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European Rail Network and Mobility Management

Deliverable D27.1
Data model and format for a harmonised EU planning of railway assets, starting from CCS+

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1. Executive Summary

The present document examines how a harmonized set of data can be used to realize the idea of SERA and a Single European Railway Traffic Management system.
This vision is based on the concept that a common data model can be used in the supply chain, regardless of the specific domain. The System Pillar CCS-TMS Data Model is a first instance of a common model fully dedicated to CCS-TMS engineering and operations. The potential utilization of such data in other domains besides signalling, such as diagnostics, maintenance, and so forth, is analysed through the presentation of a set of business cases. The business cases allow us to identify key data requirements for the WP27 digital planning toolbox and other applications.
The content of this deliverable (D27.1) will be used as input for the task 27.2 to guide the extraction of selected objects from the data sources identified. The extracted objects can be used by both the toolbox and other railway applications as a result of FP1 and other FP interactions and collaborations.

2. Abbreviations and acronyms

The proposed definitions were mainly collected following:

- The System Pillar orientation for a shared glossary across SP, MOTIONAL and other FPs
- Recent Shift2Rail projects (LinX4Rail, X2Rail, OPTIMA, etc.)
- The web

Abbreviation / Acronym	Description
ATO	Automatic Train Operation
BIM	Building Information Modelling
CENELEC	(Comité Européen de Normalisation Électrotechnique , European Committee for Electrotechnical Standardization)
CCS+	Control, Command and Signalling
CCS-TMS	Control, Command and Signalling- Traffic Management System (used to refer to the current version of the data model under the system pillar Transversal CCS domain.
CDM	Conceptual Data Model
CFD	Computational Fluid Dynamics
DT	Digital Twin
ERA	European Railway Association
ERJU	Europe's Rail Joint Undertaking
ERTMS-	European Rail Traffic Management System
ETCS	European Train Control System
ETCS Level 2	ETCS Level 2 is a radio-based system which displays signalling and movement authorities in the cab.
FDS	Federated data space
FP	Flagship Project
FP1-TT	Flagship project 1 (MOTIONAL) work packages 26- 32
IM	Infrastructure Manager
IFC	Industry Foundation Classes
IPCC	Intergovernmental Panel on Climate Change
LIDAR	Laser Imaging Detection and Ranging
LOD	Level of Detail
MAWP	Multi Annual Work Program
RCA	Reference CCS architecture
RU	Railway Undertaking
ScanMed	Scandinavian-Mediterranean corridor
SERA	Single European Railway Area
SGx	Subgroup of MOTIONAL project
TCCS	Transversal CCS (Sub Domain 1)
TE	Technical Enabler
TEN	Trans-European Transport Network
TMS	Traffic Management System
TSI	Technical Specifications for Interoperability

TT	Transversal Topics
UAV	Unmanned Aerial Vehicle
UC	Use Case
WP	Work Package
WS#	Workstream

This section includes a glossary to define some key concepts used in Task 27.1 and that could be also used across SP, MOTIONAL and other FPs.

Concept	**Description**
Building Information Modelling	AS PRODUCT: A digital model of a building containing various information needed at the stage of design, implementation and operation of a building (roads, engineering structures, architecture, structures, installations, equipment) which is a digital presentation of the physical and functional features of the building. AS PROCESS: Creating, editing, and using information about a building object during design, construction, operation, and other phases in the object life cycle. AS DATA DEFINITION: Managing the investment process by using the parameters of a digital model of a building object to obtain and exchange information about assets.
Cloud Point	A set of data points in a three-dimensional coordinate system, typically obtained through 3D laser scanning or other surveying methods.
Common data format	A common data format is a standardized or widely accepted structure for representing and storing data. It serves as a common framework that enables different applications, systems, or platforms to deliver, convey, or consume data. The purpose of a common data format is to establish a consistent and interoperable way of encoding data so that it can be easily parsed and processed by various stakeholders and software components. Examples of common data formats: • CSV (Comma-Separated Values): A plain text format where data values are separated by commas. It is commonly used for tabular data and can be easily opened and processed in spreadsheet applications. • XML, or eXtensible Markup Language, is a standardized markup language designed to store and transport data in a format that is both human-readable and machine-readable. XML uses a set of rules to encode documents in a format that is both structured and customizable. • JSON (JavaScript Object Notation): A lightweight data interchange format that is easy for both humans and

	machines to read and write. It is commonly used for web APIs and data serialization.
Conceptual Data Model (CDM)	Within MOTIONAL, the Conceptual Data Model (CDM) is an open, federated, and layered model of the railway system. The CDM was first established under Shift2Rail, and further developed under WP30. The LINX4RAIL and LINX4RAIL-2 projects have initiated the definition of a Conceptual Data Model offering a project-independent railway system model with rich semantics based on a federation of UML source models.
Data model	A data model is a conceptual representation or blueprint that defines the structure, relationships, constraints, and semantics of data in a specific domain. Wikipedia Definition: "A data model is an abstract model that organizes elements of data and standardizes how they relate to one another and to the properties of real-world entities. For instance, a data model may specify that the data element representing a car be composed of many other elements which, in turn, represent the colour and size of the car and define its owner."
Digital Twin	A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity. Definition extracted from Digital Twin Consortium. A simple digitalisation of an asset does not represent a digital twin but only a part of it. The most important application of a Digital Twin is to make virtual simulations of real-world behaviours under different scenarios.
Domain Data	Domain Data (as defined in TCCS CCS-TMS - Scope and Approach for Collaboration and Specification) is a use-case-specific representation of information following the specific needs of affected systems and their functionalities implementing the use case. Domain data are a tailored and potentially transformed subset of Engineering Data.
Engineering Data	The Engineering Data (as defined in TCCS CCS-TMS - Scope and Approach for Collaboration and Specification) contains all the base data (i.e., track topology, track geometry, track asset configuration) for compiling the next version(s) of use case-specific Domain Data. The standardized Engineering Data covers generic aspects only without specific additions of infrastructure managers or suppliers (e.g. for migration reasons).
ERTMS	ERTMS encompasses a broader scope. It includes not only the train protection aspect (ETCS) but also the traffic management and infrastructure control components. ERTMS aims to harmonize and standardize the entire railway signalling and control system across Europe for interoperability.
ETCS	The European Train Control System (ETCS) is a train

	protection system designed to replace the many incompatible systems used by European railways, and railways outside of Europe. ETCS is the signalling and control component of the European Rail Traffic Management System (ERTMS). ETCS consists of 2 major parts: • trackside equipment • on-board (on train) equipment ETCS allows all trackside information to be passed to the driver cab, removing the need for trackside signals. One of the key safety features of the European Train Control System (ETCS) is its ability to enforce speed limits and apply brakes if a train exceeds the authorized speed. The ETCS system continuously monitors the train's speed and compares it to the permitted speed for the specific section of track. If the train surpasses the authorized speed, the ETCS will initiate a series of interventions to bring the train back within the acceptable speed range.
Object Extraction	This is a semi-automatic procedure that involves the processing of a collection of digital data, such as images, point cloud, and other similar data, with the objective of identifying specific assets such as track, switch, bridge, and other similar assets, and determining their specific characteristics such as length, location, relationships with other assets, type, and so forth. Any asset identified and related characteristics will be stored in digital and machine-readable format for further use.
Toolbox	As part of WP27, the toolbox refers to a collection of software applications, equipment, techniques, and resources that the signalling engineers can use to perform the CCS-TMS planning.
Track Edge	Track edge is a linear object (part of CCS-TMS Data Model) that defines an uninterrupted stretch of a railway track without divergence or convergence. A track edge is defined along the centre line of the 2D or 3D track alignment and has a finite length. A track edge is associated with track edge links to determine navigability between track edges.

3. Background

Within the MOTIONAL project, WS 2 "Digital Enablers" focuses on delivering essential new digitalisation capabilities to RUs, IMs and Rail Industry companies. WS2.3 Digital Assets Engineering has the aim to deliver Digital Assets and Engineering methodology and toolbox to support the digitalisation of the end-to-end design, development, delivery, operation and maintenance process of rail systems and components ("digital continuity").
In general, for an infrastructure asset manager a complete process encompasses at least six phases of the asset life cycle, which include:

- Planning
- Design
- Construction
- Commissioning
- Operation & Maintenance
- Disposal

Although it would be a significant undertaking to implement a uniform toolbox across all phases, it has been demonstrated in WP27 that the data objects utilized at the asset level are uniform. Despite WP27's primary focus on the planning of railway assets starting from CCS+, a diverse set of data objects are utilized in multiple phases (refer to *Figure **1***), not only within the signalling domain (such as design and maintenance) but also outside the signalling domain, such as for track maintenance.

Figure 1: Illustration of the multiple phases of the asset life cycle

The toolbox enables the collaborative creation of digital designs and specification of systems and components as an enduring, authoritative shared source of truth, moving the primary means of communication across the engineering community, between end-users and suppliers, and with regulation authorities, from paper to shared formal digital models (Enabler 30).
Designing and implementing the toolbox is a part of the 27th Work Package. The present document constitutes, within WP27, the D27.1 "Data model and format for a harmonised EU planning of railway assets, starting from CCS+" in the framework of the Flagship Project "MOTIONAL" as described in the EU-RAIL MAWP.

4. Objective/Aim

4.1. WP27 Overview

This document has been prepared to specify a set of objects and input data, starting from CCS+ assets, to enable the digitalization of planning, engineering, maintenance, and operational processes of the digital Rail System. The document is the first deliverable of the Work Package 27 "Digital Assets Engineering part" of the MOTIONAL project.

WP27 aims to digitize and automate the whole planning phases to ease engineering work, reduce costs of development and testing, and reduce time to deployment. It is anticipated that errors in design can also be minimized. The ability to conduct comprehensive simulations and testing prior to the building phases and in diverse scenarios will make this feasible, and the simulation outcomes will be incorporated into an information model which is shared with the other actors along the supply chain.

The WP 27 is based on the outcome of past and current initiatives that are trying to harmonise the different data models in place, namely, EULYNX (RCA Model), the data model produced by LinX4Rail project and EU-RAIL System Pillar as well as ongoing work part of WP 30 (MOTIONAL Project).

Other initiatives such as OTL Spoor/Rail OTL (Object Type Library) at Prorail (Netherlands) are ongoing in Europe to address similar problems but these have not been considered in this work mainly because they are driven by the need of a specific railway organisation (national rules).

WP27 is composed of 6 tasks covering:

Task	Name	Main Work (Sub-Tasks)
27.1	Harmonised input data builds the "Single Source of Truth"	• Analysis of Input Data & Digital Twin Approach. • Business Case studies for the planning, engineering, maintenance, and operation process. • Attributes Specification required by Users.
27.2	Deep Learning for Object Extraction	• Access to the available data. • Object Extraction Software Development. • Change Detection and Update of Data.
27.3	Efficient and coherent processing of data during the engineering process (digital continuity)	• Start from relevant data extracted from available data model. • Set a standard format and apply harmonised engineering rules. • Asset Information Requirements (AIR) during the production process.
27.4	Planning result testing and optimizing, considering BIM and co-simulation up to automated testing	• Use the planning results for more efficient system integration. • Develop and test use cases on a railway station project. • Plan according to the findings, process and tooling of the WP five reference implementation projects.
27.5	Demonstration of the Process using industrialised tools	• Evaluate the possibilities to implement the EULYNX data model for the control, command and signalling system. • Develop a data platform for object and information management.
27.6	Develop guidelines and standards for acquiring, updating, and developing BIM/AIM data and models for developing and maintaining Digital Twins	• Definition of information requirements in a human and machine-readable manner. • Development of methods and standards for updating the Digital Twins for management purposes. • Combining construction data acquired by different methods, from various sources and in different formats with DT.

The primary objective of Task 27.1 is to conduct an analysis of input data for the purposes of planning, engineering, maintenance, and operation procedures. The analysis is conducted starting from CCS+ and its EULYNX Data Model, and subsequently acquiring a set of business cases spanning the entire life cycle of railway infrastructure assets. The obtained selection of objects across the different business cases can be used to implement and prioritize the digitalization of assets to be executed using data by monitoring surveys of railway network infrastructures.

When the extracted data are exchanged with a common data model, this enables:

- Interoperability among different systems using such data.
- Take advantage of new data applications (e.g., Simulation, Artificial Intelligence, etc.) to extract new value.

In the context of BIM, industry-standard formats such as IFC are commonly used. If not IFC, other formats like DWG, PDF, etc., are employed. Unfortunately, these data formats are not based on a common data model, so a harmonisation process (part of the work of FP1 WP30) is required.

To identify and specify a set of objects to be extracted and exchanged using a common data model, Task 27.1 centred on generating a set of business cases (ref. 5.5. for more information about Business Case, Use Case and EPIC).

4.2. The WP27 workflow

WP 27 is contextualized at the commencement of the signalling asset life cycle, when, for instance, the ERTMS installation must be planned. In *Figure **2***, a schematic representation of the various components that are integral to the WP27's objective of standardizing digital planning is depicted. One of the key requirements of the workflow is that the CCS Objects required by the ERTMS design and extracted from the digital data be modelled in the selected Standard Data Model. In this task, the Transversal CCS Sub Domain 1 (CCS-TMS) of the ERJU System Pillar used as "Standard Data Model" indicated in the *Figure **2*** below. As far as the data are modelled according to the CCS-TMS, any format can be adopted for data exchange, simple conversions of formats increase interoperability of any data with multiple systems.

The steps illustrated in *Figure **2*** are described below:

- **Site Survey**: This is the starting process of the WP27 workflow. Using existing technologies a scan of the track infrastructure is executed by backpack, train, drone or plane/helicopter and Point Cloud data are generated that can be used to extract the required objects.
- **Object Extraction**: In this phase Point Cloud data and other survey outcomes (e.g. 360° video) are merged and post-processed with Artificial Intelligence Algorithms (e.g. Deep Learning) to extract the objects required. This phase can also include the formatting of the extracted objects in the Standard Data Model.
- **Result Validation**: To ensure that the extracted objects meet the accuracy levels of the final users, a validation phase is required using a set of engineering rules. The data does not conform with the validation guidelines will be rejected.
- **Formatted CCS Data**: At this stage in the process, the validated data are delivered to the engineers. The engineers use the data in addition to other information provided (e.g. timetable, demand analysis, infrastructure capacity) to design CCS assets in the area of

interest. The results are then passed down to the component developer who produces and maintains the assets.

- **Digital Twin Environment Update**: Using the previous design result, the assets are developed, built, installed and commissioned. The operation and maintenance of the assets starts after commissioning, where the data engineered plays a vital role in digital twin monitoring of the assets.

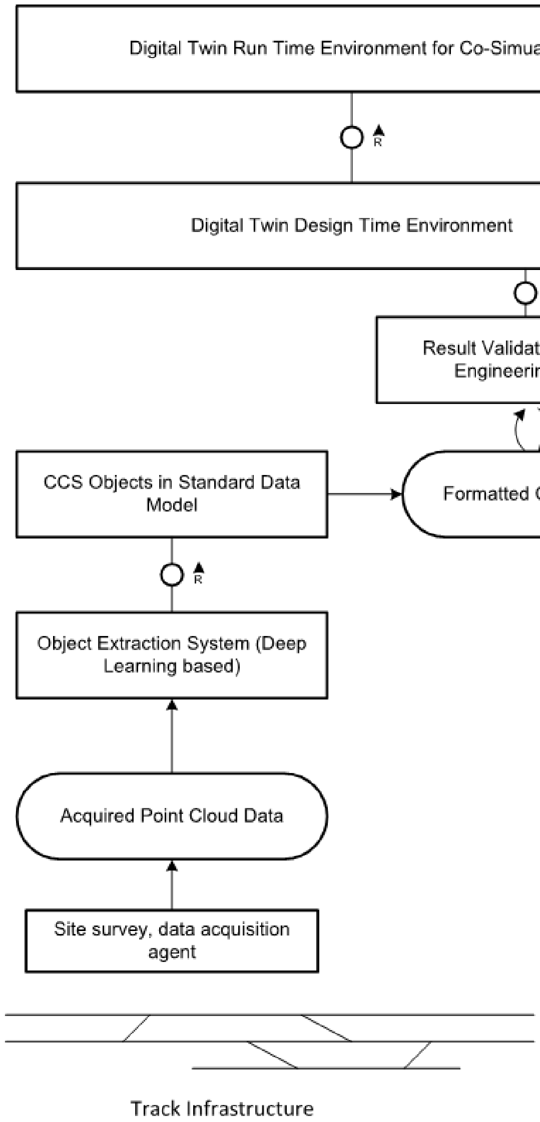

Figure 2: WP27 Workflow

4.3. Task 27.1 Work Description

The results described in this document are the result of the following activities:

Activity	Description
Analysis of input data for construction projects, starting from CCS+ and its EULYNX Data model.	The analysis of the CCS+ and EULYNX Data model entities is considered as input to drive the selection of the data objects to be considered. In particular, the Transversal CCS Sub Domain 1 (CCS-TMS) of the ERJU System Pillar is used. The CCS-TMS Data Model is focusing on the first layers (topology, geometry) and shall demonstrate the CCS-TMS approach practically because the first layers are used by almost any track related application. The evaluation of EULYNX DP has been done in the scope of CCS-TMS and some inputs have been already included in CCS-TMS. The usage of the CCS-TMS by this Work Package is a further evaluation of EULYNX Data model.
Analysis of Digital Twin approach along the production process to operational phase based on BIM.	The Digital Twin approach along with a BIM based process is analysed starting from completed and ongoing projects involving European railways. These mainly include: • Rail Innovation Hub (BIM initiative in Spain) • IFC Rail Because most of the BIM initiatives are considering IFC Rail and as part of FP1 WP30, the interface between the CDM and other data models is analysed. For this deliverable, it was decided to focus only on the Transversal CCS Subdomain Model. Station buildings are considered through the use of the IFC model being already part of the common practices within the railway sector. Development of Digital Twin in WP28/29 will provide all Destinations with common tooling for virtual replicas of cyber-physical assets. This tooling should be using data that can be extracted with the practices developed within WP27.
Use cases for data models, common data format for the planning, engineering, maintenance, and operation process.	The data model to be considered for this work package should satisfy different requirements such as. • Stakeholder's requirements • Application's requirements • Other asset life cycle phases (e.g. operation) requirements A set of business cases have been specified thanks to the participants contributing to both WP27 and WP26. These business cases can evolve in use cases, as part of D27.1 the main aim is to identify at least the objects, used by the use cases, already specified in the CCS-TMS Data Model "common engineering core".
Specification of the attributes required by the Digital Twins by users involved in design, construction, and maintenance.	From the use cases specified by the contributors a set of common attributes required for the implementation of the prospect use case are specified and cross checked with the attributes already foreseen in the CCS-TMS Data Model. For the purpose of Task 27.2, providing the first layers (e.g. Topology, Geometry) data of the CCS-TMS Data Model attributes is sufficient. Adding objects and attributes from other layers for Digital Twin

	related applications would be out of scope for WP 27, however any stakeholder can use any object from other layers as far as they are associated to objects of the first layer.
The specification must be per mode of acquisition (e.g. drone, train, etc.), speed of acquisition, number of points minimum track length.	Track objects can be identified by different acquisition devices. Station objects require specific types of acquisition devices such as backpacks or drones. For the purpose of Task 27.2, the following acquisition devices are considered: • Aerial Surveying - UAV LIDAR • Track Vehicle Surveying

5. Introduction

5.1. Business Need

To operate any railway, different data ranging from infrastructure to rolling stock, from technical to commercial, from engineering to operational domains, and so on are required. The systematic and widespread adoption of Digital Twins across the Rail System requires any stakeholder to exchange comprehensive, complete and consistent data through the entire supply chain. The basis for comprehensive data exchange is the specification of a common data model (such as the EULYNX data model). The common data model is essential for various process steps; it can be used for:

- **Referencing common names** to the asset data (objects and related attributes) across national boundaries, different companies, different systems, and various phases of the asset life cycle from design to decommissioning. When the asset is mapped with the same object, this enables the elimination of the need of agreeing on how to access to an instance of such object for a specific use. The implementation of a common name has a significant impact on the time required to access the data. Furthermore, the required data can be referred to and utilized for multiple purposes with a known name, regardless of its usage. The common terminology can be derived from the data model itself (e.g. CCS-TMS) and all the harmonization tasks executed by System and Innovation Pillar (e.g. Common Data Model part of WP30).
- **Standardizing the data management process**: in terms of creation , update, data transformation, etc. This facilitates the optimization of data storage and associated interfaces for data exchange, primarily affecting the cost of accessing the information.
- **Promote data use and re-use**: using a common data model facilitates the usage of the same data.

Today, common data models are rarely adopted in the railway industry. Different stakeholders as well as different organizational units within the same stakeholder use the same data (e.g. track speed) according to different models. In general, there is one model for each use of data (like planning, signalling, maintenance, and checking things) or one model for each person involved in the supply chain (like one for managing the infrastructure and one for hiring contractors)

One actor in the supply chain traditionally provides information (structured according to a model, namely the source model) using drawings, documents, spreadsheets and other files in custom formats. Another actor in the supply chain interested in accessing the information is required to extract, transform, and load the data into their tool chain and generate a new instance of the same information (structured according to a different model, namely destination model). In general, any actor interested in using the information painstakingly collects, analyses, interprets, and filters such data. The repeated process of information exchange is both inefficient and ineffective, costly and prone to human error.

For example, for the building and configuring a signalling system of a yard, IMs traditionally provide plans, text, and tables. The suppliers of signalling equipment copy the information into their tool chain, carry out the signalling work and return the as-built information to the IM. Skilled signalling engineers of the suppliers painstakingly collect, interpret and filter entries in all sorts of files and plans. The repeated process of information exchange is wasteful, especially because of costly error correction loops.

Currently, the transition towards the digital twin approach is influenced by a similar, repeated process of information exchange, as well as the numerous and unstructured data that are stored and not yet fully utilized. There are several reasons for this misuse, such as

- The lack of connections between disparate data sources.
- The absence of effective tools for extracting and updating data.
- The storage of information in a proprietary data format that restricts alteration and usage

These inconveniences have a negative impact on the rail system, such as:

- Difficulty to correlate and to control data quality.
- Individuals expend considerable amounts of time and effort to extract and modify the data.
- Manage multiple instances of the same data (data redundancy)

Any tool to automatically extract and update the data shared with Federated Data Spaces is expected to:

- Promote re-use and correlation of the different data.
- Reduce the amount of work that needs to be done manually.
- Improve the distribution of the data.

It is imperative to consider that the track and certain crucial components, such as balises, are identical across all nations, irrespective of the IM and suppliers. Furthermore, they are tagged with geo-location data, thereby allowing for at least a basic level of information to be considered a component of a common data model and utilized to enhance the railway system processes. Moreover, several railway infrastructure components are already digitalized (stored and not still fully used), so there is room for creating digital and machine-readable data instances for such models.

Unfortunately, even if an object is digitalized, there could be some attributes or relationships that can change from one country to another, these could require an extension of the common data model considered.

5.2. Data Quality

Manual data flows need careful review and validation, but automated data flows should use automatic procedures to make sure the data are as good as if they were done manually.

Managing data quality in an automated process is crucial for ensuring the reliability and accuracy of the data being processed. Here are some key practices to address data quality that should be considered in the proposed automated data flow.

- **Data Validation and Cleansing**: Implement robust data validation checks at various stages of the automated process to ensure that incoming data meets predefined data model's requirements (e.g. CCS-TMS model requirements). Cleanse and standardize data by removing duplicates, correcting errors, and formatting data consistently. A validation tool will be developed by the ERJU and used within WP27.
- **Exception Handling:** Implement mechanisms to handle exceptions when the validation tool encounters data that does not meet the expected criteria.
- **Metadata Management**: Maintain comprehensive metadata that describes the characteristics and quality of the data. This metadata can include information about data sources, transformations, and applied business rules.
- **Data Governance:** Define and enforce data governance policies to ensure that data quality standards are consistently applied across the organization. This includes roles and responsibilities for data stewards and data custodians.
- **User Feedback and Collaboration:** Encourage collaboration between data producers and consumers. Solicit feedback from end-users to identify potential issues and improve the data quality process.
- **Audit Trails and Logging:** Maintain detailed audit trails and logs that capture information about data processing activities. These logs can be valuable for troubleshooting and identifying the root cause of data quality issues.
- **Data Quality Metrics:** Define key performance indicators (KPIs) and metrics to measure and monitor data quality. Regularly assess these metrics to ensure that the automated processes are meeting predefined standards.
- **Data Quality Dashboards:** Create dashboards that provide real-time insights into data quality metrics. This allows stakeholders to easily monitor the health of the automated processes and take corrective actions as needed.

By incorporating these and other practices into automated processes, railways can proactively manage and improve data quality, ensuring that the data used for decision-making is accurate, reliable, and aligned with business objectives.

5.3. Data & Process Enablers

Traditional and new railway infrastructure survey methods can acquire a big quantity and a vast variety of data. The volume of such data reaches several gigabytes per kilometre and ultimately reaches a staggering amount of data, amounting to several petabytes, for the storage of numerous survey campaigns. Furthermore, due to the possibility of railway infrastructure alteration, the data obtained during a survey may be rendered obsolete in the event of any alterations. This leads to a scenario where to detect any change; you need to survey at least with a frequency aligned with the changes on track you intend to detect.

Tools such as the federated dataspace (being investigated as part of FP1 WP31), which facilitates the utilization of digital replicas of physical assets, necessitate the acquisition of digital data and associated processes. In WP27, the enabler 30 is about the development of methodology supported by toolbox for digital assets engineering. The methodology must cover a process to create the digital replica from the collected data. The methodology is characterized by 4 key phases:

1. Identification and specification of the assets (to be extracted).
2. Data Acquisition
3. Assets Extraction
4. Verification and validation of the assets

Most of the railway assets are digitalized today from point clouds. A point cloud is a set of georeferenced 3D points obtained by LIDAR capture (*Figure **3***), representing a digitized area. This solution acquires a million points per second and guarantees a high density throughout the region surveyed.

A point cloud offers numerous advantages over conventional geometric data obtained through topographic surveys, including the ability to move freely within the infrastructure, enlarge a portion for more precise analysis, conduct measurements on the three axes (x, y, z) and furnish crucial information regarding the actual state of the infrastructure.

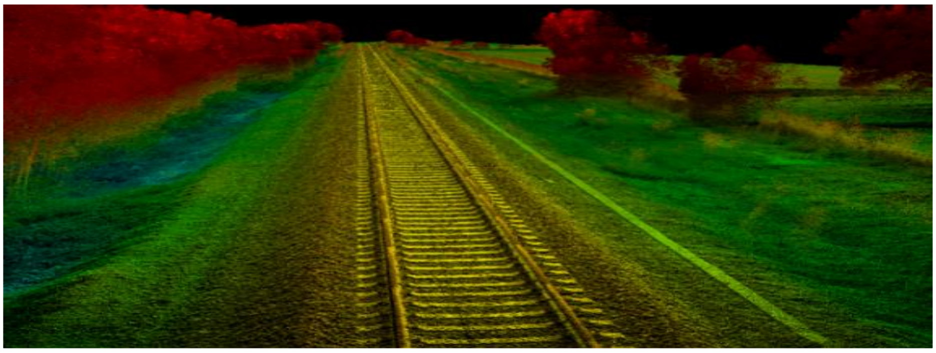

Figure 3: Cloud Point obtained by LIDAR.

For railway asset digitalisation LIDAR surveys can be performed via:

- **Train:** The LIDAR system allows a rapid topographic survey of the railway network with a measurement range which extends itself transversely up about 30 meters (at each side, 60 meters in total) from the acquisition track.
- **Plane/Helicopter/Drone:** The aerial survey is to be considered optional, as it adds to the information already made available by the train survey, to provide a complete view of the territorial context characteristic of the railway corridor. The survey area of interest extends up to about 500 meters close to the outermost track and allows the identification of macro-characteristics of the network not identifiable by the train survey (e. g. Buildings, bundle tracks, car parks, station yards, etc.)

The density of the points determines the quality of a LIDAR acquisition. Several parameters influence the quality of the point cloud density like the sensor sensitivity, the intensity of the

pulses emitted, the characteristics of the laser beam, the flight parameters (altitude and speed flight plane), etc. All these features can change the density of the point cloud from less than 1 point to several hundred points per square meter.
The table below shows the different density level per acquisition method and a list of candidate objects. It should be noted that a significant expansion of this table and a deepening of the requirements for measurement methods and their accuracy and precision in relation to BIM and DT models will be made in the guidelines developed under the task 27.6.

Acquisition Method	Number of Points	Main Candidate Objects
Laser/Inertial Based Systems	Around 4pts/m (linear density)	• Curvature • Rail Type • Catenary Poles
Machine Vision	Number of pixels/mm² (according to the camera and acquisition speed)	• Track & Catenary components • Surface Defects • Catenary Poles & Defects
UAV LiDAR	Around 450 pts/m²	• Any object visible
Lidar (Train)	Between 1000 and 6000 pts/m²	• Track & Catenary components • Surface Defects • Catenary Poles & Defects
Lidar (Plane)	Between 250 and 450 pts/m²	• Yard Tracks • Track Centreline • Access Points

Table 1: Density and objects per acquisition methods

Additional LIDAR acquisition can also be conducted via static stations and Unmanned Aerial Vehicles (e.g., drone). This can be considered when automatic extraction of data for digital twin management is specific to a fixed or selected locations. In general, drones have a smaller coverage compared to Plane and Trains.

5.4. BIM

The BIM (Building Information Modelling) is an increasingly implemented methodology thanks to the benefits it offers for asset management throughout its entire life cycle. A collaborative approach, accessible to all parties involved, enhances project oversight capabilities and minimizes uncertainties, duration, and expenses.
This methodology is founded on a collection of data that must be appropriately classified according to a model and effectively managed throughout the life cycle, in order to be utilized by distinct users or different tools. The Railway Innovation Hub (RIH) project is a noteworthy BIM initiative within Europe. Its objective is to promote research, development, and innovation in the railway sector through collaborative projects. Its objective is to establish a railway BIM classification, which can be implemented in BIM projects due to the need for a specific classification in railway infrastructure.

This research activity is carried out by companies belonging to the RIH, with extensive knowledge and experience in the infrastructure and technology sector. The vocation of the Railway BIM Classification presented by the RIH is open and aimed to facilitate digitization for all the stakeholders in the railway field.

The data model adopted by RIH has taken into account certain track assets that are included in IFC 4.3, such as sleepers. However, other assets that are required by WP27 and modelled in IFC 4.3 have not been taken into account, such as balises, as they were not considered part of the scope of work, except for station buildings.

5.5. Business Case, Use Case and EPIC

As part of WP27, we decided to use a Business Case approach to understand how data are used in the supply chain. We will talk about the current problems and how we can solve them using a common data model (like CCS-TMS). The Business Case approach is a more high-level approach compared to the Use Case approach considered in WP26. WP26 will collect and analyse use cases and guidelines from all EU-RAIL Destinations and the System Pillar, generating common requirements and constraints for the digital enabler components.
The Business Cases identified and described have been shared with WP26, WP30 and WP31 members in order to further detail and evolve them to Use Cases and EPICs[1]. An illustration of the work package relations (for example between WP26 and WP27) considered in the FP1 is provided *Figure 4* extracted from the MOTIONAL Grant Agreement.

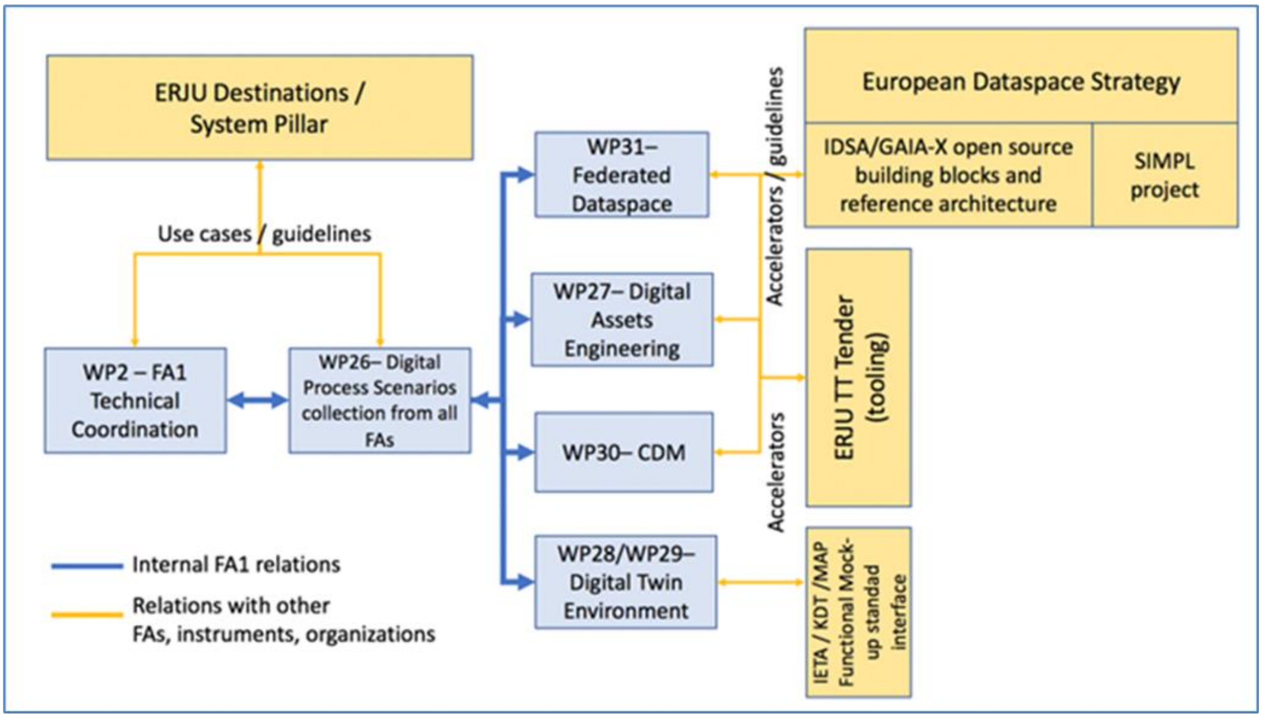

Figure 4: Work Package relations

Business case, use case, and EPICs are concepts often used, also as synonymous, in the context of project management as well as agile software design and development. They represent different aspects of the user requirements and planning process. In the table below are reported come key differences among them:

[1] EPIC is not an acronym. In the context of Agile software development, it refers to a large body of work that can be broken down into smaller tasks or stories.

Concept	Purpose	Audience	Content
Business Case	A business case provides a justification for initiating a project or undertaking a particular action. It outlines the reasons why a project is necessary and the benefits it is expected to deliver.	Business stakeholders, executives, and decision-makers are the primary audience for a business case.	Typically includes the problem statement, objectives, scope, risks, costs, benefits, and the expected return on investment.
Use Case	A use case describes how a system interacts with an external entity (could be a user or another system) to accomplish a specific goal. It focuses on the functional requirements of a system.	Primarily used by analysts, developers, and testers to understand how a system will be used and to design and test system functionality.	Describes a specific scenario, including the actors involved, the flow of events, and possible alternative paths.
Epic	Broad and overarching, encapsulating a significant business objective or theme.	Primarily for stakeholders, product owners, and those involved in strategic planning.	Follows the format "As a [type of user], I want [an action] so that [benefit/value]," specifying the desired outcomes. The content is independent from the adopted technology and on the specific user and/or stakeholder.

Table 2: Differences among Business Case, User Case and Epic

In summary, the business case provides the overall justification for a project, the use case details how the system will function in certain scenarios, and user stories capture specific functionality from the end user's point of view, especially in agile development. These concepts are often used together to provide a comprehensive understanding of project requirements and goals.
In the next section, a template for Business Case is proposed.

5.6. Template for Business Cases

The D27.3 includes five reference demonstration outcomes demonstrating feasibility of the output from task 27.1, 27.2, 27.3 using multiple datasets from different European countries applied to CCS+ scenarios.
Before moving towards D27.3 with more detailed use cases, a business case provides a justification for initiating the use cases specification. It outlines the reasons why the demonstrating feasibility is necessary and the benefits it is expected to deliver in the future.
To identify the assets to digitalise, the following template has been specified. The aim of this business case is to describe the current challenges and how they could be addressed with a

common data model and related asset digitalization services.

Section	Description
Name	Insert a name for the presented use case
Proposer	The name of the stakeholder proposing the use case as part of the MOTIONAL project.
Domain	It specifies if the business case involves CCS objects or assets of other domains such as stations or rolling stock only.
Current Situation	Describe the current process, how the use of data is conducted today and for what purpose.
Objects Involved	List the data objects for the use case. It is not necessary to specify the attributes and relations. Additional details about the objects will be specified after the use cases are finalised. Objects of interest in WP27 include mainly track and signalling assets and components. Most of those assets are transversal and used by multiple domains. For example, maximum track speed is used for signalling planning but also for track maintenance purposes. Key objects investigated in the WP27 business cases include: - **Track, Points & Crossings** - **Maximum Speed** - **Tunnels** Please refer to Figure 7 in Section "7.3 Common Objects" for a more extended list.
Actors Involved	List all the stakeholders involved in the use cases and their role, in particular; specify who is data provider and who is data consumer. Key stakeholders involved in WP27 include: • Infrastructure managers: they operate and manage the entire railway infrastructure, including tracks, signals, stations, and other related facilities). • Operators: they manage day-to-day train operations and ensure the safe movement of passengers and goods. • Manufacturers: they provide the necessary equipment, rolling stock, components, and infrastructure for the railway industry. • Contractors: they support the previous listed stakeholders in the operations such as infrastructure or signalling renewal, condition monitoring, maintenance, etc. Any of these stakeholders can act as data provider and/or data consumer. The greater the number of stakeholders involved in accessing and/or utilizing a specific asset, the higher the benefit of digitalization of the asset.
Challenge	Describe what are the key challenges in the current process.
Risks	Describe the impact the key challenges above have in term of efficiency and efficacy in the current process. Identify extra cost, extra time and reduction of perceived quality.
Opportunity	Describe the expected change enabled by the innovation proposed.

6. Business Cases

6.1. TCCS CCS-TMS Business Case

This use case specifies the potential usage of the System Pillar CCS-TMS Data Model by other domains and Flagship Projects. This use case can be part of different use cases identified by WP26 in Flagship Project 1:

Section	Description
Name	TCCS CCS-TMS Data Model
Proposer	System Pillar
Domain	Signalling
Current Situation	Today, several standards provide interface data formats, such as EULYNX Data Prep, RailML, RailSystemModel, RCA, IFC-rail, Linx4Rail, and X2R4. These partially overlapping standards complicate the decision process of Infrastructure Managers or other parties to invest and build toolchains following long-term road maps. Also, the coexistence of several data standards in parallel for the same use case is not acceptable for safety, functional or economic reasons if a new, standardized architecture, as intended by the System Pillar, is developed. The Transversal CCS Sub Domain 1 (CCS-TMS) of the ERJU System Pillar started its activities in December 2022. As part of the ERJU System Pillar, standardisation focuses on traffic/train CS, traffic management, or use cases such as diagnostics.
Objects Involved	The current version of CCS-TMS Data Model is focused on CCS-TMS-related use cases and systems. Key entities managed include: • **Track edges and links** • Track alignment in terms of horizontal and vertical curves • **Cant values** The entities will be extended with new object types in the new versions.
Main Actors Involved	• **Contractor** involved in ATO, TMS, Train Protection, Localization, Diagnostic Systems, etc. (Data Consumer). • **Infrastructure Manager** having the responsibility to provide to the various actors of the supply chain, access to the single source of truth. (Data Provider) .
Challenge	As with national BIM plans by infrastructure managers, a proper digitisation strategy also relies on the standardisation of interfaces within this process to support coordination, data exchange, and close collaboration within the project. The data structures developed in national contexts are a first step towards this digitised process flow. The international standardisation of data formats, rules, and processes improves the business case and the return of investment due to scale. Higher development costs related to safety, such as CCS, increase the need for a standardised environment with the semi-automated, digitised engineering process, i.e. planning, validation or transformation functions.
Risks	• No input or low buy-in from all stakeholders involved with data consumption for using a standard data model. • Issues when data being brought into the systems isn't in a format and quality usable by data consumers. • Complex data transformation required to access to common data.
Opportunity	• ERJU System Pillar shall improve the situation by harmonising the input

	information required from engineering or infrastructure data inputs to operate the System Pillar systems within their area of operation. • Picking and recombining fragments from existing data models to fit the requirements of multiple data users. • Direct using the data models by the systems without complex transformation. • Support the migration to the SERA with specific extensions of the model data interfaces.

6.2. MERMEC Business Case

This use case is provided as an example use cases, it could be considered for implementation, and supported by MERMEC, if at least one Infrastructure Manager commits to the implementation in their infrastructure condition monitoring process.

Section	**Description**
Name	Common Infrastructure Data for Infrastructure Condition Monitoring
Proposer	MER MEC
Domain	Track
Current Situation	Diagnostic services use a set of trains and vehicles, equipped with diagnostic systems, to inspect and measure the railway infrastructure. The systems collect condition data used by the Infrastructure Manager for identifying safety related defects and planning the maintenance & renewal intervention. Any diagnostic system requires some infrastructure data to process the condition data collected. Such infrastructure data belong to four main classes, namely: • Railway Network: track name, start location and end location, etc. • Track Layout: curve locations, start location of the curve, curve radius, etc. • Assets: switches, level crossing, bridges, poles, etc. • Operational Data: maximum speed of the tracks, etc. Certain data such as track references, are utilised to reference the collected data on the track model, while other data are required for the identification of defects such as track speed for the calculation of track geometry defect thresholds.
Objects Involved	Considering what EN 13848 specifies in terms of track features required for data analysis, objects involved should include at least: • **Line Speed** • **Geo-spatial positioning** • **Line features** such as level crossing, bridge and tunnels. • **Track components** to establish the train route (including switch) • **Track horizontal alignment parameters** (tangent, curve transition) including can and radius. • Eventual other **singular points** (that may change from railway to railway)
Main Actors Involved	• **Infrastructure Manager** in charge to provide the infrastructure data required at configuration time and at any update of the data for the entire duration of the service (Data Provider). • **Diagnostic Service Contractor** that takes the data provided by the Infrastructure Manager and loads them in the format required by the

	diagnostic system (Data Consumer). • **Software Service Provider** that supports the conversion (Extraction, Transformation and Load) of the data provided by the Asset Data Manager and the format required by the Diagnostic Service Operator (Data Consumer).
Challenge	With the increase of the number of measuring systems in production at the Infrastructure Manager, the number of data exchanges has increased. Without a standard reference for the exchange of such data, Infrastructure Manager and Contractors must foresee custom data interfaces that leads to the railway industry adopting multiple data interfaces one for each actor involved in the use of the system. In some cases, even if there is a single data interface, some data are still in a format not readable by a machine and requires manual work by the operator.
Risks	The lack of a standard data interface can lead to the following: • Higher cost to develop and maintain multiple custom data interface to exchange the same data types. • Higher cost for updating the same data in different systems. • Extra time within projects to get access and use the data. • Overall reduced data quality assuming that the more a single data source is used also efficiency and efficacy of data auditing increases.
Opportunity	With the adoption of a common data model, a reference data format can be defined and used across the supply chain without requiring custom solutions.

6.3. DB Business Cases

Section	**Response**
Name	Harmonized Digital Engineering Process and Data Exchange
Proposer	DB
Domain	Signalling
Current Situation	The current engineering process of ERTMS-Interlocking across Europe is at different level of digitization. In addition, the process of engineering is very diverse which contradicts the idea of SERA and European Railway Traffic Management system. The goal of this use case is to harmonize the processes according to the target system architecture. This involves harmonizing data requirements as well as information exchange format.
Objects Involved	**Objects which are required for ETCS Level 2 planning** such as: 1- Track 2- End of track 3- Track Layout (straight, curve or transition curve) 4- Point 5- Crossing 6- Derailer 7- Level Crossing 8- Landmark 9- Speed restriction signs 10- Movement permission target marker 11- Stop location sign.

	12- Light signals 13- ETCS Marker 14- Balise 15- Balise group 16- Tunnels 17- Bridges and culverts 18- Station platforms 19- Mileage change 20- Track Bed 21- Train detection units 22- Indusi magnet[2] 23- Fouling point marker (Danger Point for safety) 24- ETCS-Level 25- Underpasses 26- Track junction[3]
Actors Involved	1- **Requirement provider** based on their use cases. 2- **Contractor** responsible for rail lines operation and maintenance (Data Consumer). 3- **Modeler** to ensure the correct integration of different requirements into a comprehensive model that can serve all needs (Data Consumer). 4- **Software vendor** that provides computational tools and digitize the engineering process (Data Consumer). 5- **Signalling manufacturer** (Data Consumer). 6- **Signal engineers/designer** (Data Consumer). 7- **Infrastructure manager** (Data Provider). 8- **Signalling Project manager** (Data Consumer).
Challenge	1- Change in the naming convention and/or semantics across different requirements providers. 2- Developing a modelled entities that can express the requirements. 3- Integrating all process components from end to end.
Risks	• Diverging process which leads to increase in cost and loss of interoperability. • Vendor locking and monopoly.
Opportunity	• Foster innovation by reducing market entry barrier. • Reduce cost and delivery time thanks to interoperability.

Section	**Response**
Name	Data platform for structured documentation of objects and object information
Proposer	DB
Domain	Station
Current Situation	Objects and object information is stored in several different data formats (e.g. spreadsheets, text files, pdf etc.) and furthermore in different locations (file paths). Therefore management of the data are time-consuming and error prone. It is necessary to combine different data sources to make relations between objects, assets, attributes and other documents visible and manageable.

[2] This object is known as Class B systems in signalling. They are magnet that are activated to stop a train in case of malfunction. They are usually attached to the track.

[3] This is not an object, but the information required about the level of ERTMS (Level 2 or HL3).

	No or low availability of object libraries of structural and non-structural elements of the rail station, its equipment and its surroundings. Publicly available libraries are prepared in native software formats, which limits their applicability only to programs that are compatible with the native format.
Objects Involved	All 3D-objects of a train station, for example - Platform edges, floorings and roofs - Lighting poles - Weather shelters - Litter garbage cans
Actors Involved	Stations involve data providers and consumers including: • **BIM-Content Manager** (Requirements Manager) in charge to providing the data required. • **Modellers/Planners** as end users • **Project Managers** as end users • **BIM Managers /BIM Consultants** as end users • **Software Developers** (Backend, Frontend, User Experience)
Challenge	- Unify components by preparing them in open data formats. - Define the requirements for geometric and non-geometric information necessary to be considered during the component construction to provide their usability in the various stages of the life cycle
Risks	Data quality
Opportunity	Provide consumable and manageable data by reducing different data structures and formats.

6.4. OBB Business Case

Section	**Response**
Name	Asset data completion / extraction
Proposer	OBB
Domain	Signalling
Current Situation	The infrastructure corridor consists of many assets, all necessary for train operation providing safety, punctuality and comfort for the customers. Assets are usually managed in several databases (or even in paperwork, XLS or doc files); each database is administered by the relevant department of the IM. Sometimes databases are not correct or complete, e.g. some elements of the track do not need absolute position information (co-ordinates). Usually OBB uses the official Austrian co-ordinate system (Gauss-Krueger) but GPS-coordinates in both directions can be provided. For a digital end-to-end planning and building process, this information must be complete, consistent and correct. Automated object extraction algorithms based on LIDAR or photo data (Mobile Mapping Data) allow for a homogenous look at the infrastructure assets. Several objects on the track can be extracted and located within a homogenous coordinate system. This is the basis for merging all information sources / databases for consistent digital planning.
Objects Involved	All objects of a certain size, which are visible in the Mobile Mapping data. Candidate objects include:

	• **Signals** • **Tracks** • **Sleepers** • **Balises** • Various (passive) information panels (for train drivers) • Others not identified at this stage of the project

Actors Involved	• **Infrastructure Manager** for (Data Provider)
	  ○ Definition of relevant assets to be extracted.
	  ○ Mobile mapping data and databases to be checked/updated/completed.
	• Supplier of Mobile Mapping System (Data Provider & Consumer)
	• Specialist for extraction algorithms (Data Provider & Consumer)

Challenge	Merging different database information of a multitude of infrastructure assets is a challenging task to be done by every IM. This virtual representation of the infrastructure network has to be the basis for all upcoming tasks.
Risks	Digital planning along the full supply chain will not be possible with inconsistent or incomplete data.
Opportunity	Standards for merging/checking of existing data and future periodic updating processes necessary to support the digital planning processes.

6.5. CEDEX Business Case

Section	**Response**
Name	Common Infrastructure and CCS Data for ESC checks in Laboratory
Proposer	CEDEX
Domain	Signalling & Rolling Stock
Current Situation	The ETCS System Compatibility checks are a set of tests, defined by every Infrastructure Manager, to be used by every train which wants to get an authorization to circulate over this line. They are the mechanism prescribed by the Technical Specification of Interoperability for Control, Command and Signalling for the trains to be authorised to circulate on a track section managed by an Infrastructure Manager. Nowadays, these checks are mainly performed in track, with a cost (in time and money) very difficult to estimate.
Objects Involved	• Track topology and geometry • Trackside CCS elements like signals, balises, train detection devices (axle counters, track circuits, etc.) • ETCS relevant areas (tunnels, bridges, stations, powerless sections, etc.) • GSM-R relevant information (network identification, radio holes, etc.)
Actors Involved	• **Infrastructure Manager** (Data Provider). • **Railways Undertaking** (Data Consumer). • **ERTMS supplier** (Data Consumer). • **Notified Bodies** (Data Consumer). • **Testing Laboratory** (Data Consumer).
Challenge	Use a common data model for the exchange of information associated to the trackside. Define a homogeneous process for the ESC checks, from its definition to their execution, information retrieval, analysis and results. Implement the tests in accredited laboratories. Include the new technologies, currently under

	development: ATO, FRMCS, Hybrid Level 3, Absolute Safe Train Positioning, etc.
Risks	Delays in the Rolling Stock authorization process, especially in European corridors, involving several countries and, hence, several infrastructure managers.
Opportunity	Harmonize the Authorization process in Europe, from the exchange of Track and CCS information in a reference data format to the formalization of the procedure (test definition, execution and analysis).

6.6. SNCF Business Case

Section	**Response**
Name	Cross-referencing of multi-source weather data
Proposer	SNCF
Domain	Track
Current Situation	Currently, there is no process for cross-referencing weather data. They are used punctually for everyday maintenance, with no long-term projection. What's more, such data are managed locally, which runs counter to the desire for harmonized data management.
Objects Involved	Several **track objects** required for weather data analysis: 1- Track, (rail, ballast, sleeper) 2- Catenary 3- Earthworks 4- Level crossing 5- Tunnels 6- Bridges 7- Track bed
Actors Involved	Infrastructure (Data provider) providing: - database of weather-related incidents - weather forecasts - IPCC predictive models (provided by international experts concerned about global warming) Data consumer: - **Infrastructure manager** - **Data scientist** - **Software developer** - **Contractor** for rail lines operation and maintenance.
Challenge	Anticipate global climate change by estimating its impact on the rail network
Risks	Have to deal with important restoration costs due to lack of knowledge of climate change
Opportunity	Several objectives are envisaged: - limit the impact of incidents/accidents through better risk prevention (vegetation management, water run-off, etc.) - optimizing facilities replacement through better management of financial investment - use and create a history of climate-related events to perfect the model

6.7. Voestalpine Business Case

This use case is about the predictive detection of ballast degradation and deterioration of the track settlement in the switch area to initiate the necessary measures to preserve the system and prevent impending ballast degradation and overstressing of switch components.

Section	**Response**
Name	Monitoring of Track Settlement and Identification of Single-Faults in Switches
Proposer	Voestalpine
Domain	Track
Current Situation	In addition to the track geometry, the track component turnout is the most important parameter for track maintenance. Currently, the inspection is carried out by means of fixed inspection cycles and manual measurement or special measuring vehicles. Predictive detection of ballast degradation and deterioration of components in the switch area is of great importance in order to be able to initiate necessary measures at an early stage and, thus, to protect the system with regard to imminent ballast degradation and overstressing of switch components.
Objects Involved	• Switches • Track
Actors Involved	• Infrastructure Manager in charge to provide the infrastructure data required at configuration time and at any update of the data for the entire duration of the service (Data Provider) Data Consumer • Diagnostic Service Contractor that takes the data provided by the Infrastructure Manager, loads them in the format required by the diagnostic system and provide data of current condition of the specific object. • Maintenance Service Contractor that provides information of the specific maintenance activities and strategies. • Software Service Provider that supports the conversion (Extraction, Transformation and Load) of the data provided by the Asset Data Manager and the format required by the Diagnostic Service Operator • Specialist for model development that provide numerical models for prediction of the object degradation and behaviour over the live time
Challenge	• Data recording and provision of live condition data. • Standardized metadata format and sensor labels for collected data. • Storage of (big) data • Merging various data sources of different formats • Development and accuracy of model
Risks	• Interface issues with incoming data. • Incomplete metadata or invalid formats • Invalid data and sensor issues • Accuracy of model is not satisfying. • Storage capacity issues • Licensing issues
Opportunity	• Automated prediction and optimisation of maintenance intervals for

	switches. • Possibility to transfer results to track. • Data can be used as basis for development of new models.

6.8. Institute for Energy Technology (IFE) Business Case

Section	**Response**
Name	Cross-Referencing travel and track maintenance data
Proposer	IFE
Domain	Track
Current Situation	Track maintenance is currently carried out by means of fixed inspection cycles and manual measurement. Understanding of how track design combined with track operation affects maintenance requirements is lacking. Predictive detection of ballast degradation and deterioration of track components can give early indication of track component turnout and enable early corrective measures, thus avoiding emergency replacement of track components and reduce the number of required manual inspections.
Objects Involved	• **Track** (rail, ballast, sleeper) • **Structure** (Level crossing, Tunnels, Bridges) • **Track Bed** • **Track geometry** (horizontal and vertical alignment and curvature) • **Track speed** (cant, acceleration, retardation) • Track operation (vehicles crossing, train weight, etc)
Actors Involved	Data provider: 1) **Infrastructure Manager** in charge to provide the infrastructure data required. • Database of incidents and emergency maintenance requirements (near-misses) • Database on location tagged track design and geometry. • Database on location tagged operational data. 2) **Contractor** in charge to provide information on maintenance and renewal works executed. Data consumer: • **Infrastructure manager** • **Contractor** for rail lines operation and maintenance. • **Provider** of predictive model for expected remaining useful life, object degradation and maintenance need
Challenge	Optimize track design and operation by introducing the ability to further anticipate how track layout and usage affects future maintenance needs of the rail network.
Risks	• Accuracy and efficiency of maintenance corrective measures is not optimized. • Long term planning of rail maintenance is not possible, and infrastructure managers and maintenance providers are faced with unexpected and unnecessary restoration costs.

	• Track operation is not tailored to optimize long term sustainability of rail infrastructure. • Design of new tracks is unable to plan for long term sustainability of the rail infrastructure.
Opportunity	• Limit the number of incidents and emergency restoration projects. • Limit the impact of incidents. • Improve the maintenance planning capability. • Reduce maintenance and inspection intervals. • Improve the ability to plan for low maintenance track construction. • Predict the effect of track operation on track maintenance and costs.

6.9. CAF Business Cases

Section	**Response**
Name	Digital twin for braking/traction virtual acceptance
Proposer	CAF as part of FP1 WP28 & WP 29 and FP2 WP 34.5 & 35.5
Domain	Rolling stock
Current Situation	The traction/braking system is a critical part of railway vehicles. This system controls to some extent the braking distance, the velocity, the prevention of wheel-slide, the passenger comfort and the energy efficiency. These systems require validation before the vehicle is accepted to start service operations. An accurate digital twin for this system would impact positively the design periods but also, but virtual validation could also shorten periods regarding system certification, which in turn would reduce the time for vehicle acceptance.
Objects Involved	Several subsystems are part of the braking/traction system and subsequently, they should be accounted for by the digital twin, they include: • Train Control and Management System, which is responsible for sharing the efforts among the motors and brakes. • Traction Control Unit, responsible for traction and electrodynamic braking system • Braking Control Unit, responsible for the pneumatic braking system. • Motor, responsible for applying the electrodynamic forces. • Pneumatic brakes, responsible for applying friction forces. • Track, which accounts for geometry and adhesion conditions. Potentially, it might involve also data provided by balises. The operation of the braking/traction system is affected by internal vehicle conditions such as vehicle longitudinal and wheelset dynamics. Therefore, they should be accounted for by the digital twin. Moreover, external conditions are also important, especially track slope and contact adhesion conditions.
Main Actors Involved	CAF, DLR, Deutsche Bahn (DB), Alstom and Knorr Bremse (KB). **Software developers:**

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Architecture (CAF & DLR): CAF as rolling stock manufacturers are suitable to define and/or assemble the software architecture. DLR can assist with the development of a standardized architecture that eases data and model sharing.
Specific functionalities (CAF): CAF, as a specific component manufacturer they might provide virtual models or integrated DT representing physical assets of the rolling stock, especially, the braking and traction system.

Data Consumer:

Proof of concept (PoC) developers (CAF & DLR): CAF, as the main actor, will be in charge of receiving the necessary data from all the actors for the PoC development and demonstration. DLR will assist in this task.

Data Provider:

Rolling stock manufacturer (CAF): Provider of the necessary vehicle data and traction system.
Railway Undertaking (DB): Information regarding track geometry.

Advisors (Alstom & KB):

Alstom & KB are part of FP2 WP 34.5 & 35.5, where CAF is the project leader. FP2 WP 34.5 & 35.5 deals with DT requirements and implementation. Via this collaboration, Alstom as a rolling stock manufacturer and KB as a brake device manufacturer might provide valuable insight into specific subsystems if needed within the framework of the presented use case.

</td></tr>
<tr><td>Challenge</td><td>

The subsystems involved in the digital twin as well as other phenomena affecting the braking/traction operation have different natures. Therefore, it is necessary to merge different approaches to identify the required level of accuracy for each virtual model.
There are several sources of uncertainties that introduce a large variability in the braking/traction operation. For instance, contact conditions.
The representativeness of the virtual model with the actual implemented signal. The braking/traction system might involve components provided by different suppliers, which introduces difficulties in tracing and unifying the necessary data for model definition.

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<tr><td>Risks</td><td>

Low efficiency of the virtual model. The whole model involves many different parts requiring different types of solving methods and time-step lengths, which may hinder the computational efficiency of the system.
Failing to represent dispersion of the different input parameters of the system.
Not achieving a flexible model able to adapt to different short of vehicle configurations.
Lacking actual value of key parameters of the model when they involved different stakeholders.

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<tr><td>Opportunity</td><td>

This use case would allow to address generic requirements that affect the acceptance process regarding categorization and credibility. In this way, it would foresee the requirements of a potential generic standard for virtual verification that three CEN/CENELEC working groups are currently

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	developing (WG55, WG47 and WG32). • The definition of an architecture in which the interface of different subsystems is standardised in such a way that different suppliers could contribute with their own models to the digital twin. • Reducing cost and time for approval of the braking/traction system.

Section	**Description**
Name	Standard Data Model for Signalling
Proposer	CAF as part of FP1 WP26
Domain	Signalling
Current Situation	Today, different standard de facto data models are available which allow suppliers to evaluate each system separately, and use for different purposes (e.g., data preparation, data interchange with customers, testing…). The lack of a common standard hampers the interaction between stakeholders and introduce additional costs and possible errors in the process because of required data model conversions. Previous projects as INESS, Linx4Rail and initiatives such as EULYNX have investigate and made data model proposals. The System Pillar is also defining a so-called CCS-TMS Data Model that could be the European standard. Moreover, there is no automatic way to generate the topological data of a track. It is true that this topological data can be generated in a semi-automatic way, but this involves a lot of time investment in preparing all these data. Any advancement on the object extraction would need a common data model.
Objects Involved	The objects that be involved are: • Trackside **CCS elements** like signals, balises, train detection devices… • **Track topology** and geometry • **ETCS profiles** like gradients, SSP, … • **ETCS relevant areas** as tunnels, stations, bridges…
Main Actors Involved	Data Consumer - Rolling stock manufacturer: CAF - Testing laboratory - Signalling Track Side (Alstom) - Railway Undertaking (NS) Data Provider: - Infrastructure Manager - Rolling stock manufacturer: CAF
Challenge	The main objective is to define and generate a standardized data model for signalling, With the line already digitized, we will be able not only to prepare the data but also to validate it in order to use it for different processes and interaction with the customer, ensuring compliance with standards. It will also allow us to reduce costs of testing because we will do it in a simulated way, reducing or even avoiding the use of on-line tests.
Risks	• Modifications to the infrastructure would require us to redo the entire digital twin to meet our needs. • Not having the systems in their most updated version. • Depending on the quality of the recording and accuracy of sensors, the measurement error needs to be considered.

	• Potential delays in the usage of the standard due to lack of tools that starting from a point cloud recording of a line can transform it, picking the relevant information and populating a standard data model. Although the point cloud has information with the structure (x,y,z), for the signalling sector the value of coordinate z does not give valuable information. In the future, when geolocation systems will be defined, this coordinate z would become valuable as it would allow us to locate the train.
Opportunity	This definition of a standard data model is aligned with the objectives that are in the SP and its CCS-TMS Data Model already addressed in WP27.

6.10. INECO Business Case

Section	**Description**
Name	Track Inspection Defect semantics for railway maintenance works
Proposer	INECO (candidate for WP30)
Domain	Track
Current Situation	Currently, there are some railway maintenance works on super structure (mainly rails, ballast, sleepers and fastening) that still need forcefully of on-foot visual inspection by maintenance staff. This opens the door to human error and/or attention deteriorating conditions, especially in a very time-consuming and tiring task such as a whole railway line's visual inspection. Moreover, track inspections are usually executed during night shifts to take advantage of the low railway traffic conditions, so that it has a minimum impact on daytime trains' schedules. Usually, the data of any defect detection performed under these conditions is gathered and stored/inserted either digitally or even physically on paper. When physical, the possible usage of these data with its full potential is extremely limited for obvious reasons. But when the data are digitalised, also the usual current means of local classification and storage of data limits very much both its later exploitation and its interoperability capacity. With the latest technological developments, a new generation of on-foot visual inspection capabilities is possible, either with the support of new innovative inspection systems or with a simple mobile device (e.g., a smartphone) to store the inspection outcomes. At the core of these improvements is the availability of an ontology/semantics covering at least two types of inspections: 1. The on-foot visual inspection procedures for maintenance works of track. 2. General inspections e.g., railway corridor infringements by new buildings/walls, animals on the railway corridor, etc. This use case will focus on the first type of inspections (it excludes the general inspections and Switch & Crossing that require dedicated procedures).

	Today, there are new official inspection procedures applicable to the on-foot human visual inspection. These new procedures force to perform some kind of electronical storage, processing and control, as they set some conditions for raising defects that cannot be controlled just by human means. Hence, this is a very timely chance to standardize an incident detection semantics that allows to fulfil these new generation of procedures that optimize railway maintenance, while accomplishing at the same time the compliance with the new European interoperability needs. But, beyond both new official inspection procedures and European cross-border interoperability, the purpose of this use case also takes the most of the proposed standardization by allowing to broaden its full potential in many other ways, as it also opens the door to succeeding new added-value innovations and capabilities for maintenance, such as: • Controlling the evolution of the defects as time goes by • Establishing relations of the defects with the type of track and its tracing, stress suffered by the railway depending on its usage and the types of trains that circulate on it, etc. This leads to an improvement of the cause-effect relation, which is so important when designing and maintaining new railway tracings and publishing the European norms that regulate them. • Boost simulation capabilities in a digital twin of the railway network, or also in the cases where the simulation is limited to laboratory tests specific for one type of track, trains, etc. • Be able to compare afterwards divergences between the previous simulations and the later real degradation of the railway track in the physical world
Objects Involved	A first approach to the properties that this informative object “Defect” should have: type, geo-location of the defect (and/or positioning relative to the track where it was detected), asset suffering the detected defect, time/date of detection, maintenance team that detected it. Key candidate data objects (as part of WP27) may include (the list is not exhaustive): • **Railway asset** the defect refers. • **Railway infrastructure localisation data** e.g., track name, absolute or relative localisation, etc. Other data to be modelled include: • Defect Types and properties e.g., localisation, maintenance team, time stamp, measurement size, etc. • Defect impact on traffic and maintenance operations e.g., failure requiring lowering the speed or closure of the line, defect requiring maintenance actions within an imposed time, etc.
Actors Involved	Data provider: • Infrastructure manager that performs the track inspection in its railway network • Contractor that performs the track inspection and auditing tasks

	• System Manufacturer: Any contractor (e.g. MER MEC) that support the track inspection process with an IT system that generated in automatic a specific set of defects or is in charge of the management of the related data. Data consumer: • Contractor that needs to interoperate with ADIF defects. • Data scientist that analyses such data Any European railway stakeholder (e.g., infrastructure managers, railway undertakings, European-wide knowledge base, other) that needs to have access to such defect data. For this concrete use case as prime supporter and leading participant: ADIF. Despite the use case as an initial proposal includes ADIF as main infrastructure manager involved, this use case is open to any other European infrastructure manager interested in the initiative, and hence there could be finally more data providers in addition to ADIF
Challenge	Reach an agreement on - a common semantics for all of the European railway companies related to railway maintenance's defect detection and management. - the specific defect/s whose detection semantics is going to be standardized as an initial stage, and also plan its gradual broadening to a more complete set of defects (once at least a Proof of Concept and first initial standardization have been produced). The benefits that overcoming this challenge will bring are diverse and very important. In terms of maintenance, its improved quality and multiplied capacities will benefit not only reactive maintenance (fixing works), but also the preventive one (anticipation and/or simulation) In a standardized way, overcoming the challenge of producing this semantics would enable (among others): • Store information of the assets in the inventory, enabling the management of the follow-up and evolution of its defects • Perform AI-powered simulations that work out predictions for the future evolution of defects, enabling their storage/management, as well as making them shareable with other European operators and infrastructure managers. • Interoperate at a trans-national level, as the defect's information can become shareable (only the data that infrastructure managers qualify as disclosable), and allows to broaden the knowledgebase (evolution of defects, their relation to the type of track and tracing, stress suffered depending on the type of trains circulating it, divergences between the real evolution of defects and the one predicted by the simulation, etc.).

	• Improvements to the cause-effect relations and AI-reasoning based on patterns' detection, once a vast European-wide incidents' knowledgebase becomes available
Risks	Not reaching an agreement in the common semantics, in the type of defects whose detection semantics is to be standardized, and/or in the information of the incident that should be qualified as disclosable.
Opportunity	European-level standardization for a first maintenance semantics that will be suitable for being shared across borders between European companies. This might need to be done: 1) to share operational info for the route of an international trains 2) to share info on the degradation of the railway with a European counterpart 3) to broaden the knowledgebase of railway maintenance by gathering more defect's detection and evolution data from other European railway networks. Talking strictly about interoperability, this capacity is going to be essential in the industry in the coming years. Interoperability is increasingly key to IT systems, either internally and across in-house systems within the same company collecting the data, when exchanging data with other companies in the industry at a national level, or also when interoperating with other European counterparts. Besides the great advantages found in standardization of interoperability per se, interoperability has become a must in the context of the ESRA (European Single Railway Area). The usage and exploitation possibilities of a standardized interoperability go far beyond a mere technical context, but also contribute with many other advantages at many other levels: it boosts competition, reduces costs, promotes the creation of new enterprises, and brings innovation closer to its full potential.

Business Case implementation considerations:

As stated, what is proposed here is a standardization for a defect detection semantics (this topic is closer to the work being done in WP30), but under a specific business case that comes with a first implementation and a testbed applied to on-foot visual inspection maintenance. Notwithstanding, the scope of this semantics can also be extensible/applicable to other inspection works in general; for example: automated inspection. Automatic inspection involves data such as that provided by the ADIF's SENECA measuring train: its data can (and should) also be standardized under the European common defect detection semantics. The same advantages that are applicable to ADIF's SENECA or other measuring trains.

Being MER MEC supporting this use case, as manufacturer of machine vision systems it must be considered that "mechanised track patrolling" is still not a common practice among the railways and in most of the cases they are trying to replace the on-foot human visual inspections', so based on this consideration starting with an on-foot human visual inspections' semantics should be considered already beneficial.

Additionally, apart from the mentioned semantics development, it has been considered that proposing a practical testbed would add value as a part of this new use case proposal. With it, the first versions of the semantics to be produced with this use case will be implemented and tested by quite straightforward and practical means. The goal in this is very aligned with the railway innovation goals that are also at the core of the ERJU project, as the existence of this semantics will improve these on-foot visual inspections and enable automation, and hence will give the chance of complying with new quality standards and railway infrastructure managers' procedures, quitting human errors, and reducing overall costs. The data set being used as a part of this testbed will be anonymized, so that this datum is meaningful for the semantics' testing, but totally meaningless and without traceable correlation with any real incident in a physical railway network.

The final aim of the business case is to harmonize the on-foot track inspection related semantics, as a matter of facts the data models for installations, telecom, signalling, maintenance, etc. would result in a far too ambitious goal for the scope with which our specific use case as is posed now. Being the use case originated to identify transversal objects, it will borrow the localization related objects resulting from CCS-TMS current work. So the defects modelled as part of the use case will refer to the entities already present in TMS/CCS. If this reference is not possible, it means that TMS/CCS is generic and requires an extension with new data, this decision is part of the SP governance process where when engineer data do not cover specific requirements, an extension in terms of either engineering or domain data are considered.

6.11. PKP Business Cases

Section	Response
Name	Asset management (with optional space management and tracking complemented by record modelling)
Proposer	PKP
Domain	Station
Current Situation	1. Asset management is mainly based on analogue source materials, often significantly outdated. In addition, the knowledge they contain is available to a small group of people with many formal restrictions. 2. The management of the station space is not optimised, and business decisions are often taken ad hoc, despite a potentially very attractive location. The station spaces are usually filled to their full capacity with contractors. There is no digital system and no digital methodology for managing and tracking changes in the use of the station space, particularly relating to the organisation's business objectives. 3. Digital time domain records for the station space are not maintained and updated at this time.
Objects Involved	Station buildings and elements of transport linear infrastructure within the station or its surroundings, the close socio-economic environment of the station buildings. In particular, in the architectural layer, these may include: - Ceilings, ramps, floors - Walls - Windows and doors - Cranes and escalators - Curtain walls and skylights - Suspended ceilings - Handrails and balustrades

	In the construction layer, these may include, in particular: - Foundations - Reinforced concrete structures - Metal structures - Prefabricated structures - Wooden structures - Stairs, landings and platforms - Roofs and canopies In the MEP layer, these may include, in particular: - MEP equipment - Ventilation ducts - Pipe ducts - Cable trays - Ventilation accessories - Ventilation system terminations - Pipe equipment In terms of landscaping, these may include: - Terrain, - Roads, parking areas and green areas around the rail station, - Development of the station area with close surroundings - Small architecture In terms of temporary objects, this may include: - Site development - Temporary installations - Existing infrastructure - Temporary ground reinforcement - Cranes - Formwork - Demolitions In terms of fit-out, this may include: - Movable items of equipment
Actors Involved	Stations involve data providers and consumers including: • Contractors • Rail companies • Station managers • Rail maintenance staff • Installation inspectors • Architects • Constructors • MEP engineers • Geotechnicians • Surveyors
Challenge	Aggregate the information in the Asset Information Model in a way that does not increase the cost of the station's daily operations exponentially, but which provides a solution to issues 1-3 outlined in the *Current Situation*
Risks	• The technological barrier related to the knowledge of how to build a correct

	Asset Information Model • Costs and keeping a working culture to support keeping the Asset Information Model up to date. • Linking the station use space change monitoring to the organisation's business objectives and keeping the data up to date. • Correct selection of time resolution of model record elements, systematic updating of the record and correct diagnosis of the needs and motivations for which the record should be maintained.
Opportunity	• Having a consistent database on the building's history and the equipment inside to analyse the condition of the building and the equipment. • The ability to analyse space occupancy, customer energy consumption and support the lease space management process. • Creating a cost estimate of current station assets to support the financial reporting process, estimating the cost of upgrading or replacing specific assets. • Storing equipment specifications, operating manuals, guarantees, maintenance schedules, manufacturer, repairman, owner data and performance information over time. • Analyse the station's condition and the equipment inside it. • The ability to update model records, including importing new information into the model to enable up-to-date information to be stored on station assets for the entire life cycle of the building (i.e., including information on modernization, replacement, maintenance)

Section	**Response**
Name	Using geospatial/surveying measurement technics for capturing and modelling existing conditions within the rail station and tracking the progress of construction process
Proposer	PKP
Domain	Station
Current Situation	For the most part of rail station buildings in Poland, the available documentation is outdated and prepared in classic form, i.e. in the form of 2d drawings. The as-built inventory is selective and is done after the completion of construction, not including an inventory of disappearing works. The progress of the works is not recorded in the form of model records, but only as partial works acceptance reports.
Objects Involved	1. Structural elements (ex. foundations, reinforced concrete structures, prefabricated structures, wooden structures, metal structures, roofs, stairs, cranes and escalators, ceilings, ramps, windows, doors, railings, balustrades, skylights) 2. Installations (ex. equipment, ducts, cable trays, piping, installation accessories) 3. Landscape elements (ex. terrain, roads, small architecture including platform equipment) 4. Elements of temporary works (formwork, cranes, temporary installations, site development elements, existing infrastructure) In general, platform equipment includes benches, bins, information boards, among others. In Poland, the infrastructure manager is not always responsible for this part of the station. These are usually managed only for big railway

	stations.
Actors Involved	Stations involve data providers and data consumers including: Architects, Engineers (Construction, Plumbing, Heating, Ventilation & Air Conditioning, Electrical), station managers, surveyors, modellers, software engineers
Challenge	Specifying the required accuracy of object modelling depending on the construction process stage and the related required LOD level. Selection of measurement equipment and parameters for the data acquisition process to allow the object modelling at the referred level.
Risks	1. Long measurement data processing time and high data weight. 2. Choosing the timing of measurements according to defined needs. 3. Giving an adequate level of reliability to the measurements made
Opportunity	1. Increase the accuracy of the existing conditions documentation. 2. The ability to create inventory and as-built documentation based on taken measurements. 3. The ability to use models for visualization purposes. 4. Verification of the quantity of materials used and tracking of construction progress.

Section	**Response**
Name	Building systems analysis
Proposer	PKP
Domain	Station
Current Situation	The client's requirements and the current design process often do not require designers to include the necessary data for energy, lighting, ventilation, CFD fire and solar analyses in both 2D and 3D documentation. The necessary parameters for the above-mentioned analyses are difficult to access and hard to estimate at the design stage. The unavailability of clear specifications for the creation of 3D models limits the exchange of necessary information between different software vendors, so that the data are often underestimated and require the analyst to re-create the 3D model. This leads to a later incompatibility between the design and the built object.
Objects Involved	- Electrical installation, - Heating installation, - Cooling installation, - Abstract concepts such as: heat transfer coefficient, Losses (thermal bridges, material imperfections, equipment efficiency), - Flow sensors (air, smoke)
Actors Involved	Stations involve data providers and consumers including: • Client (data provider) - definition of the required level of building emissivity, estimation of the maximum limit of building energy demand, provision of assumed costs of building construction/operation, • Material provider (data provider) - provides thermal and moisture parameter of materials and their degradation over time, • Equipment manufacturer (data provider) - providing energy consumption parameters, cooling/heating power, lighting power, flow and loss values, inspection frequency, replacement of operating materials, • Designer (data consumer) - finding a balance between the client's requirements, current standards and regulations and available

	materials, equipment and technological solutions on the market, • Facility manager (data consumer) - continuous monitoring of the energy, heating or solar demand of the building, modification of the monitoring tool for future refurbishment or equipment replacement, estimation of costs and timing of refurbishment or replacement of operating materials,
Challenge	Development of a uniform data exchange interface between the model and energy/performance analysis software
Risks	1. The complexity and difficulty of entering parameters at the design stage will significantly increase the length and financial cost of the design process. 2. The possible non-continuous exchange of information can cause that a lot of work will not be used. 3. The need to continuously improve the competence of each actor increases costs.
Opportunity	1. Increased accuracy of energy analyses due to the use of a model with accurate geometric and non-geometric data. 2. Possibility of building variants using parametric modelling and optimisation of building energy consumption in both the design and operation phases. 3. Support for the building audit process. 4. Enable more efficient planning of costs and timing of refurbishment and replacement of maintenance materials.

7. Specification of the object extraction process

7.1. DB Use Case

The DB Business Case is being detailed with more information to evolve it to a use case. The DB Use Case contains additional details to implement a toolbox that shows how ETCS planning and engineering rules allows ERTMS to be implemented in a harmonised way. This will be shown at least on a section of the TEN (Trans-European Transport Network) starting with ScanMed (Scandinavian-Mediterranean corridor).
A collaborative digital assets engineering tooling will be delivered to create, maintain and enforce the common engineering rules and digital models.

Below, are details on the DB Use Case using the UC template specified in WP26 in the D26.1.
As anticipated at the start of this document, WP26 coordinates the work performed in the development of common digital enablers (Workstream 2), connecting it to the MOTIONAL project's workstream 1, to all other Destinations and to System Pillar activities.
It designs, deploys and executes the MOTIONAL project's process to collect use cases from all Destinations, complementing them with System Pillar guidelines, in order to drive development of digital enablers according to the Destinations' actual requirements, constraints and timelines.

At the time of completing this document, the D26.1 is still under review; however the key requirements of the UC template include:

Name	Descriptive name of the UC
ID	ID of the UC "UC-FP1-WPx-number"
Description	Short description of the UC
Related to task / subtask(s)	Precise task/subtask that this UC relates to (specification/implementation/demonstration)
Impact on other task(s)	Indicate the tasks that may depend on the result of this UC (dependencies identification)
Technical Enabler	Indicate TE involved "Nr.-Name"
Interactions SP/FP	Indicate when applicable the interaction between SP and other FP
Actor(s)	Involved Actors
Trigger	Action or event that triggers the UC
Pre-Condition(s)	What is the state of the system, which allows to perform the use case
Initial Input	Required input to execute the use case
Result/Requirement	What will be the expected result of the use case
Final state	If applicable, describe the expected finale state of the system after the use case was performed

Sequence	List the steps of the use case (to be filled during specification phase) 1. 2. 3.
Expected Implementation / Release Date	Date when the UC is expected to be ready for tests (Monthly/Year)
Involved components (Systems level)	List of software/hardware components that will be involved to run the UC (to be filled during the specification phase)
Responsible partner / person	Company or main contact who is responsible to describe this UC and guarantee the system design and implementation
Link to detailed document	
Notes	Additional notes of the UC

WP27 already started the collection of use cases using a simplified version of this template and below instead the DB use case filled using the WP26 template. This shall help to harmonize the inputs received from the other destination to facilitate further consultation with the Motional project, as it is requested in the DoA.

Name	Harmonized Digital Engineering Process and Data Exchange
ID	"UC-FP1-WP27-1"
Description	A collaborative digital assets engineering tool will be delivered to create, maintain and enforce the common engineering rules and digital models.
Related to task / subtask(s)	All WP27 tasks. In particular, five reference implementation projects for ETCS L2 or LR will be planned according to the findings, process and tooling of this use case (Task 27.4). As of now, potential references are Brenner (TEN T), Scheibenberg (Germany), Anonymous station (BELGIUM), ÖBB (Austria) A demonstration of the process using an industrialised tool is planned as part of the Task 27.5.
Impact on other task(s)	Tasks that may depend on the result of this UC (dependencies identification) include any task part of WPs of FP dealing with track data to. For example a sub-set of data used for signalling engineering are required also for track engineering and maintenance operation (e.g. for track condition monitoring and maintenance). In general, some WPs from FP1, FP2, FP3 and FP6 are affected .

Technical Enabler	Enabler 30: development of methodology supported by toolbox for digital assets engineering
Interactions SP/FP	Interaction between SP and FP1 is present for at least the following WPs: WP26 for sharing the identified use cases. WP28/29 for simulation implementation WP30 for support in the alignment between CCS-TMS Data Model and CDM WP31 for support on the candidate dataspace and sharing the use cases involving data providers and data consumer for track data. Interaction between SP and FP3 is not present but it could be foreseen of other use cases intend to use the same data for other purposes (e.g. track maintenance). An ongoing activity is being executed at the time of writing this document and the final list of relationships will be consolidated in the next tasks of WP27.
Actor(s)	**Infrastructure Managers** (DB, RFI, OBB). **Requirements providers** based on their use cases (SP, MER MEC, DB, OBB, CEDEX, SNCF, Voestalpine, IFE) **Actors responsible for rail lines operation and maintenance** (e.g., SNCF Réseau, DB NETZ, NS, EUROSTAR) **Modellers** (DB and SP) ensure the correct integration of different requirements into a comprehensive model that can serve all needs. **Data extraction tools** (MERMEC) that provide computational tools for digitizing the data required the engineering process. **Data validation tools** (Accenture) that provide tools to check the quality of the data. **Processing and visualisation tools** (DB) that provide computational tools for implementing the engineering process rules and visualise the outcomes. **Signalling suppliers** (Thales). **Signalling Project Manager** (Stefano Marcoccio, RFI)
Trigger	The use case is triggered by the need to plan and design the installation of the ERTMS on a line that is already equipped with a traditional signalling system.
Pre-Condition(s)	Pre-condition for the execution of the use case include: Availability of input data Input Data converted in the data format adopted by the toolbox (e.g. IFC, DWG, CSV, XLSX)

	Data uploaded on the toolbox
Initial Input	The following data sets are required as input to execute the use case: digital data according to the data specification engineering rules to be activated in the tool
Result/Requirement	Using the toolbox the engineers involved in design and planning can: Avoid manual and paper-based procedures that are considered non efficient and prone to error. Simulate different ERTMS installations to identify which one offers more traffic capacity so il allows to optimise traffic operation
Final state	The toolbox will visualise the outcome of the application of the engineering rules, final user can
Sequence	List the steps of the use case (to be filled during specification phase)
Expected Implementation / Release Date	It will be provided at the end of the specification phase.
Involved components (Systems level)	It will be completed by the end of the specification phase.
Responsible partner / person	*Kehinde Emmanuel Enisan* from DB describes this UC and guarantee the system design and implementation
Link to detailed document	Not available at the time of issuing this document.
Notes	**Data quality requirements** All the objects present on the field must be made available; otherwise the toolbox will not be fully representative of the field. The use case assumes that the data are accurate and valid. It is imperative that a procedure to guarantee that the requirements for data quality are met. Final users should not use data that has not undergone a verification and validation process. **Planned/required update cycles of the dataset.** The last data update is considered. In case a renewal work affecting the current signalling system occurred, this will require a re-surveying of the tracks affected by the renewal works.

	Aggregation level of the data set (pre-defined) network (operational nodes), macro (line level), meso, micro (track level), nano (component level) No aggregation required. **dataflow/ typical applications/tools/interfaces used today/ available in data formats as of today.** The current process involves manually and visually extracting data from PDFs, depreciated databases, and sometimes missing data. The tools available are custom-made and limited to each country, as they depend on existing data processes. The format in which information for the engineering are imported are DWGs, XLSXs, CSVs and the engineering output are printed on paper or delivered as the formats listed previously.

7.2. Object Extraction in the processes

The DB use case will be using a set of objects extracted in automatic mode from a data source to avoid or at least reduce the inefficiencies mentioned above and present in today practices.

The object extraction is one of the first steps in the overall process specified in [1] and that can be summarised and illustrated with the Figure 4 and Figure 5 below:

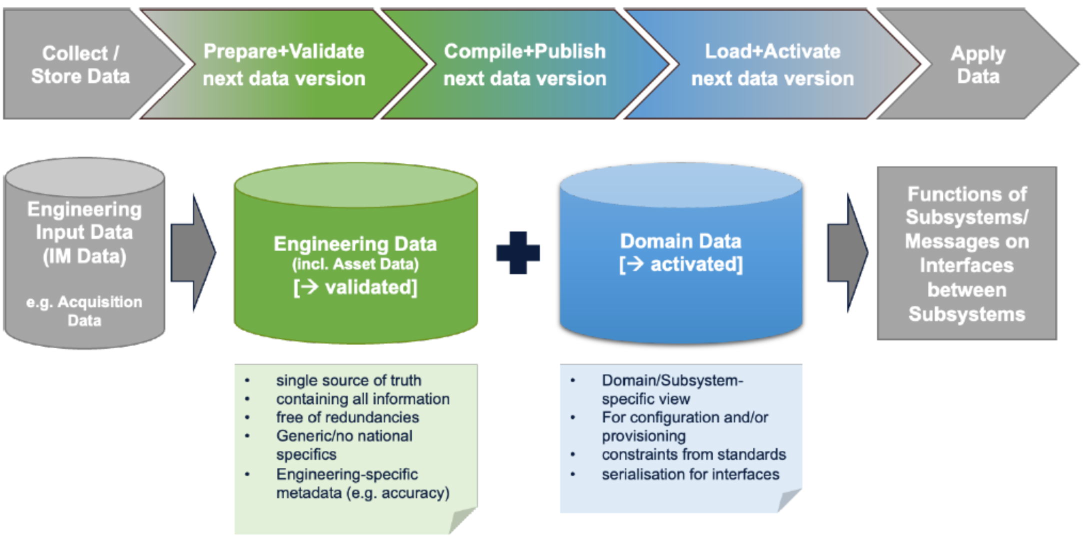

Figure 5: Main activities involved from data collection to data usage.

After the data are collected in the field, they are prepared and validated to generate the engineering data as the single source for the next steps. The extraction process does not include the transformation (Compilation) of this Engineering Data into the data structures as required by the consuming systems (referred to as Domain Data in TCCS CCS-TMS).

As part of TCCS CCS-TMS scope "*standardisation focuses on traffic/train CS, traffic management, or use cases such as diagnostics. Subsystems and interfaces are standardised within the System Pillar to implement functionality such as Train Protection or Automated Operation, representing different use cases (white) for Domain Data (blue) and its underlying Engineering Data (green).*" [1].

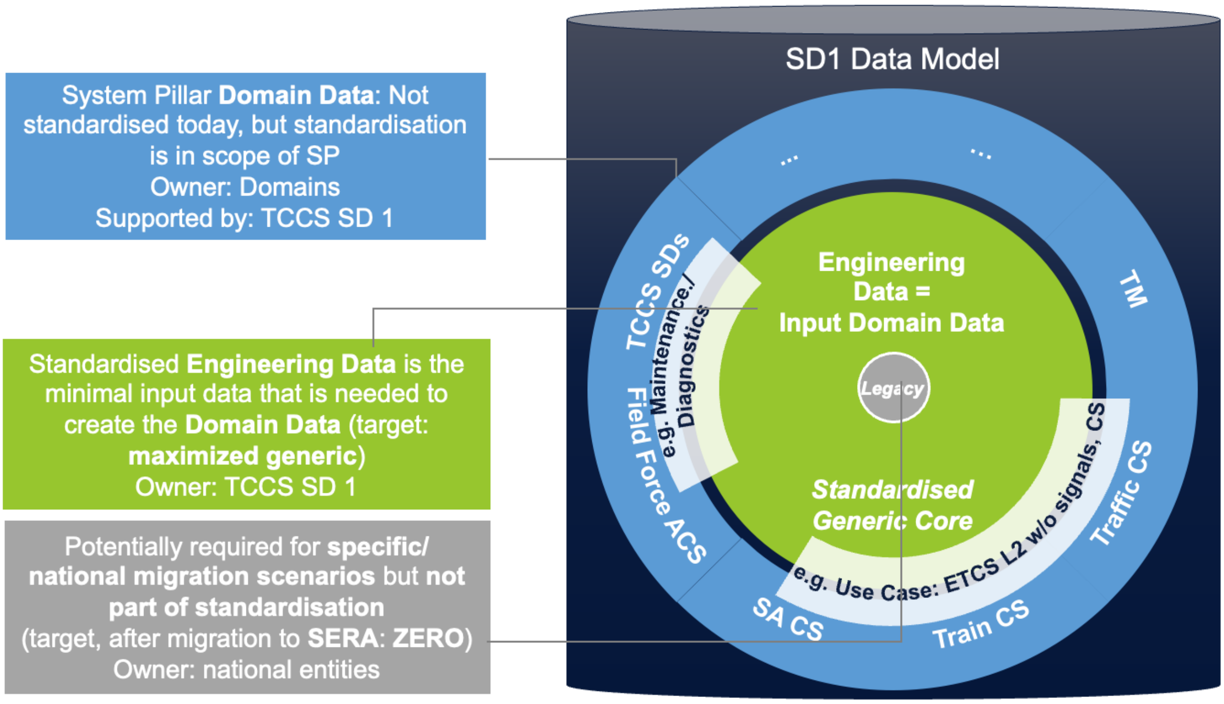

Figure 6: Scope of TCCS CCS-TMS from Engineering Data to Domain Data

7.3. Common Objects

Specific object types are required by DB Business Case and also required by the other use cases (with a high usage score e.g., track edge). The use cases refer to multiple phases of the asset life cycles as illustrated by the Figure 6 below:

Phase	CCS-TMS	MER MEC	DB	OBB	CEDEX	SNCF	Voestalpine	IFE	CAF	INECO
Planning	x		x	x						
Design	x		x							
Construction										
Commissioning					x				x	
Operation & Maintenance		x				x	x	x		x
Disposal										

Figure 7: Mapping of Asset Life Cycle Phase with Business Cases

Some DB Business Case identified objects related to the planning phase are used also in other phases confirming the transversality of the object across the process. Based on the analysis of the use cases identified in this document, the list of objects required can be ranked according to the number of times (namely Usage Score) the object is required across all the use cases identified within WP27.

Objects transversal to multiple business cases (ref. Figure 7 below) confirm the nature of the engineering data as well as set them as candidate to be extracted with higher priority compared to others less used.

TCCS SD1 Name	Item	MER MEC	DB	OBB	CEDEX	SNCF	Voestalpine	IFE	CAF	INECO
SPT2TS-49005	TrackEdge	x	x	x	x	x	x	x	x	x
SPT2TS-63836	TrackEdgeProjection	x	x	x	x	x	x	x		x
SPT2TS-49005	TrackEdgeLink	x	x	x	x	x	x	x	x	x
SPT2TS-63860	Maximum permitted speeds	x	x						x	
SPT2TS-122294	danger points		x							
SPT2TS-64101	crossing /slipCrossing	x	x	x	x	x	x	x		
SPT2TS-63833	Track Gauge		x							
SPT2TS-49048	Point	x	x	x	x	x	x	x		x
SPT2TS-49044	radius of curves	x	x		x	x		x	x	
SPT2TS-63833	Big Metal Masses		x							
SPT2TS-100570	Buffer stops		x							
SPT2TS-64102	Bridges (before and after)	x	x		x			x		x
SPT2TS-64100	Tunnels (tunnel portals)	x	x		x			x		x
SPT2TS-49102	Stop locations if there are any specified before hand		x							
SPT2TS-49105	Start points for a train		x							
SPT2TS-63833	Tunnel stopping area		x							

Figure 8: Mapping of Objects with Business Cases

The priority of some key data has been confirmed also in WP31. In the FP1 MOTIONAL, WP31 (Federated Data Space) has the objective to deliver data federation services for building a trusted, reliable, cybersecure federated data space for the rail. It is quite important for a federated data space to create value for multiple stakeholder groups, the more data consumers are willing to use the federated data space the more value it has, a data provider without a data consumer does not generate any value.

WP 31 has considered with high priority the following four business cases resulting from the task 27.1:

- Common Infrastructure Data for Infrastructure Condition Monitoring
- Cross Referencing travel and track maintenance data
- TCCS CCS-TMS Data Model
- Virtual Certification of Asset following build or maintenance

These use cases are being combined in one (within WP31) for efficiency and coherence, moreover other use cases (e.g., INECO Track Business Case) could be also linked because they share the same objects part of the common data model (developed as part of WP30).

An additional criterial to prioritize the objects to be extracted could be also the reference to existing standards. For example, EN standards could refer in explicit (naming an object or a class of objects) or implicit (naming a data type that is in general coupled with an object) mode specific object types. In the Figure 8 below, an example of relationships between objects and three selected EN standard is illustrated (ref. Appendices A – Referenced EN standards for more details on the content of the standard).

TCCS SD1 Name	Item	EN 13848	EN14363	EN12299
SPT2TS-49005	TrackEdge	Track Component	Track Component	Track Component
SPT2TS-63836	TrackEdgeProjection	Geo-spatial		
SPT2TS-49005	TrackEdgeLink	Track Component	Track Component	Track Component
SPT2TS-63860	Maximum permitted speeds	Line Speed	Line Speed	Line Speed
SPT2TS-122294	danger points			
SPT2TS-64101	crossing /slipCrossing	Switch&Crossing		Switch&Crossing
SPT2TS-63833	Track Gauge			
SPT2TS-49048	Point	Switch&Crossing		Switch&Crossing
SPT2TS-49044	radius of curves	Horizontal Alignment	Horizontal Alignment	Horizontal Alignment
SPT2TS-63833	Big Metal Masses			
SPT2TS-100570	Buffer stops			
SPT2TS-64102	Bridges (before and after)	Line features		
SPT2TS-64100	Tunnels (tunnel portals)	Line features		
SPT2TS-49102	Stop locations if there are any specified before hand			
SPT2TS-49105	Start points for a train			
SPT2TS-63833	Tunnel stopping area			

Figure 9: Mapping of Objects with EN standards

7.4. DB Business Case Attributes requirement and rules

The attributes considered relevant in the DB business case will be selected by fixing a set of engineering rules (for ETCS Level 2). At the time of writing this document, the set of rules to be considered for the use case has not been fixed. By correlating the rules with the object used, the required attributes can be identified. For example below you find the rule 3.2.6. (and related rule 3.15.2):

3.2.6. The minimum distance of an axle counter to a point or crossing SHOULD be the maximum expected vehicle overhang but MUST NOT be located behind the marker bord (see 3.15.2 Vehicle Overhang).
3.15.2. Vehicle Overhang
3.15.2.1. TVPS borders (and the respective train detectors) MUST be placed so that for every violation of the kinematic gauge the related TVPS becomes occupied.
This is especially important in case of points where the vehicle overhang must be added to the distance in which the TD has to be placed BEFORE the clearance mark of the point.
3.15.2.1.1. IFF the line is a High-Speed Line AND the track gauge g = 1435 mm: at a minimum distance of 5 m to the danger point
3.15.2.1.2. IFF the line is NOT a High-Speed Line AND the track gauge $g \in$ {1435 mm,1524 mm,1600 mm,1668 mm}: at a minimum distance of 4,2 m to the danger point.
3.15.2.1.3. IFF the line is NOT a High-Speed Line AND the track gauge = 1520 mm: at a minimum distance of 3,5 m to the danger point

This rule makes uses of a wide range of attributes such as: DangerPoint.id, DangerPoint.pos, DangerPoint.TrackEdge, etc. Both attributes and rules can be visualised in a heat map (Figure 9). The heat map can be used to

1) Showing the attributes used by a specific rule.
2) Showing the rules using a specific attribute.
3) Counting the number of attributes used by a specific rule or showing which rules use a specific attribute.

For example, from the heatmap the number of attributes for rule 3.2.6 can be counted and you can derive that the rule uses 25 attributes. Viceversa, for example the attribute *DangerPoint.pos* is used in four rules, namely:

- 3.5.12.3.2
- 3.5.17.2.1
- 3.15.2.1.2
- 3.15.2.1.3

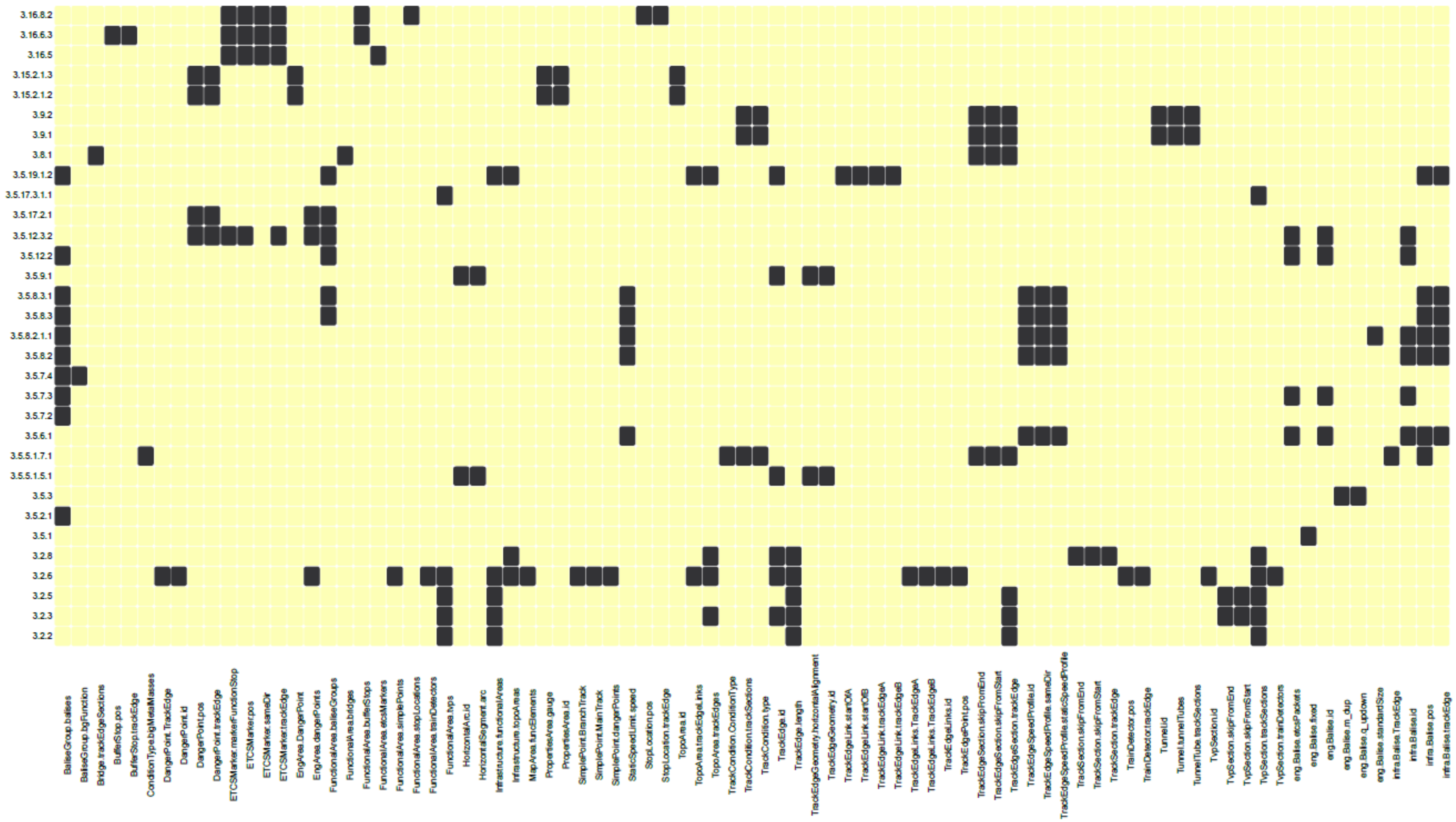

Figure 10: Heat Map for correlating attribute (x axis) with a rule (Y axis)

8. Data Samples

8.1. Template for data sources

In order to identify the data sources to be used for Task 27.2, the Data Sources are specified with the following template (Figure below); data available satisfying such requirements can be used for the object extraction projects (at least for the track related objects required by WP27).

	AERIAL SURVEYING - UAV LiDAR	TRACK VEHICLE SURVEYING
SYSTEMS	LIDAR, PHOTOGRAMMETRIC CAMERA	LIDAR, TRAIN LOCALISATION SYSTEM (GNSS+IMU+Odometry), 360° CAMERA (recommended)
SAMPLE DISTANCE	FRAMES GROUND: <=4 cm (optimal mean) <=8 cm (minimal mean) ORTHOPHOTO GROUND: <=5 cm (optimal) <= 10 cm (minimal)	FRAME 360° CAMERA: 8000x4000 (30 MP) FPS max 10Hz
FOV	<=±30 m for track assets only <=±120 m (includes buildings) <=±500m (includes power sub stations)	<=±30 m for track assets only
POINT CLOUD DENSITY	>= 9 pts/m^2(optimal mean) >= 4 pts/m^2 (minimal mean)	Between 1000 and 6500 pts/m^2 depending on the speed.
POINT CLOUD ACCURACY	Relative <= ±20 mm Absolute <= ±100 mm (Minimal)	Relative ±5 mm Absolute ±100 mm (Minimal)

Figure 11: Input Data for Object Extraction

A set of data samples have been analysed at the time of writing this document, they will be further analysed as soon as the Task 27.2 starts. The outcomes of the preliminary analysis of the collected data are described in the following sections.

8.2. Brenner Station Data

A set of data related to the Brenner Station have been received. The only data available at the time of writing this document include two PDF files, namely:

- Drawing of the schematic of the railway station
- Line Dossier

Unfortunately, this document format is designed to support visualisation and printing and not exchange of the data included. Both documents include relevant information for:

- Railway personnel, including train drivers, maintenance crews, and safety inspectors.
- Engineers involved in the track design and digital planning.

8.3. DB Data

For selected entities (TrackEdge, TrackEdgeProjection, TrackEdgeLink, Point) of the CCS-TMS data model the following data files have been received:

- JSON Schemas
- Data in XML format
- Data XLSX format (ref. Figure 11 below)
- XSD used to validate the XML files.

XSD are generated using a custom script developed by DB (the logic takes the JSON model and produce XML and JSON Schemas). The XSD validates the data structure and the data types, it does not validate the values themselves. Other railway specific validation rules are required to be full in control of the data quality. For example, you cannot have two curves with different radius on the same location.

id	name	length
8253c753-c18b-4da3-8668-38b170e3c211	[([1],0,000)->([1],388,851)]	388,851
b53daada-eeac-4de5-913e-502a0844c63c	[([3],0,000)->([3],510,259)]	510,259
db573abd-9833-41b5-9d32-d5e9d5f792e5	[([3],510,259)->([3],1373,615)]	863,356

Figure 12: Trackedge values in xlsx data format

8.4. OBB Data

OBB has executed a measurement campaign in May 2021 registering the line from Bruck/Mur to Graz (approx. 50km, double track -> 100 km).

The measurement campaign has generated the following data that could be used for further analysis:

- Point cloud in LAS-Format.
- Extracted objects, *.gml, extracted from this point cloud (Figure 12): track centreline, rails, platform edges.
- Track geometry in shp-Format (Available for the entire railway network)

Figure 13: Example of extracted objects: platform, rails and track centreline

9. Conclusions

The task 27.1 is a first step in the specification of the methodology for the digital planning of the ERTMS as specified in the WP27 scope of work. Today skilled signalling engineers painstakingly collect, interpret and filter entries in all sorts of files and plans. The repeated process of information exchange is wasteful, mostly because of costly error correction loops.
It is expected that the novel digital ERTMS planning approach will be based on a harmonised data exchange that make the signalling design process more efficient and effective.
Moreover, basic data objects (i.e., track topology, track geometry, track asset configuration), namely Engineering Data, used for ERTMS planning are needed also by other railway applications. This might confirm the transversality of the Engineering Data, as well as it could lead to identification of new opportunities to introduce benefits, not only in signalling but also in other domains.

As part of Task 27.1 a set of business cases that can take advantages on the usage of digital data were described with the contribution of several partners. The business case related to the digital ERTMS planning has been detailed and described using the template proposed by WP26 for the specification of the use cases.

We analysed the data on object level because the CCS-TMS Data Model attributes were considered sufficient. Our business cases confirmed the transversality of the Engineering Data, as well as identified some opportunities outside the signalling domain such as track diagnostic and data analytics for maintenance purposes. The task 27.1 did not produce any specific data model, because this activity is already addressed by the System Pillar CCS-TMS working group and does not belong to Task 27.1 scope.

It is up to the System Pillar governance process to analyse the extension of the data engineering with new attributes. Within WP27 we expect that the attributes required for each object (within any business case considered for implementation) are analysed and mapped to identify eventual gaps that can lead to a revision of the current engineering or domain data.

Based on the information collected and data samples available, the partners of WP27 consider the planned objectives of the task as achieved. WP27 will move from task 27.1 to task 27.2 to extract the required objects in the format required from a data source as well as to the other tasks. The extracted data could be used by both the WP27 toolbox and other railway applications as result of FP1 and other FP interactions. These interactions will require continuing the work started with the preparation of the use cases for the business cases presented.

10. References

EULYNX Data preparation model (https://eulynx.eu/index.php/dataprep/78-what-is-eulynx-data-preparation-2)

IFC-rail https://www.buildingsmart.org/standards/domains/railway/ifc-rail-project-phase-1/

Linx4Rail https://projects.shift2rail.org/s2r_ipx_n.aspx?p=LINX4RAIL

RailML (https://www.railml.org/en/)

RailSystemModel (https://rsm.uic.org/)

RCA (reference CCS architecture, https://eulynx.eu/index.php/news/45-rca-alpha-published)

System Pillar, TCCS CCS-TMS - Scope and Approach for Collaboration and Specification - 2023 (rev. 40951)

ULYNX Data Prep (https://eulynx.eu/index.php/dataprep/63-eulynx-data-preparation-model-public-snapshots)

X2R4. https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-4

11. Appendices A – Referenced EN standards

11.1. EN 13848

"EN 13848 - Railway applications. Track. Track geometry quality" is a multi-part document divided into the following parts:

- Part 1 Railway applications. Track. Track geometry quality. Characterisation of track geometry
- Part 2 Railway applications. Track. Track geometry quality. Measuring systems. Track recording vehicles
- Part 3 Railway applications. Track. Track geometry quality. Measuring systems. Track construction and maintenance machines
- Part 4 Railway applications. Track. Track geometry quality. Measuring systems. Manual and lightweight devices
- Part 5 Railway applications. Track. Track geometry quality. Geometric quality levels. Plain line
- Part 6 Railway applications. Track. Track geometry quality. Characterisation of track geometry quality

Part 2 specifies that the track features used for data localisation shall include at least:

- Line identification.
- Track identification.
- Kilometrage.
- Increasing/decreasing kilometrage.
- Events such as switches, level crossings, bridges, tunnels.

Other inputs may be required as, for example, the altitude for inertial devices. All these data shall be able to be entered by manual or automatic means.

11.2. EN 14363

This European Standard defines the process for assessment of the running characteristics of railway vehicles for the European network of standard gauge tracks (nominally 1 435 mm).

The assessment of running characteristics applies to vehicles which: are:

- Newly developed.
- Have had relevant design modifications.
- Have changes in their operating conditions.

The assessment process is based on specified target test conditions, for example test zones are defined according to ranges of radius value, so the horizonal alignment data are required.

11.3. EN 12299

This standard specifies methods for quantifying the effects of vehicle body motions on ride comfort for passengers and vehicle assessment with respect to ride comfort. The following track characteristics should be described in the test report:

- Length and location of the test zones
- The designed geometry through table or schematic drawing
- Type of track and identification of the category
- Location of the track features e.g. Switches & Crossing, etc.)
- Planned speed profile.

The horizontal alignment data covers the requirement at point 2.

12. Appendices B – Data Model Schema

12.1. CCS-TMS data model

The CCS-TMS data model follows a compositional tree structure, wherein the root of the model is a composition of several packages that constitute the CCS-TMS data model (e.g., Infrastructure, Restrictions, Rolling Stock, etc.), as shown in the Figure 13 below. Every package can be divided into sub-packages (e.g., TopologyArea, GeometryArea, etc.) depending on its needs. The Figure 13 below depicts the CCS-TMS model structure with the current included content:

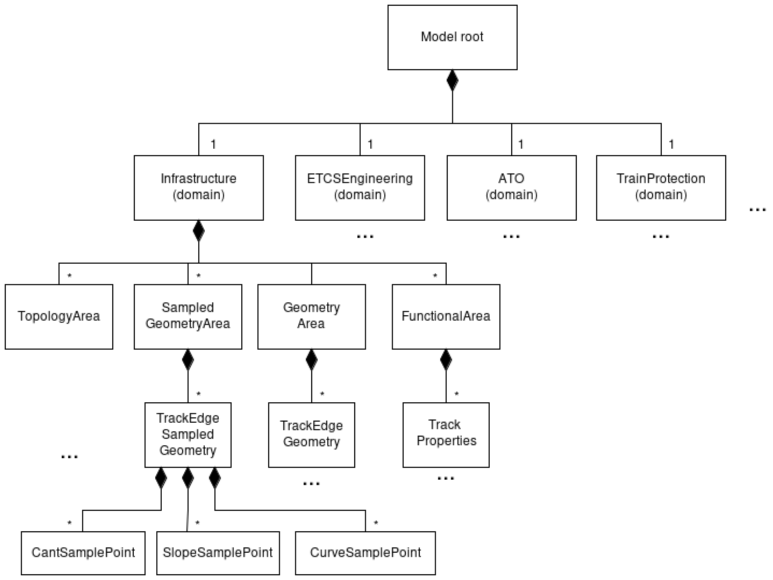

Figure 14: CCS-TMS model structure