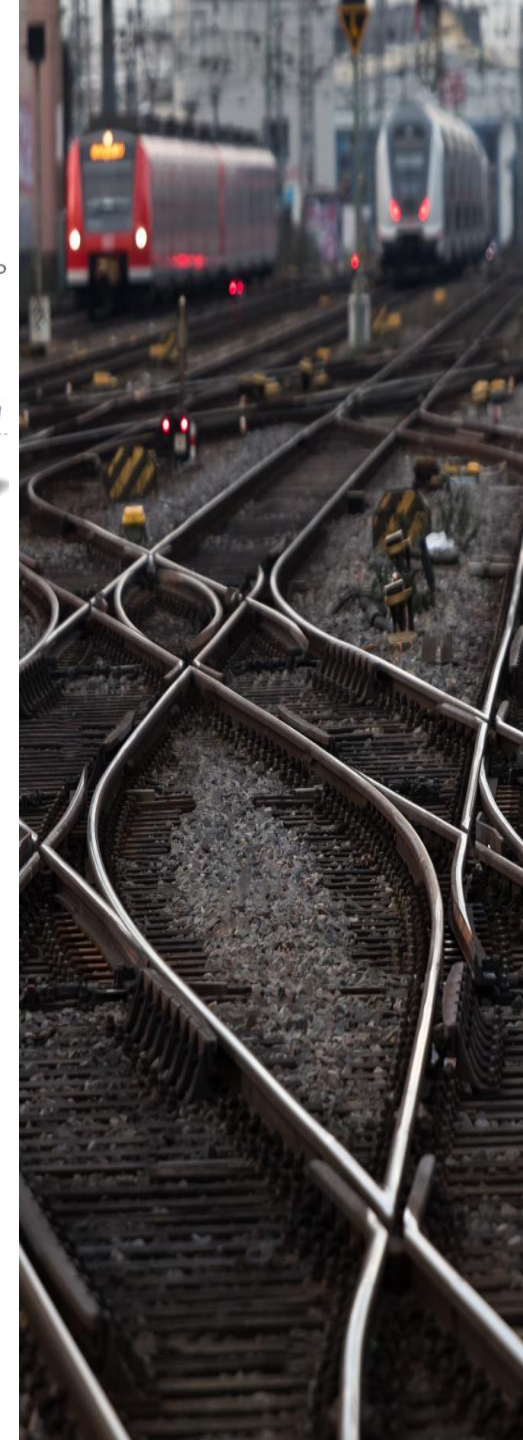
**STOP THE SPREAD OF RELATIONAL DATABASES COUPLED TO APPLICATIONS AND NEW DIGITAL BARRIERS**

**STOP** to application code modification each time there is a query, to interfaces and to APIs
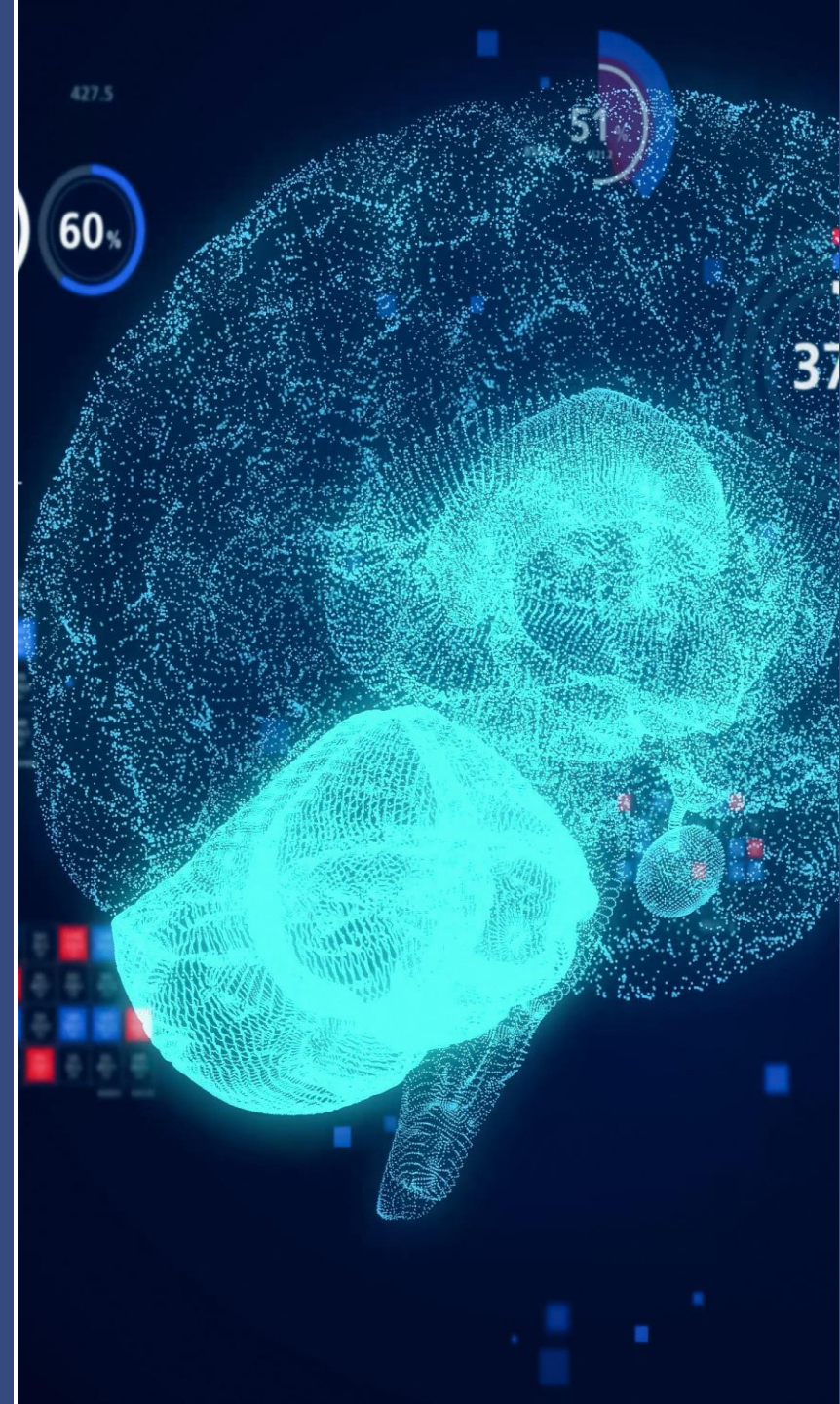
=> IT development costs and vendor lock in

**YES** to open standards, Aligned with Interoperable Europe Programme, supporting DAC and capacity management
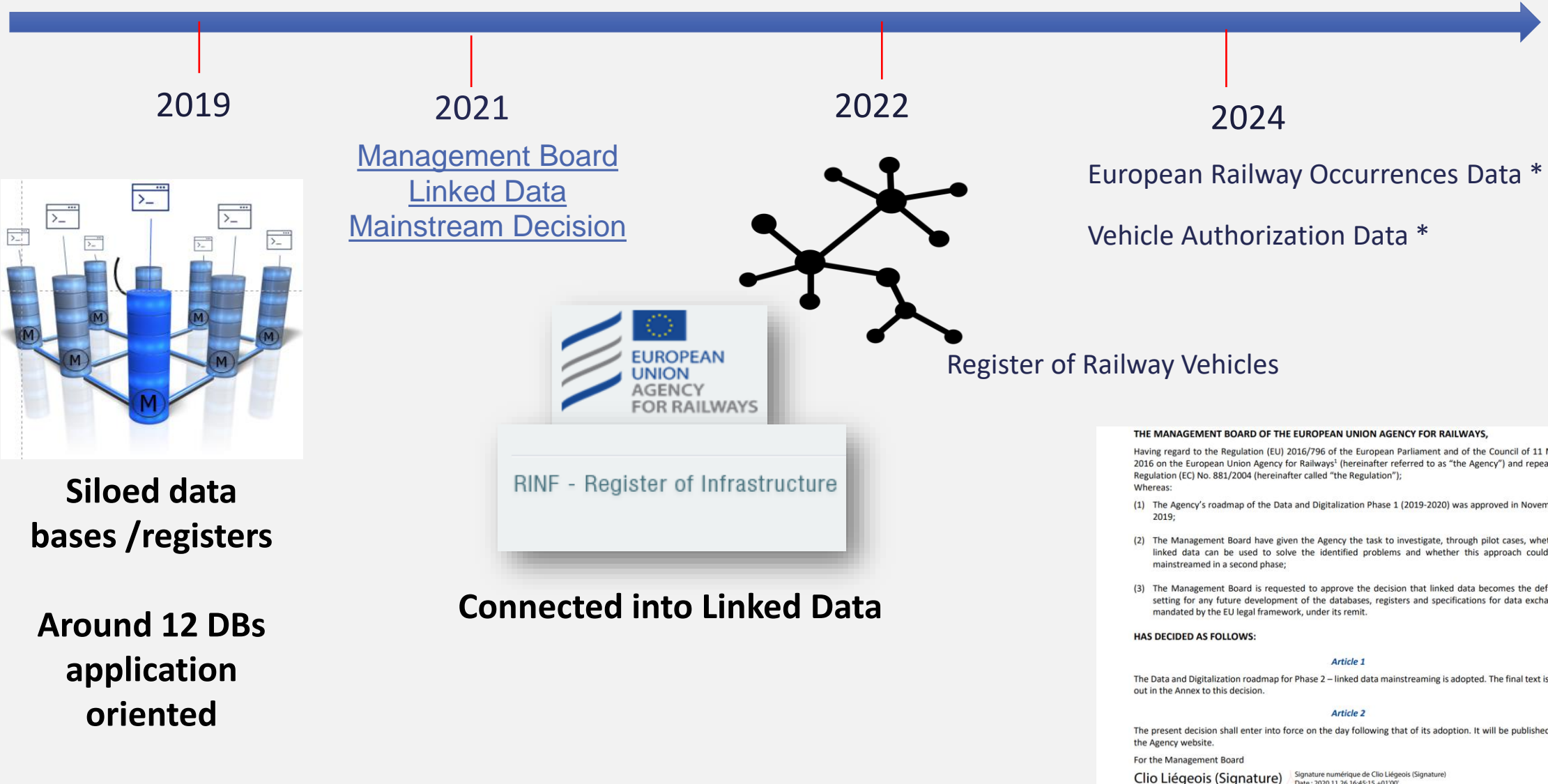
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# Our Core Principles
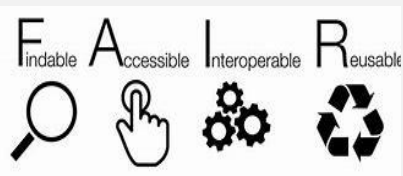## sets background to approach

| | |
|---|---|
| **Self-describing, Machine readable** | **Rail data, as a fundamental part supporting intermodal transport data and related knowledge, will be self-describing not requiring further interpretation nor translations from proprietary formats.** |
| **FAIR (findable, Accessible, Interoperable, Reusable)** | **The Agency will migrate from siloed to connected data. Using FAIR principles based on linked data. The Agency will adopt an evolvable ERA core ontology. Legacy datasets will be mapped/annotated in accordance with this ontology. Data storage of the annotated data in the ERA knowledge graph.** |
| **Once Only/ Single Source of Truth** | **An e-government concept that citizens, institutions and companies as data providers must provide information to the authorities & administrations only once.** |
| **Secure Data** | **Access to and security of the data is a responsibility of the data layer and not managed by applications. Personal data is managed on a privacy by design principle.** |

# The Journey towards Data Centricity

**2019**

**2021**
Management Board
Linked Data
Mainstream Decision

**2022**

**2024**
European Railway Occurrences Data *

Vehicle Authorization Data *

Register of Railway Vehicles

**Siloed data bases /registers**

**Around 12 DBs application oriented**

RINF - Register of Infrastructure

**Connected into Linked Data**

THE MANAGEMENT BOARD OF THE EUROPEAN UNION AGENCY FOR RAILWAYS,

Having regard to the Regulation (EU) 2016/796 of the European Parliament and of the Council of 11 May 2016 on the European Union Agency for Railways[1] (hereinafter referred to as "the Agency") and repealing Regulation (EC) No. 881/2004 (hereinafter called "the Regulation");
Whereas:

(1)  The Agency's roadmap of the Data and Digitalization Phase 1 (2019-2020) was approved in November 2019;

(2)  The Management Board have given the Agency the task to investigate, through pilot cases, whether linked data can be used to solve the identified problems and whether this approach could be mainstreamed in a second phase;

(3)  The Management Board is requested to approve the decision that linked data becomes the default setting for any future development of the databases, registers and specifications for data exchange mandated by the EU legal framework, under its remit.

HAS DECIDED AS FOLLOWS:

*Article 1*

The Data and Digitalization roadmap for Phase 2 – linked data mainstreaming is adopted. The final text is set out in the Annex to this decision.

*Article 2*

The present decision shall enter into force on the day following that of its adoption. It will be published on the Agency website.

For the Management Board

Clio Liégeois (Signature)    Signature numérique de Clio Liégeois (Signature)
Date : 2020.11.26 16:45:15 +01'00'

# Collaboration Effort... LD4Rail

The __common European mobility data space__ will build upon existing EU and Member States' legislation and infrastructures related to transport data

# A successful PoC



### European Register of Authorised Types of Vehicles (ERATV)

The types of railway vehicles authorised by ERA or the Member States

**Application**

Data base →

**No connection**

**Application**

Data base →

### Register of Infrastructure (RINF)

Register of infrastructure stating the values of the network parameters of each subsystem or part subsystem concerned

First step to extract 'operational' value from ERA base registers

### ERA ontology

**Semantic Vocabulary**
Transformation to a commonly understood language

### ERA knowledge graph

**Business value**

Provider interest on sharing the data once and in a reusable manner ('once only' principle)

### Route compatibility check

Find and analyse the information for the network topology and the vehicles to automatically display all the potential routes where a type of vehicle is technically compatible and able to run

**Users**
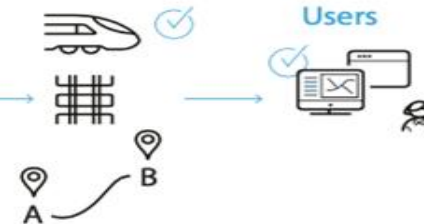
The tool provides support for the planning activity within the operational railway cycle via a web app, a simple user interface displaying the data of a knowledge graph
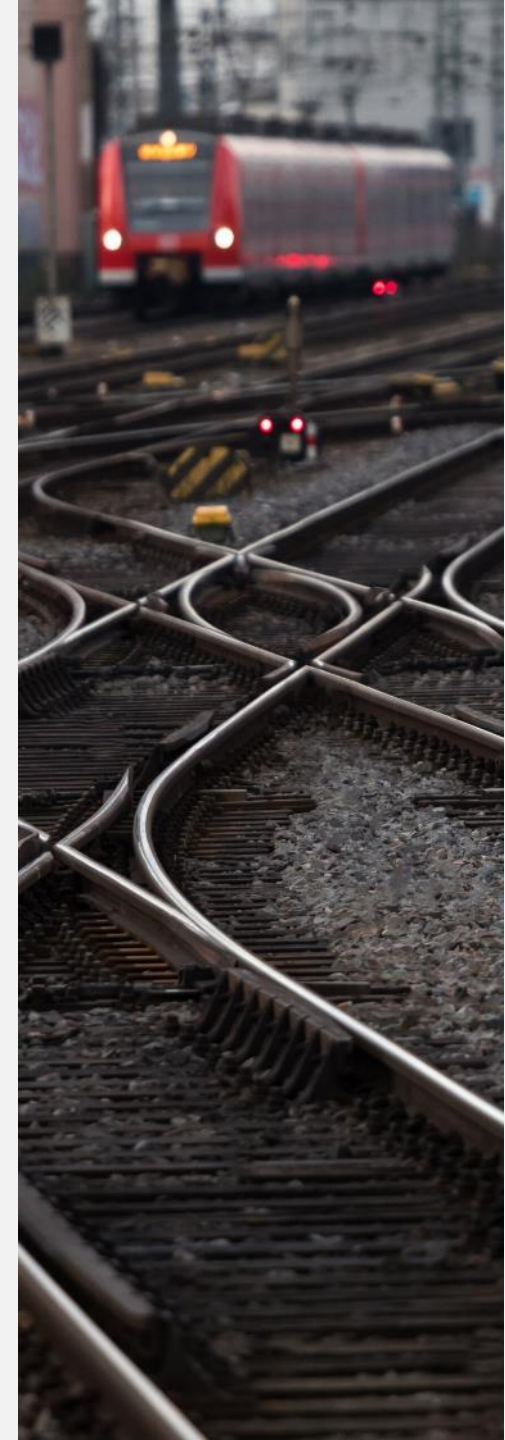
A Little Semantics Goes a Long ~~way~~ Rail

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# Competency questions

- CQ 1 — •How many tunnels are there per member state?
- CQ 2 — •Which are the distinct values for a particular parameter P of a track in member state C?
- CQ 3 — •What is the tunnel length per member state?
- CQ 4 — •What is the railway length per member state? (takes into account sections of lines and tunnels)
- CQ 5 — •What are the platform lengths in ascending order? (What is the variety of platform lengths in Europe?
- CQ 6 — •What are the parameters of a certain entity E in the vocabulary
- CQ 7 — •Which are non TSI compliant legacy signaling systems existent in the different countries?
- CQ 8 — •What are the number of tons per track?
- CQ 9 — •Which are the energy supply system values (voltage frequency) per SOL per member state?
- CQ 10 — •What is the network of an infrastructure manager IM?
- CQ 12 — •Which are the diesel vehicle types?
- CQ 13 — •Which are the tracks with a contact line system type that is not electrified
- CQ 14 — •What is the track length of Trans-European Transport Network (TEN-T) lines per member state?
- CQ 16 — •How many tracks are equipped with GSM-r per member state (rate of deployment)?
- CQ 18 — •Which are the tunnels in Belgium that are not category (rolling stock fire category) A nor B?
- CQ 19 — •How many countries are using local and non-international Gauges (gauging profile)?
- CQ 20 — •What are the available values for the GSM-R version per member state?
- CQ 21 — •What are the available ETCS levels per member state?

ERA Knowledge Graph | Data Stories

# ERA Ontology Overview v.3.0.x



https://data-interop.era.europa.eu/era-vocabulary/

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Resource: http://data.europa.eu/949/functionalInfrastructure/operationalPoints/a20512813f6342b5ee72ef83e2e9f980b355fa92
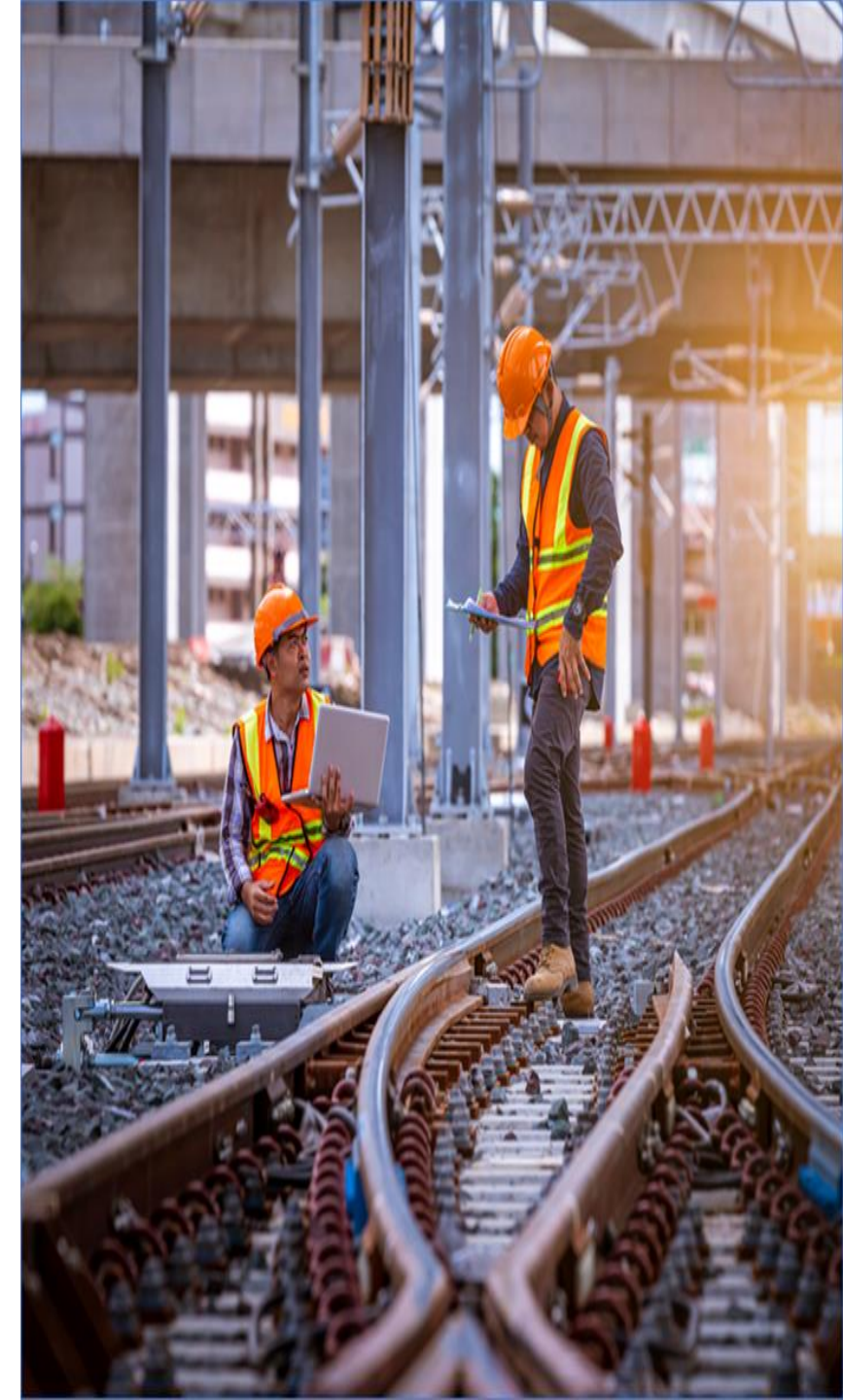
# Resource: Montpellier Sud-de-France ▸ Export

*Type: Operational Point*

## Properties

**Name of operational point** 1.2.0.0.0.1

Montpellier Sud-de-France

**Unique OP ID** 1.2.0.0.0.2

FR0000016317
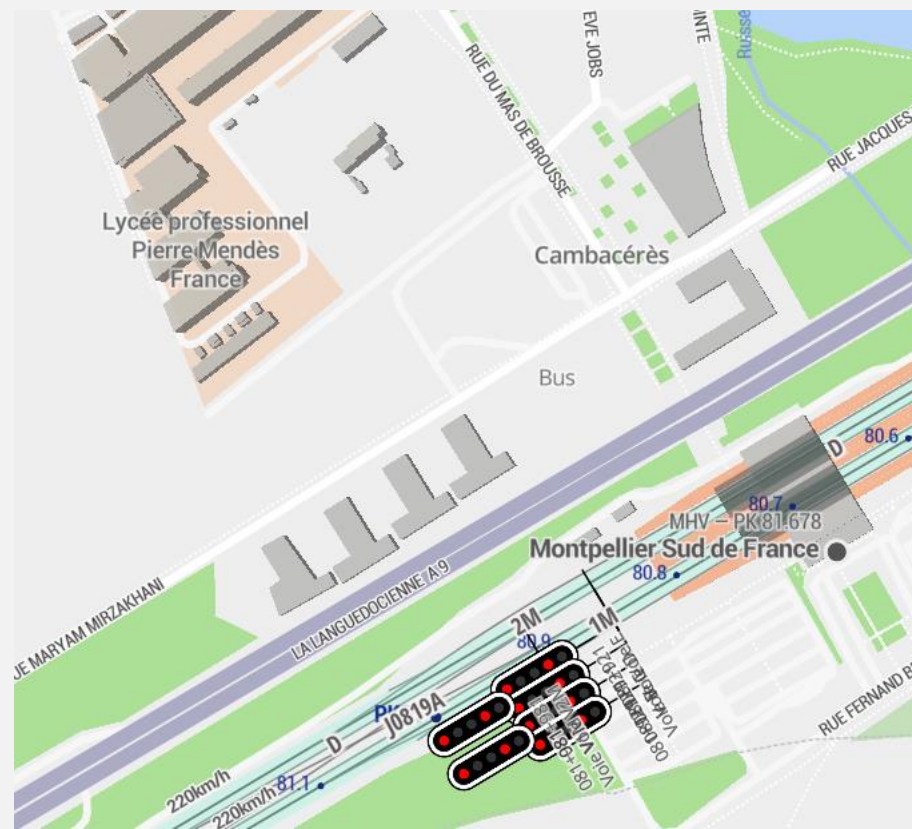
# KG GENERATION PIPELINE

ERA as neutral ontology provider and identity provider for the data exchange in the EU Common European Mobility data space facilitating data interoperability in the Transport Sector

Sectorial Legal Basis

Harmonization of Processes

Harmonization of :

- Terms – vocabulary – ontology governance
- Reference data – taxonomies controlled vocabulary
- Management of Code Lists Master data EVN, locations



Mobility

*Article 7a*

**ERA vocabulary**

"ERA Vocabulary" means a Technical Document issued by the Agency pursuant to Article 4(8) of Directive (EU) 2016/797, establishing human and machine readable data definitions and presentations and linked quality and accuracy requirements for each data element (ontology) of the rail system.

The Agency shall ensure the ERA vocabulary is maintained to reflect regulatory and technical developments affecting the rail system. The first update shall be made available by [*PO please enter 6 months after enter into force of this regulation*]";

(6)  the Annex is amended in accordance with Annex VII to this Regulation.

➢ Article 7 enacts semantic approach via ERA vocabulary/ontology

1st EU legal text enacting an ontology in the railway sector

**ERA vocabulary (europa.eu)**

**SKOS Concept Schemes used in the ERA vocabulary (europa.eu)**

**Link to ERA eng. rules**

# KG GENERATION PIPELINE



**KG generation**

RAILML XML

RINF XML full

RINF RDF partial

RINF RDF full

XML verification
- XSD verification
- "Code" verification

KG generation

SHACL verification

Actor

Publishing

save result

save result

save result

store generated KG

Adapter

S3 XML

ERATV DB

MongoDB

S3 KG

country files

S3 KG Pub

Virtuoso
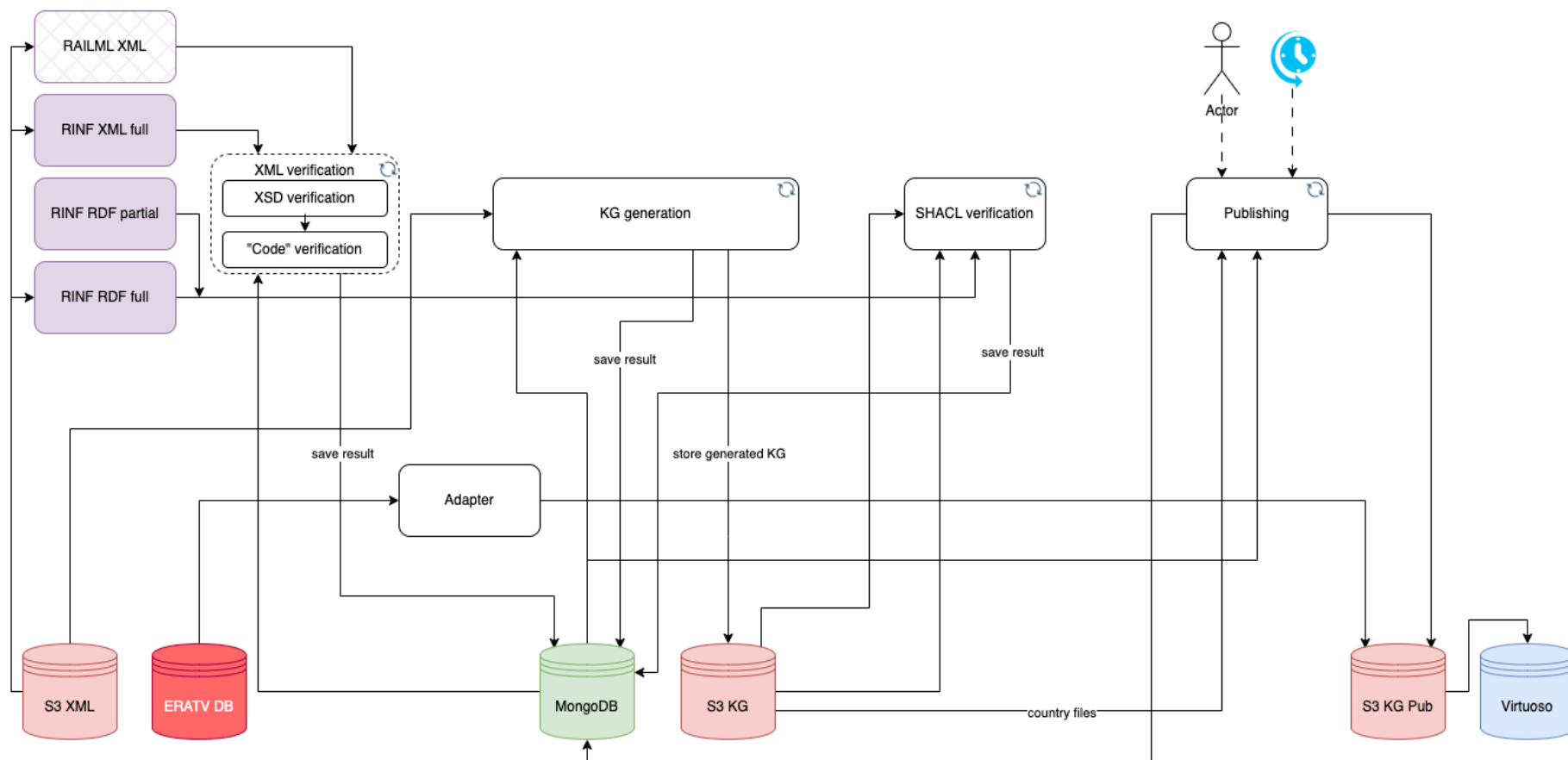
# KG PARTIAL UPDATE

# SHACL – Data Validation



era-sh: http://data.europa.eu/shapes/
sh: http://www.w3.org/ns/shacl#
era: http://data.europa.eu/949/
owl: http://www.w3.org/2002/07/owl#
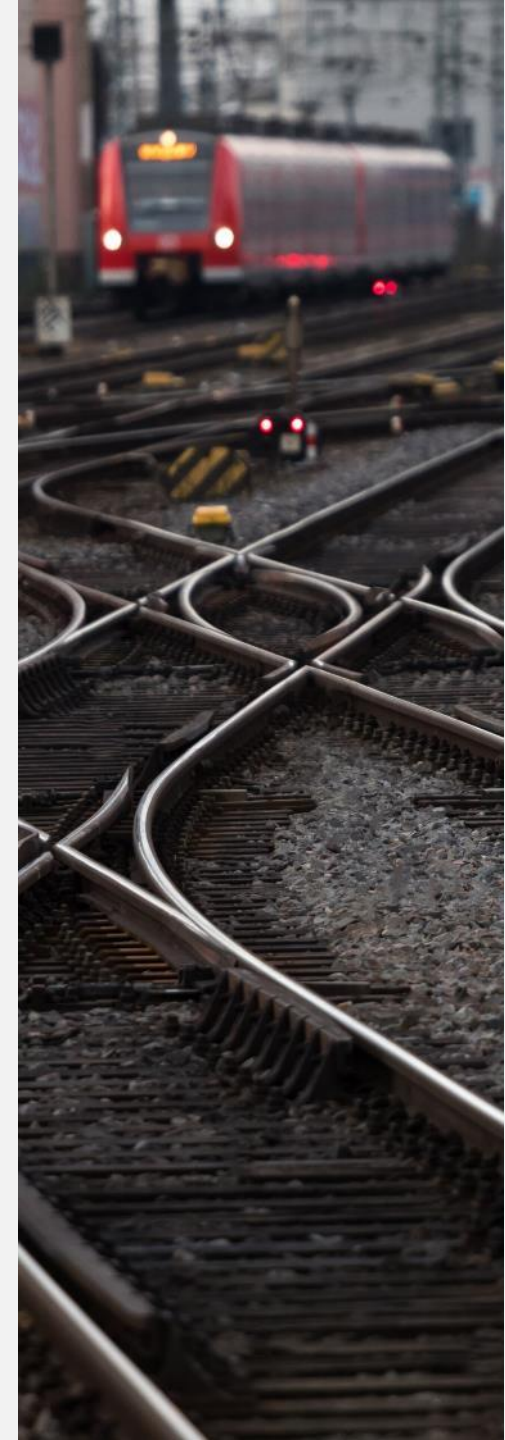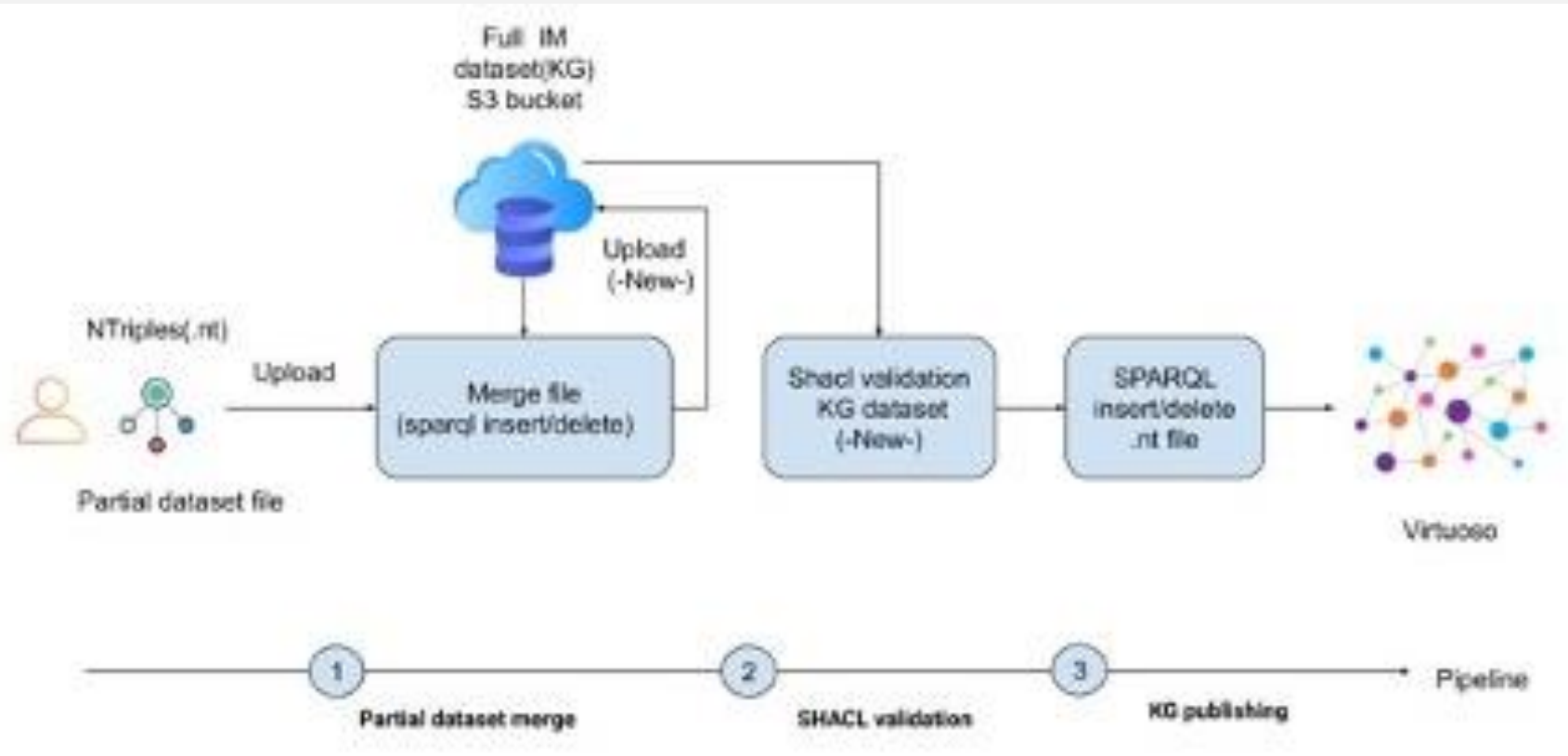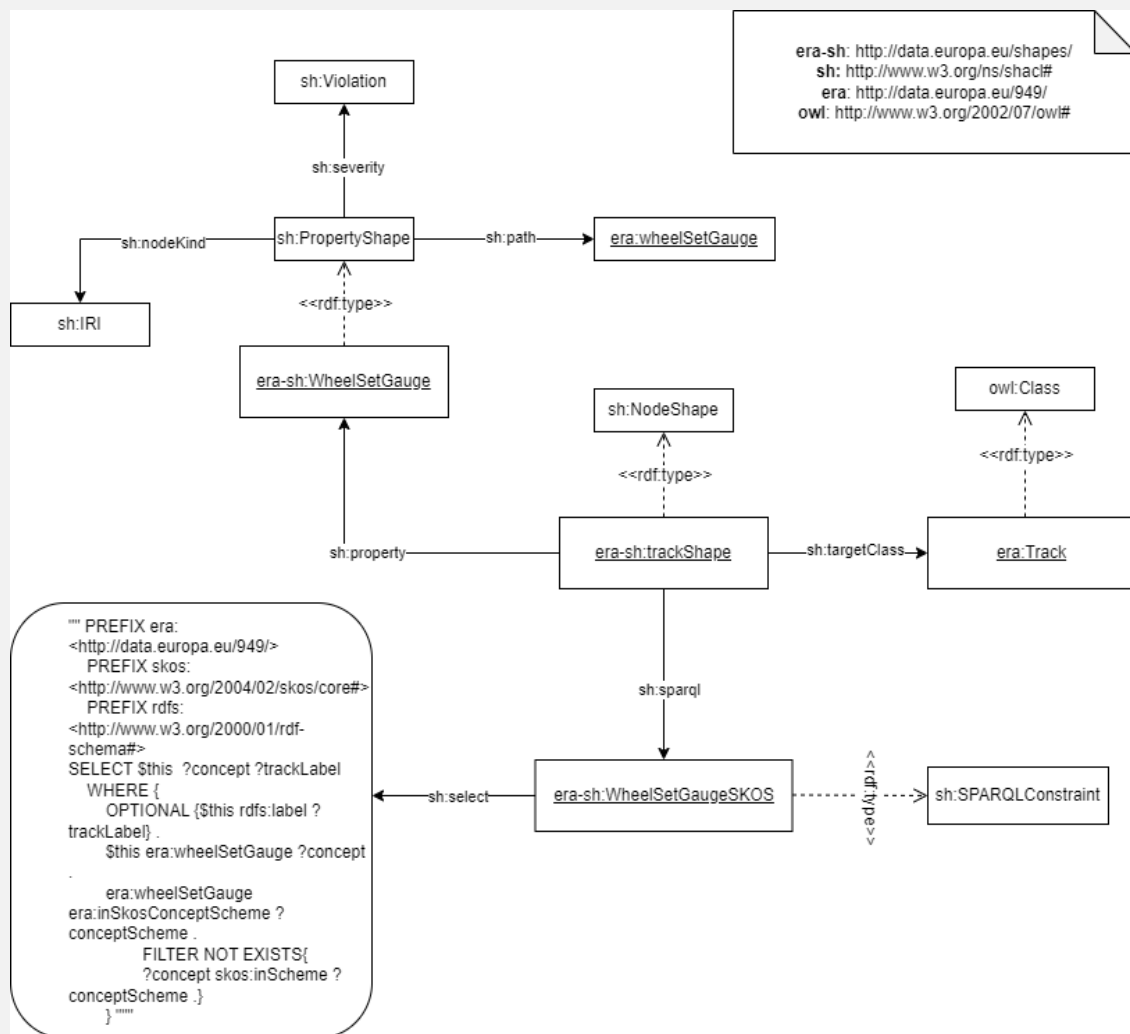
| SHACL types | #Total |
|---|---|
| sh:SPARQLConstraint | 60 |
| sh:PropertyShape | 733 |
| sh:pattern | 34 |
| sh:NodeShape | 15 |

# ERA Knowledge Graph

```
1   PREFIX skos: <http://www.w3.org/2004/02/skos/core#>
2   PREFIX era: <http://data.europa.eu/949/>
3
4   SELECT DISTINCT ?country  (count(DISTINCT ?OPCanonURI) as ?totalPassengerStation
5
6   FROM <http://data.europa.eu/949/graph/rinf>
7   FROM <http://data.europa.eu/949/graph/countries>
8
9   WHERE {
10      ?OP a <http://data.europa.eu/949/OperationalPoint>.
11      ?OP <http://data.europa.eu/949/inCountry> ?countryURI.
12      ?OP <http://data.europa.eu/949/opType> ?opType.
13
14      ?OP era:canonicalURI ?OPCanonURI.
```

https://prod.virtuoso.ecdp.tech.ec.europa.eu/sparql
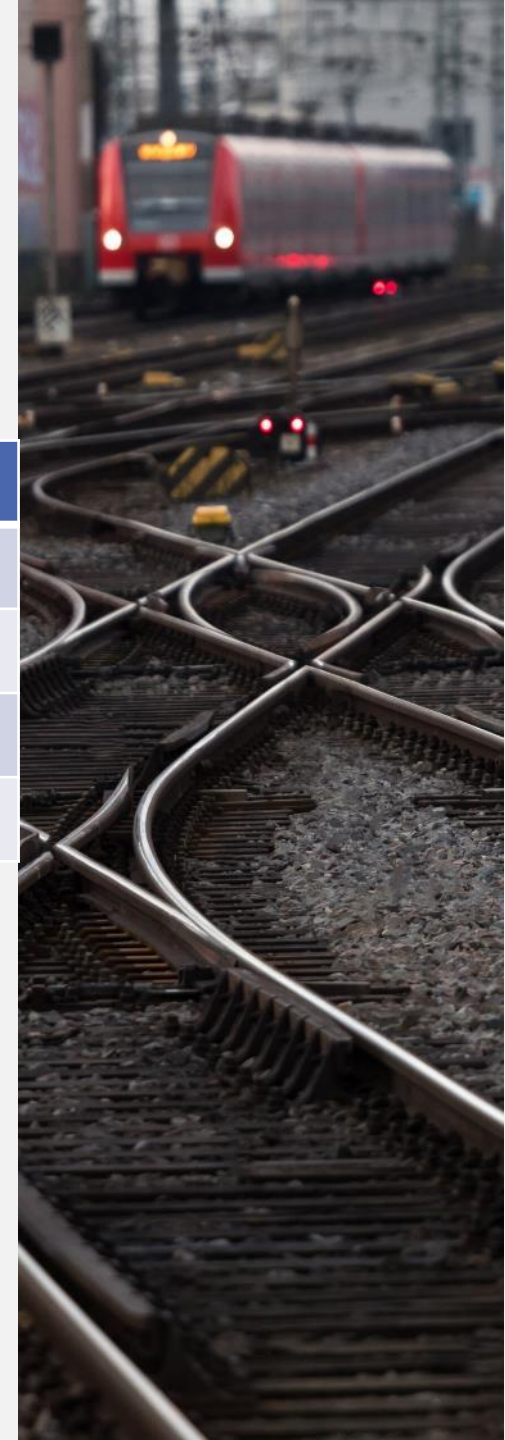
| Named Graph | URI | Triples count |
|---|---|---|
| Infrastructure managers | http://data.europa.eu/949/graph/im | 18,287 |
| ERA type of vehicles | http://data.europa.eu/949/graph/eratv | 210,715 |
| EU countries | http://data.europa.eu/949/graph/countries | 28,175 |
| Railway infrastructure | http://data.europa.eu/949/graph/rinf | 49,041,365 |
| Reference code list | http://data.europa.eu/949/graph/skos | 10,238 |
| Ontology | http://data.europa.eu/949/graph/ontology | 7,021 |
| | Total triples | 49,315,801 |

**Total passengers stations**

## ERA KG Dump.

This is the repository for the dumps of the ERA KG. It is a combined NQ file zipped (398 MB). When unzipped, it is around 15 GB.

## Zenodo

European Union Agency for Railways (ERA). (2025). ERA Knowledge Graph [Data set]. Zenodo. https://doi.org/10.5281/zenodo.14605743

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ERA — Map explorer (europa.eu).
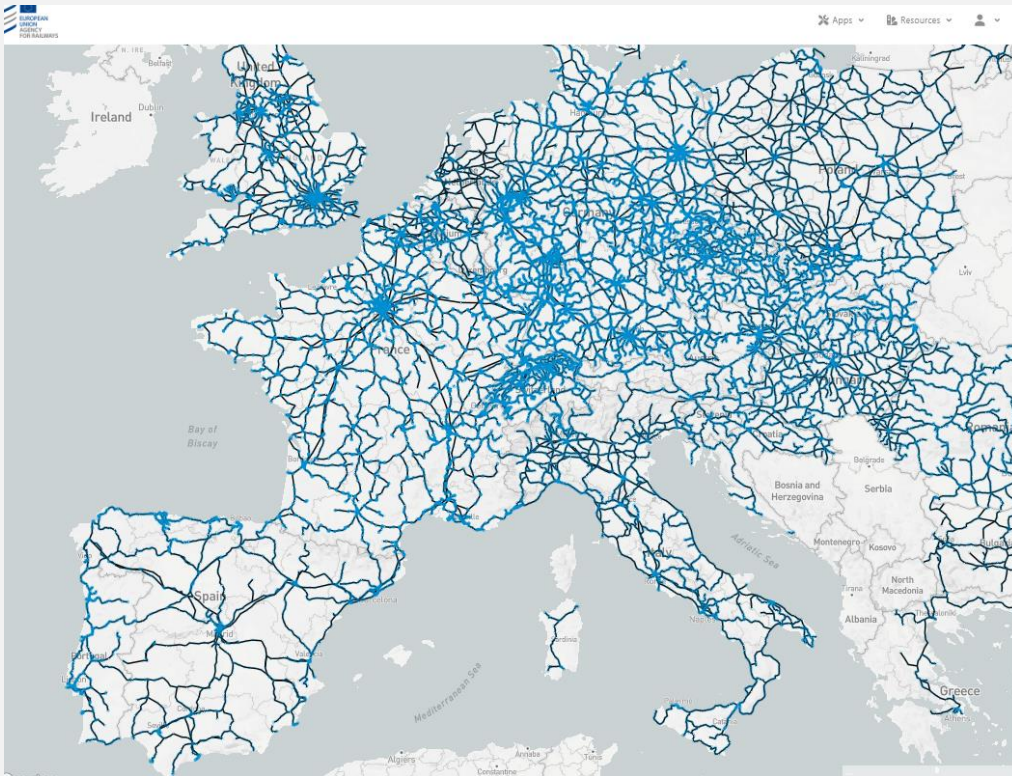


ERA — Route Compatibility Check (europa.eu)

Ontology Specification

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ERA Ontology. Version 3.0.1

This version:
https://data-interop.era.europa.eu/era-vocabulary/
Latest version:
https://github.com/Interoperable-data/ERA_vocabulary/releases/tag/v3.0.1
Previous version:
https://zenodo.org/records/12205825
Version:
v3.0.1 (released on 2024-06-18)
Publisher:
European Union Agency for Railways
Download serialization:
Format JSON LD    Format RDF/XML    Format N Triples    Format TTL
Browse SKOS thesauri:
Format HTML
Download SHACL shapes:
Format TTL
License:
License https://creativecommons.org/licenses/by/4.0/
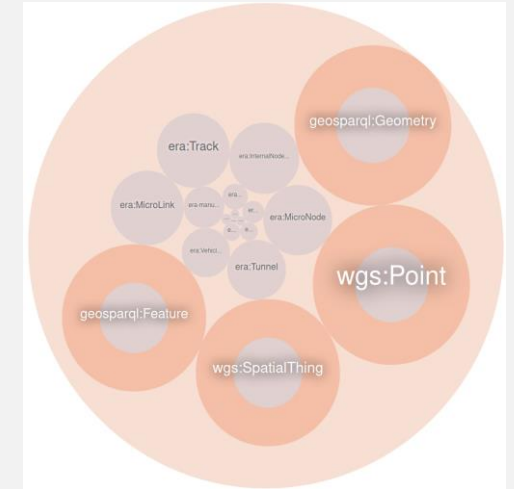


ERA KG endpoint

- More than 47 million triples
- More than 31k lines of mappings
- More than 100 SHACL shapes
- +270k track segments described
- +50k stations described
- +50k geo-referenced objects (lat/long)
- +2k Vehicle Types described
- 26 countries covered (EU countries)

# Tunnels with coordinates in Europe – Use Case of ÖBB
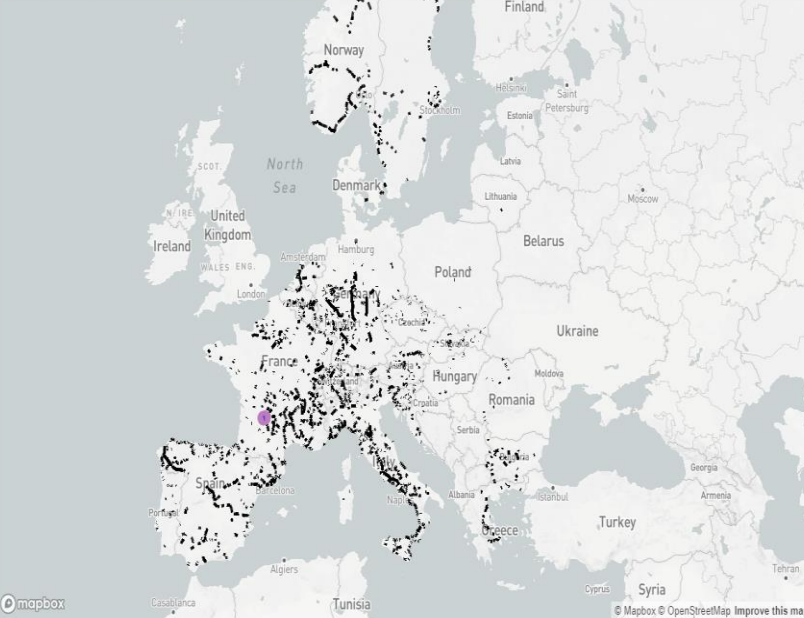


"Dear Sir / Madam,
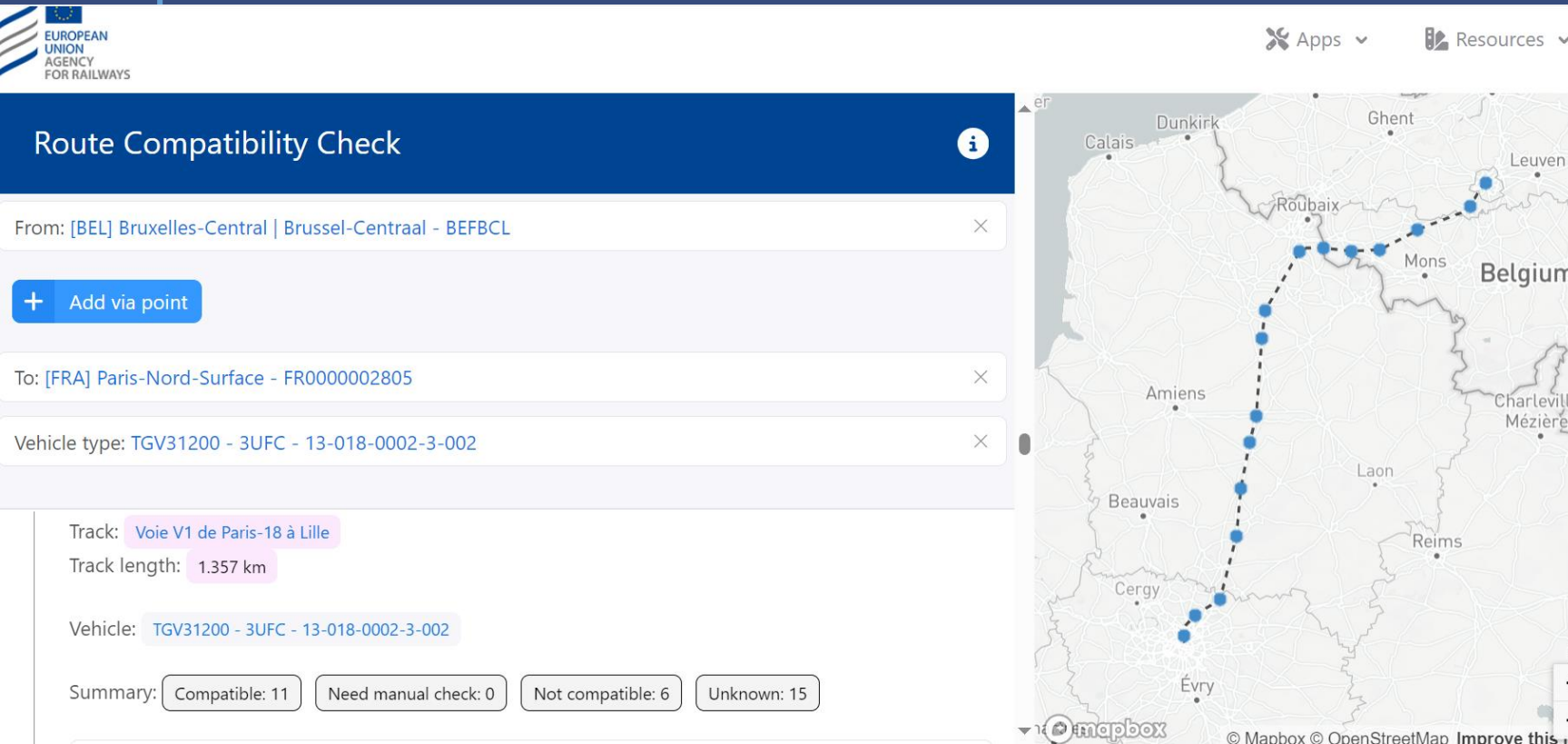
We at ÖBB are implementing an automatic smart light control prototype in our rolling stock fleet with the aim of increasing energy efficiency. The system will control the interior light in the train based on a variety of parameters, one of which is the GPS position of the vehicle.

Prior to reaching a tunnel, the interior lights should automatically be turned on. To implement this function, we would need an up-to-date database of railway tunnels in Europe.

Is there a way to export a list of all tunnels with GPS coordinates of the tunnel's end points from RINF? Unfortunately, we could only obtain the data for Austria.

Looking forward to your answer – tank you in advance.

Best regards from ÖBB

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Apps ▾    Resources ▾

## Route Compatibility Check ⓘ

From: [BEL] Bruxelles-Central | Brussel-Centraal - BEFBCL ✕

➕ Add via point

To: [FRA] Paris-Nord-Surface - FR0000002805 ✕

Vehicle type: TGV31200 - 3UFC - 13-018-0002-3-002 ✕

Track: Voie V1 de Paris-18 à Lille
Track length: 1.357 km

Vehicle: TGV31200 - 3UFC - 13-018-0002-3-002

Summary: Compatible: 11    Need manual check: 0    Not compatible: 6    Unknown: 15

© Mapbox © OpenStreetMap Improve this

## Answer with RCC powered by ERA KG

Question:
Is it possible for the vehicle type « TGV 31200-3UFC » to go from Brussels to Paris-Nord?

Vehicle Type info here:

| Attributes | Values |
|---|---|
| type | Vehicle Type |
| label | TGV31200 - 3UFC |
| Alternative name | TGV2N2 - 3UFC |
| Vehicle category | Traction Vehicles |
| Manufacturer | era:manufacturers/eratv/Alstom |
| Manufacturing country | France |
| Vehicle subcategory | Self-propelled passenger trainset (incl. railbusses) |
| Type version number | 13-018-0002-3-002 |
| Driving cabs | 2 (xsd:integer) |
| Maximum design speed | 320 (xsd:integer) |
| Nominal track gauge | 1435mm |
| Gauging | GB |
| Temperature range (maximum) | 40 (xsd:integer) |
| Temperature range (minimum) | -25 (xsd:integer) |
| Fire safety category | B |

# Demo Time

# Applications

## RINF - Register of Infrastructure

Welcome to the Register of Infrastructure (RINF) System. This platform enables the Search of information regarding the characteristics and capabilities of operational points and sections of lines that belong to the static rail network, and the Route Compatibility Check (RCC) where the objective is to check if a certain railway vehicle travel the route between two operational points. Vehicle type information is originated from the European Registry Authorized Type of Vehicle (ERATV).

User manual          Terms of use          Privacy statement          Copyright no

https://data-interop.era.europa.eu/

**Apps**
- Search Form
- Map Explorer
- Route Compatibility Check

**Resources**
- Data Stories
- Vocabulary
- Endpoint

**Management**
- Dataset Manager

**Datasets manager**

Datasets

Search

| Owner | Dataset type | Name |
|---|---|---|
| RINF IM FI | XML_FULL | 047_07... |

**Upload Files**

Dataset type: select the dataset type to begin

**Full datasets**
Full XML dataset
Full RDF dataset

**Partial datasets**
Partial RDF dataset (insert)
Partial RDF dataset (update)
Partial RDF dataset (delete)

**Railway element details**

Feature : Select

Search

**Operational Points**
VILLAVERDE-ORCASITAS
AGUJA KM 8,640
ALCORCON
SAN JOSE DE VALDERAS
CUATRO VIENTOS
LAS AGUILAS
FANJUL
ALUCHE

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Apps ∨     Resources ∨

# RINF - Register of Infrastructure

Welcome to the Register of Infrastructure (RINF) System. This platform enables the Search of information regarding the characteristics and capabilities of operational points and sections of lines that belong to the static rail network, and the Route Compatibility Check (RCC) where the objective is to check if a certain railway vehicle can travel the route between two operational points. Vehicle type information is originated from the European Registry Authorized Type of Vehicle (ERATV).

# Towards Micro Model

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# Background: Representing the multilayer approach

At macro level, all the underlying detailed elements have aggregated into elements that represent a line or corridor.

Line M — Station X — Line N

3 elements at **macro** level
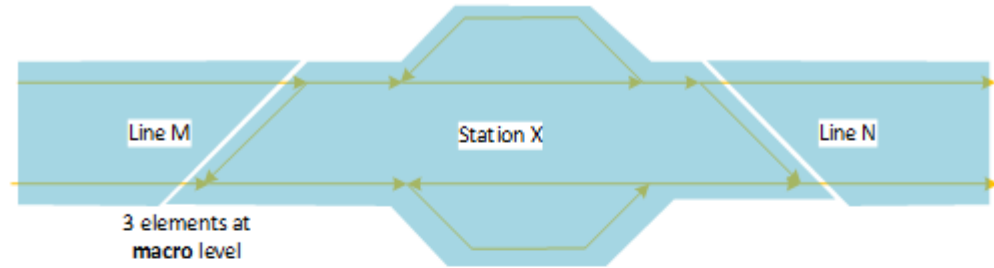
At meso level, a collection of elements aggregates into a station.

Track M1 — Station X — Track N1 / Track N2

Track M2

5 elements at **meso** level
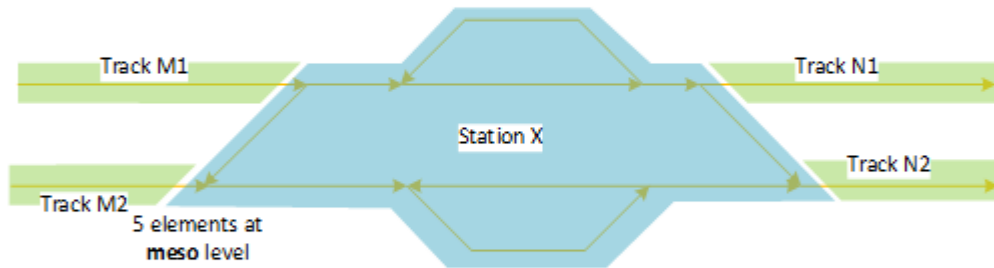
At micro level, tracks in station and sidings are revealed.

SDT1

Track M1 — STM1 — STT1 — STN1 — Track N1

CROM — STT2 — CRON

Track M2 — STM2 — SDT2 — STN2 — Track N2

14 elements at **micro** level
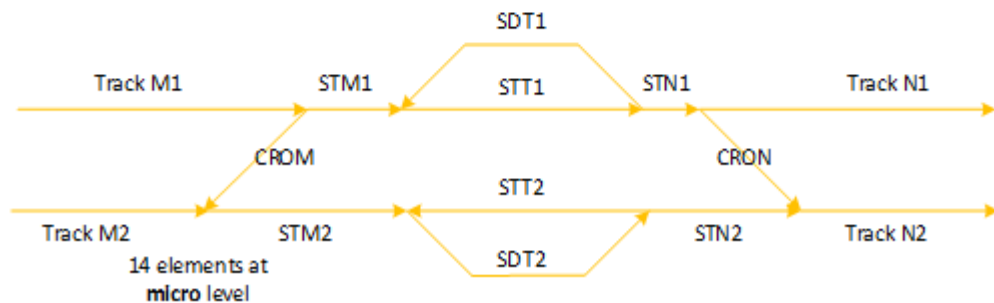
| Level | Scale | Description |
|---|---|---|
| **Corridor** | Very Small | Primary routes within a network, e.g. rail freight corridor |
| **Macroscopic** | Small | A generalized view of the mesoscopic level, e.g., multiple tracks within a line appear as a single line |
| **Mesoscopic** | Intermediate | A generalized view of the microscopic level |
| **Microscopic** | Large | Track level information at the highest level of details |

A network of two tracks and crossings represented from top to bottom
RSM (rsm-evolution.org)

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**Use cases covered**:

➢ Route book data compilation
➢ Tracks connectivity and navigability
➢ Better geographical representation
➢ Telematics locations data integration
➢ Future planning for infrastructure

Interoperable-data/ERA-Ontology-3.1.0: Extended version of the ERA Railway Infrastructure Ontology (github.com)
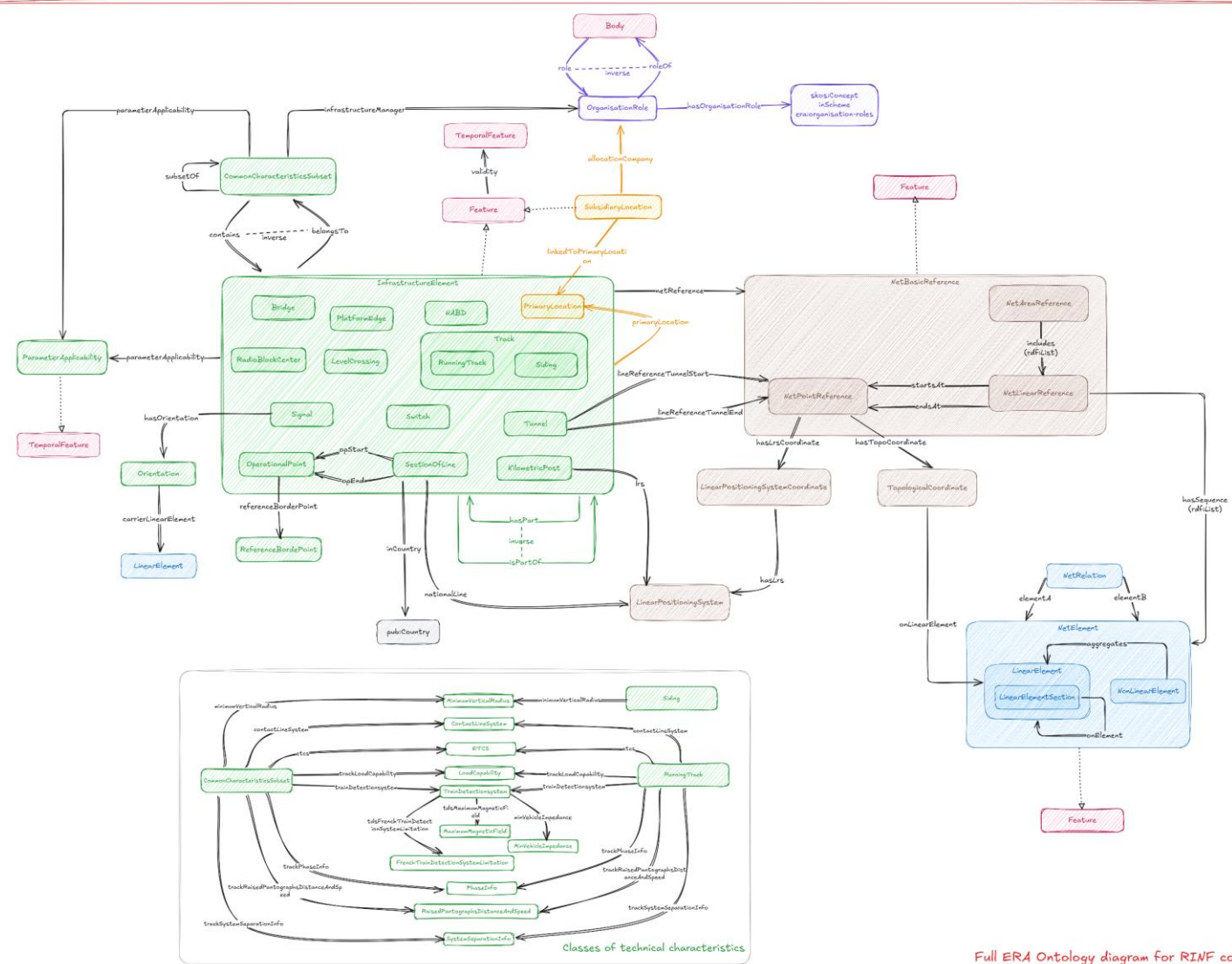


Full ERA Ontology diagram for RINF concepts

Legend

GeoSPARQL
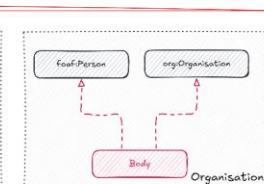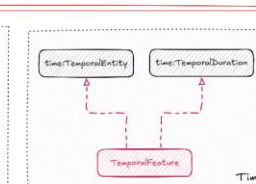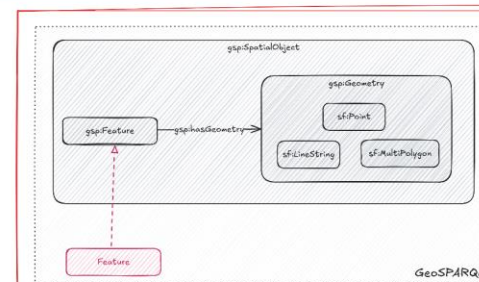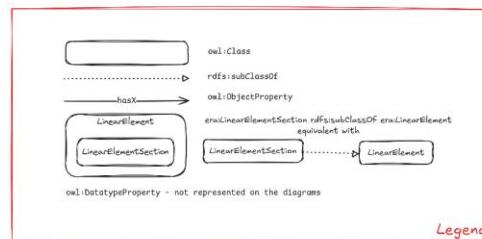
Use of external ontologies

# Challenges

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# The Challenges

- As a regulatory body our data exchange rules have an impact in the regulatory reporting actors
- Multi-lingual aspect of the ontology, due to technical terms (EU languages)
- Coexistence of data compliant with different regulatory texts.
- **Scalability issue with SHACL rules** in data provision of small updates
- Building rich application functionalities on top of KG
- Ontology alignment with other railway/transport standards

# The Challenges - Social

- General public today still reads linked data and KG as open data
- Effort explaining a KG can host "close" data, confidential information
- Initially our own limited in-depth knowledge of deploying semantics at scale (need for training, need to establish <u>bridges</u> between problems and solutions)

- Majority of our IT colleagues demonstrate **resistance to change**. Reluctancy to adopt new techniques beyond their comfort zone. Much easier to convince middle management than to encourage IT colleagues to migrate to LD.

- As a regulatory body our data exchange rules have an impact in the regulatory reporting actors and they are also reluctant to changes in their pipeline

# The Challenges – Technical (1/2)

- The heavy burden of <u>backwards compatibility</u> requirement

- Coexistence of hybrid data provisions:
    - o Data providers still uploading a full huge XML with their full railway network descriptions
    - o Differential data upload only for small changes in RDF
    - o Complicated hybrid validation engine that needs to be sync

- SHACL validation engines .. Low performant .. Necessary to run the complete graph for small change

- A fine-grained Access control model for Knowledge Graphs
    An <u>engineering</u> problem .. but still a <u>problem</u> for the deployment of KG in production

# The Challenges – Technical (2/2)

- In a Law as code scenario regulation is updated every two years
- Lack of a framework to pipeline changes in the ontology smoothly - and in a semi-automatic manner - into the different semantic artifacts. (mappings, shacl rules, embedded queries in the app layer)
- Possibility to reuse software components currently developed for Relational data base models
- Reusing semweb user interfaces for "Share-Point" tools
- Inferences automation with SHACL rules

Future Work

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# Common Ontology supporting interoperability between systems

# Ontology Governance
## Who?

**ERA team dedicated to the ERA Ontology work (Core Team) exchanging with ERA team dedicated to TSIs (Control Group) to submit to the CCM Board for approval.**

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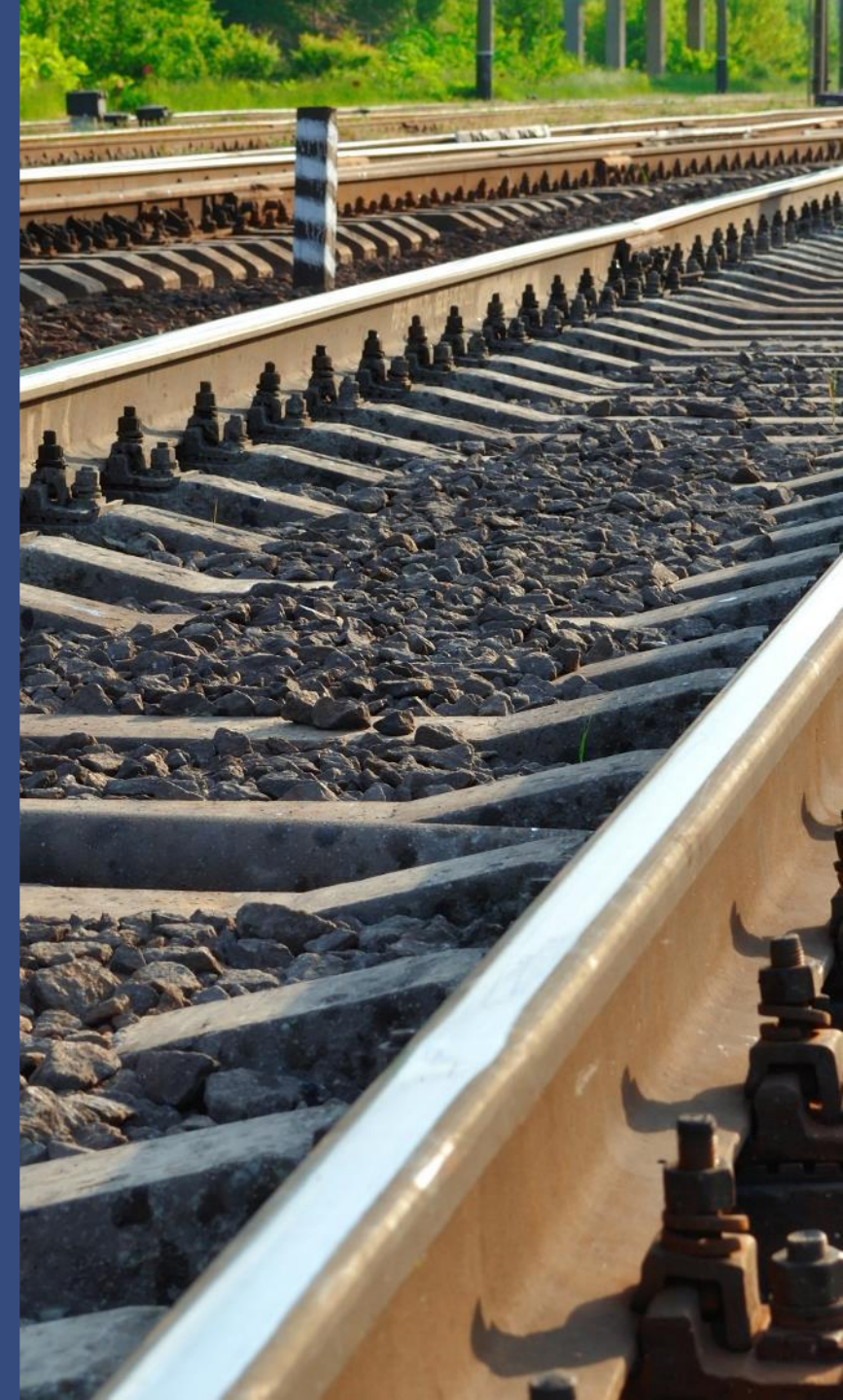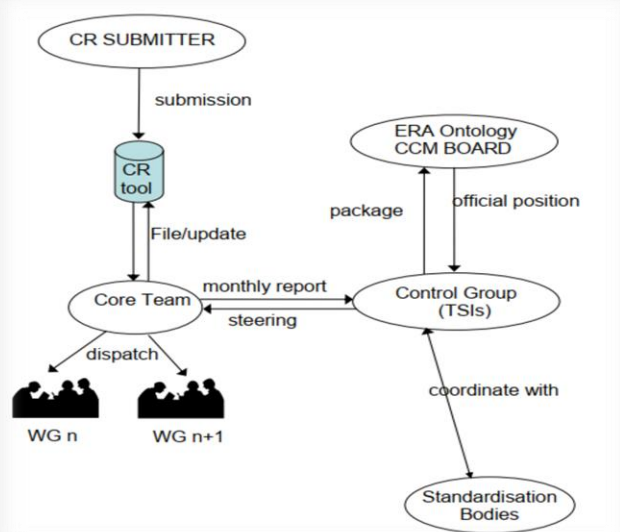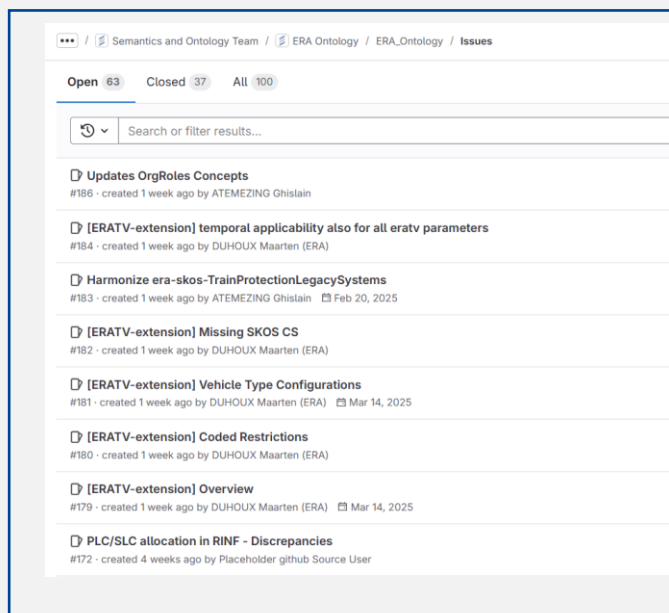
# TIMELINE RINF
## 2024-2025

**Finalising the implementation of Commission Implementing Regulation (EU) 2023/1694,** with the view to issue an ERA Recommendation to address the finding of the TWGs meetings workstream.

**ERA Recommendation in draft.** Points added:
- Update of ERA Ontology reference.
- Capture the work on Network Statement
- Proposal to work on RINF Documents digitalization.

**Q1 2025**

**ERA Recommendation issued.** Points added:
- TEN-T related parameters added, and TEN GIS ID removed.
- Capture the work on Rail Facilities Portal.
- **Alignment with TSIs revision:** Parameters revision for Communication during emergency as per CS14 in TSI revision

**Q2 2025**

**Milestone on data provision progress.** IMs' feedback on implementation.

**Q4 2025**

**ERA Ontology v.3.1.0 published.** Migration to next version will reflect the final draft of the AG.

**Final version of RINF Application Guide is ready.**

**RINF application updated in UAT.**

**Dec. 2024**

**RINF Application Guide published.**

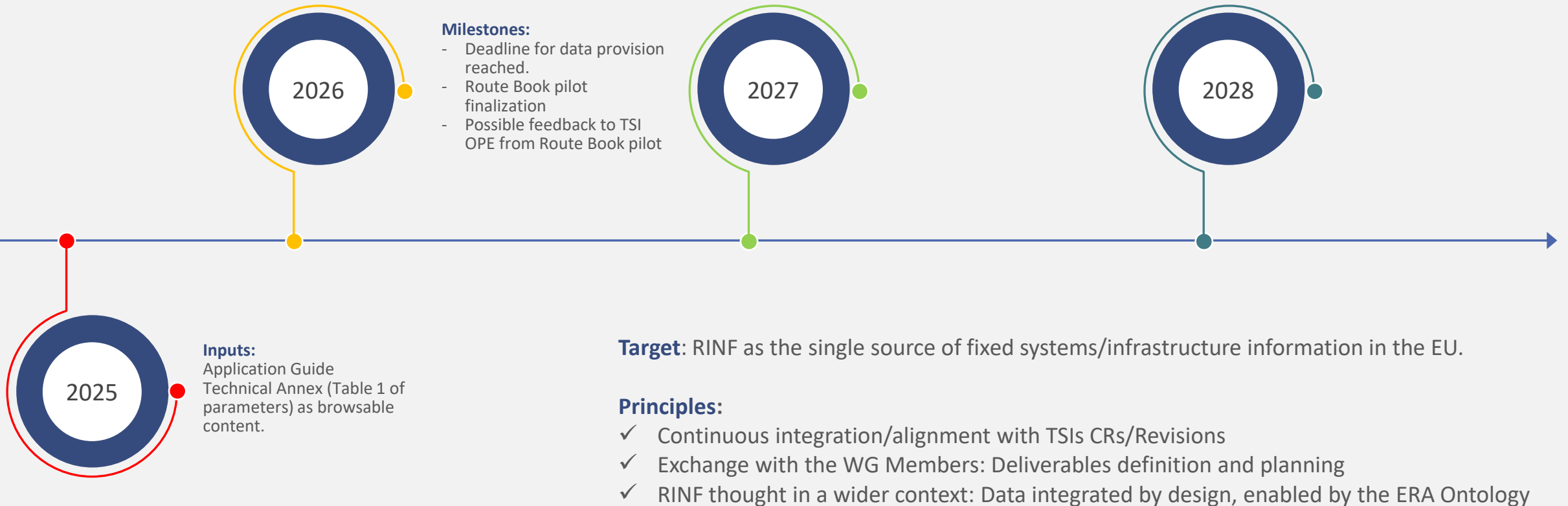**RINF Application data provision updated** in accordance with the new data provision set out in the new RINF Application Guide.

**Jan-Mar. 2025**

**Route book** pilot kick-off.

**Q3 2025**

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# TIMELINE – ERA KG
## 2026-2028

**2026**

**Milestones:**
- Deadline for data provision reached.
- Route Book pilot finalization
- Possible feedback to TSI OPE from Route Book pilot

**2027**

**2028**

**2025**

**Inputs:**
Application Guide
Technical Annex (Table 1 of parameters) as browsable content.

**Target**: RINF as the single source of fixed systems/infrastructure information in the EU.

**Principles:**
- ✓ Continuous integration/alignment with TSIs CRs/Revisions
- ✓ Exchange with the WG Members: Deliverables definition and planning
- ✓ RINF thought in a wider context: Data integrated by design, enabled by the ERA Ontology

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# Take Away Message

| | |
|---|---|
| Use of Open Software | ✓ |
| Use of W3C and open standards | |
| Agnostic to different formats  XML schemas | ✓ |
| Aligned with other existing ontologies | ✓ |
| Aligned with existing models (UMLs, XSD, etc.) | |
| New questions to the knowledge graph formulated on demand | ✓ |
| Backwards compatible with previous (in house) developments | ✓ |
| Data more relevant than the application layer Easily extendable with other sources RINF and ERATV (partially) available as 4-star Linked Data | ✓ |

- Railway infrastructure managers provide data in RDF for usage.
- ERA collects, publishes and maintains railway infrastructure using (open) semantic web technologies.
- Public Endpoint: https://prod.virtuoso.ecdp.tech.ec.europa.eu/sparql

# Rail Data Forum 2025
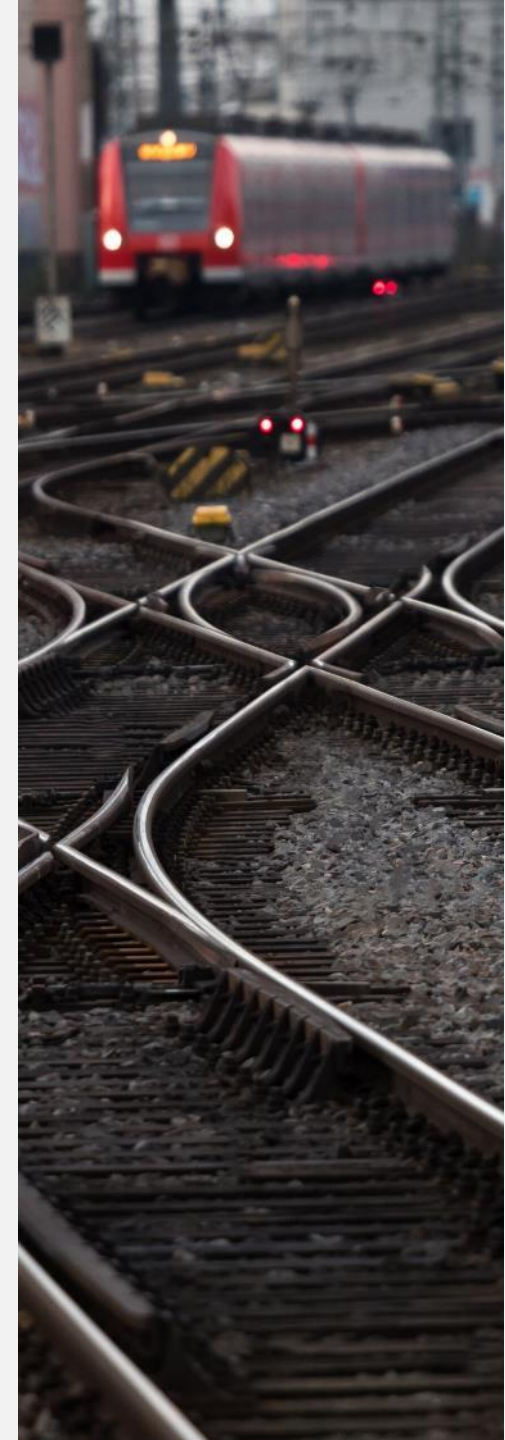
# THANK YOU

Moving Europe towards a sustainable and safe railway system without frontiers.

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