Deliverable 25.1

Report on the basic functional and technical specifications for the realisation of the technical enablers of Seamless Freight, also including the final specification input for FP1

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Report contributors		
Name	Beneficiary Short Name	Details of contribution
Felix Hildebrandt	Hacon	Lead Author
Lars Deiterding	Hacon	10. Multimodal Integration
Thomas Walker	Hacon	5. Seamless Planning
Monica Pelegrin Alejandro Mendizabal Manuel Bueso	ADIF	8. European Railway Checkpoints: Process analysis - Connections to TMS on main lines
Alejandro Perez Iñigo Adin Alfredo Artiles	CEIT	8. European Railway Checkpoints
Rico Wohlrath	DB Cargo	8. European Railway Checkpoints: Background description – Germany; Process analysis; Connection to TMS on mail lines; Considered use cases
Dr. Christopher Klein	DB Cargo	8. European Railway Checkpoints: Background description – Germany; Considered use cases
Lea Goldberg	DB Cargo	8. Considered use cases
Kay Gade	DLR	6. Seamless Planning

Andreas Lischke		10. Multimodal Integration 11. Seamless Data Exchange
Roald Lengu Giorgio Salvitti	Hitachi Rail	8. European Railway Checkpoints: Technical specifications
Rodrigo de la Iglesia Jose Manuel Gonzalez Alejandro Diaz	Indra	8. European Railway Checkpoints: Technical specifications
Dr. Behzad Kordnejad	KTH	1. Executive Summary 8. European Railway Checkpoints: Editor; Background description; Process analyses; Harmonized procedures and regulations 12. Conclusions
Dr. Ingrid Nordmark	KTH	8. European Railway Checkpoints: Editor; Background description; Process analyses; Harmonized procedures and regulations
Dr. Niloofar Minbashi	KTH	7. Intermodal Prediction: Terminal departure prediction model (based on yard departure prediction model)
Mohammad Al-Mousa	KTH	5. Seamless Planning: Identifying requirements for establishing reliable planned time of arrivals from yard/terminal departure predictions
Florian Thiery	LTU	8. European Railway Checkpoints: Technical specifications
Bente Yedema	ProRail	8. European Railway Checkpoints: Background description – the Netherlands; Process description
Paul Kootwijk	ProRail	8. European Railway Checkpoints: Background description – the Netherlands; Process description
Marcel Gerrits	ProRail	8. European Railway Checkpoints: Background description – the Netherlands; Process description
Martin Kjellin	RISE	8. European Railway Checkpoints: Background description; Interoperable IT systems for data management and processing, internal review of ch.8
Dr. Martin Aronsson	RISE	8. European Railway Checkpoints: Process

		description terminals
Yves Sterbak	Thales (GTS)	8. European Railway Checkpoints: Background description – Data sharing; Interoperable IT systems for data management and processing
Mats Åkerfeldt	Trafikverket	8. European Railway Checkpoints: Process description borders, intermodal terminals, yards
Melissa Tijink	Twente University	8. European Railway Checkpoints: Process description borders, intermodal terminals, yards
Thomas Pum	ÖBB-RCA	8. European Railway Checkpoints: Background description – Austria; Process description borders; Harmonized procedures and regulations
Johan Östling	RISE	11.1 General introduction and background description 11.2 The Purpose for Data Exchange 11.3 Comprehensive Repository of Existing Systems and Standards Initiatives and Technological Solutions
Eddie Olsson	RISE	11.1 General introduction and background description 11.2 The Purpose for Data Exchange 11.3 Comprehensive Repository of Existing Systems and Standards Initiatives and Technological Solutions
Markus Brachner Marie Lindland	SINTEF	5. Seamless Planning – long-term first- and last-mile planning systems and functions 6. Dynamic Dispatching
Angela Nocita Camilo Puerta Patino Valerio Poggi Filippo Massari	RFI	6. Seamless Planning 8. Intermodal prediction – Use Case 11. Multimodal Integration – Use Case 12. Seamless data exchange
Eric Feyen	UIRR	7. Intermodal Prediction – process analysis, timestamps, milestones
Saioa Arrizabalaga Nasibeh Mohammadzadeh Santiago Figueroa Itxaro Errandonea	CEIT	11.4. Identification of general principles for data sharing and data structure (11.4.1) 11.4.3 Investigation of data sharing, auditing and monitoring techniques
Sneha Gosavi Anders Ekmark	LSP	11. Background - Seamless Data Exchange

Reviewers		
Name	*Beneficiary Short Name*	*Details of contribution*
Björn Bryne	NRD	Main auditor/Official Review and Feedback
Kay Gade	DLR	Official Review and Feedback
Markus Brachner	SINTEF	Official Review and Feedback

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1 Executive Summary

The Seamless Freight cluster is part of the TRANS4M-R project and the Europe's Rail initiative. It aims to deliver an essential contribution towards the modernization, digitalization and harmonization of multimodal rail freight. By addressing various technical enablers identified in the MAWP, Seamless Freight bridges the gaps between actors, countries, systems, processes and transport modes.

Against this background, this Deliverable is the main output of the specification phase and includes the relevant requirements, both functional and non-functional, the main use-cases and use-case environments as well as a description of relevant systems, data types, processes and challenges. These specifications build on the basic requirements identified in the scope of the Deliverables D25.2 and D25.3. The contents of this deliverable are the result of an extensive and iterative process, involving relevant stakeholder groups (IMs, RUs, TOs, YOs, CTOs and shippers) that are all part of the TRANS4M-R team. The specifications are structured according to the different work packages, in which the solutions, that are necessary to fulfil the objectives of Seamless Freight, will be developed.

True seamless planning must result in perfectly consistent planning and allowing for smooth transition and continuity for all actors involved along the entire transport chain as well as all assets required for operating the railway system. Seamless planning therefore encompasses all planning horizons (e.g. long- and short-term as well as real-time), all planning environments (e.g. yards, terminals and all connecting infrastructure) and involves a variety of complex planning systems and processes. All these aspects feed the derivation of requirements for planning systems and their interfaces, with additional consideration of the interconnection to dispatching and keeping the information on line and network capacity updated for all actors, in order to achieve true seamless planning.

Dynamic Dispatching has focussed on the constraints of today, that hinder optimized processes due to lack of real-time information. An intensive exchange with end customers and stakeholders has led to several use cases which shall at an international level prove that harmonization and the dynamic adaption of tasks due to real-time information will lead to higher efficiency and maximizing the use of existing infrastructure.

Intermodal Prediction Systems, forecasting both the ETA and the ETD for pre-defined milestones by using advanced machine-learning models, enhance the transparency and reliability of rail freight. The systems use various TAF TSI and EDIGES message types as basis input. Its quality is evaluated using pre-defined TAF TSI KPIs. Main applications for the prediction values are the optimisation of terminal and yard processes as well as the assignment and planning of rolling stock utilization (Asset Warehouse).

The concept of Standardised European Railway Checkpoints is a further development of the previous work carried out in Shift2Rail and the concept of "Intelligent Video Gates"

(IVG). The main objective was thus a further development of the previous work. Moreover, in FP3 Checkpoints are also developed but at main lines for both freight and passenger trains. Hence, one main aim was to give a clear and through background description, including existing similar systems that the IMs in T25.4 currently possess. Process descriptions were carried out for three types of operational stops for freight trains; intermodal terminals, marshalling yards and borders. Opportunities for improving these processes though the use of Checkpoints as well as a vast set of use cases were identified. Functional and non-requirements were developed. Based on the process analysis and the defined requirements, technical specifications were outlined for detection technologies and for data sharing. Albeit technical standardisation has been addressed, further work is needed to be carried jointly between the System Pillar sub-project Harmonized European Railway Diagnostics (Herd), FP5 T25.4/WP29 and FP3 WP7. Thus, the specifications outlined in this report will be the basis for a standardised development and installation of Checkpoints within WP29.

Multimodal Integration has focussed on the constraints of today, that hinders simple bookings of freight on rail. Three primary reasons have been identified that will be tackled by use cases. The time-consuming process of finding existing freight train services, the complexity to book services if more than one primary supplying company is involved and the difficulty to establish new services where today's offering is not yet matching the market demand. All shall demonstrate that harmonized and standardized process and data exchange will lead to higher usage of existing infrastructure due to lowering entry barriers.

All this requires a high degree of collaboration between the involved actors both within and often across national borders. Today, there is a call for better synchronisation within and between transport practices. Big hopes are being placed on digitalisation as an enabler and means for integrated and sustainable performance along the multi-modal supply chain. The primary objective for enabling data exchange is to provide a framework that allows a seamless and harmonised exchange of data. This framework aims to facilitate an increased data availability and quality by reducing technical and administrative barriers for the generation and exchange of data in the project. This framework will be built on existing developments rather than introducing new elements.

2 Abbreviations & Acronyms

Abbreviation / Acronym	Description
ABD	Acoustic Bearing Detector
ABD	Axle Bearing Detector
Ac	Actor
ADR	Accord relatif au transport international des marchandises Dangereuses par Route
AI	Artificial Intelligence
ATTI	Automated Freight Train Transfer Inspections
BAM	Bearing Acoustic Monitor
C-DAS	Connected Driver Advisory System
CDM	Conceptual Data Model
CIP	Customer Information Platform
CMR	Convention Relative au Contrat de Transport International de Marchandises par Route
CNN	Convolutional Neural Network
CTO	Combined Transport Operator
DCM	Digital Capacity Management
DDT	Documento di Trasporto
DPC	Detektor-PC
ECMT	European Capacity Management Tool
EDICT	Enhanced Data Interoperability for Combined Transport stakeholders
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
EVN	European Vehicle Number
EWC	European Waste Codes
FIR	Formulario Identificazione Rifiuti
GCU Appendix 9	Appendix 9 to the General Contract of Use for Wagons: Technical Conditions for Wagon Transfers between Railway Undertakings
GDPR	General Data Protection Regulation
HABD	Hot-Axle Bearing Detector
Herd	Harmonized European Railway Diagnostics, *sub-project in System Pillar*
HWD	Hot-Wheel Detector
IDS-RAM	Industrial Data Spaces Reference Architecture Model
ILU	Intermodal Loading Unit, *containers, swap-bodies and semi-trailers*
IM	Infrastructure Manager

InGa-Z	Intermodales Gate der Zukunft (intermodal gate of the future)
IVG	Intelligent Video Gate
LIDAR	Light Detection and Ranging
LSP	Logistics Service Provider
LU	Loading Unit
ML	Machine-Learning
MVP	Minimal viable product
OCR	Optical Character Recognition
PaPs	Pre-arranged Paths
PCS	Path Coordination System
PIC	Piattaforma Integreta Circolazione
PIL	Piattaforma Integrata Logistica
RCMF	Railway Coordination Messaging Format
RFID	Radio Frequency Identification
RID	Regulations concerning the International Carriage of Dangerous Goods by Rail
RNE	Rail Net Europe
RU	Railway Undertaking
TAF TSI	Technical Specification for Interoperability relating to Telematics Applications for Freight Services
TAO	Track Assignment Optimizer
TCR	Temporary Capacity Restriction
TIS	Train Information System
TMS	Terminal Management System
TMS	Traffic Management System
TO	Terminal Operator
TOS	Terminal Operating System
TTR	Timetable Redesign for Smart Capacity Management
TTS	Track-Time Slot
UIC	Union Internationale des Chemins de fer
WDD	Wheel Defect Detector
WILD	Wheel Impact Load Detection
WIM	Weight in Motion
WMS	Wayside Monitoring System
WMS	Wheel Measurement System
WOBU	Wagon-On-Board-Unit
WTMS	Wayside Train Monitoring Systems
XML	Extensible Markup Language
YCS	Yard Coordination System
YDS	Yard Dispatching System

YMS	Yard Management System
YO	Yard Operator

3 Glossary

Term	Definition
Intermodal Operator	A transportation modality which uses standardized cargo units (such as containers, swap bodies and semi-trailers) that can be easily moved across different modes of transportation (such as ships, trucks or trains) to be brought to destination
Combined Transport Operator	Intermodal transport chain with the focus on the road for the first and last mile
Railway Undertaking (RU)	A company or entity that operates services and transportation of passengers and/or freight by rail
Infrastructure Manager (IM)	An entity responsible for the management, maintenance, and development of the railway infrastructure, which includes tracks, stations, signalling systems, bridges, tunnels, and other facilities necessary for the safe and efficient operation of trains
Intermodal	The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes." By extension, the term intermodality has been used to describe a system of transport whereby two or more modes of transport are used to transport the same loading unit or truck in an integrated manner, without loading or unloading, in a [door to door] transport chain.
Multimodal	Carriage of goods by two or more modes of transport. It extends the intermodal option and is a prevalent method for transporting freight. In multimodal transport, goods are transported door-to-door using at least two modes of transport. Unlike intermodal transport, there is a possibility of reloading when changing modes. Importantly, the number of branches in the transportation route does not affect the number of transport contracts; it remains one.
Intelligent Video Gate (IVG)	Consists of a gate system installed at relevant railway nodes and equipped with cameras and RFID readers for automatic identification

	of wagons and intermodal loading units
Intermodal Loading Unit	A standardized container or cargo unit designed for seamless transportation across different modes
Container	A standardized cargo unit used for the efficient transportation of goods (20-foot or 40-foot lengths)
Use case	One distinct application of a system/function
Use Case Environment	Geographical area in which the implementation of multiple use cases leads to a development of dedicated systems/functions and where these developments will be demonstrated
Long-Term Planning Period	Means a period of time usually limited by the moment when it is possible to establish and make changes to objects such as transport, train and its resources with sufficient lead time before implementation
Short-Term Planning Period	Means the time period bounded above by a long-term time period and ends a few hours, maximum 1 day before the realization
Real-Time/Operational Period	This period starts a few hours before the beginning of the transport, through the actual running of the train, until the end of the transport
Artificial Intelligence (AI)	Technologies to make machines think and act more like humans
Machine Learning (ML)	Science of developing algorithms and statistical models that computer systems use to perform complex tasks without explicit instructions. ML is one of the AI branches.
Common Data Model	A common data model aims to standardize that logical infrastructure so that many related applications can operate on and share the same data
Conceptual Data Model	Data model of the railway system focused on project- and platform-independent representation of the conceptual constituents of the rail system. The Conceptual Data Model adheres to a semantic approach. It leverages industry standards and federates from specialist modelling initiatives, where present, to model the various domains of the rail system.
Cybersecurity	A Method of protecting computer systems, networks, and digital information from unauthorized access, attacks, and damage to

	ensure confidentiality, integrity, and availability of data
Timetable	A scheduled plan with organized information about the arrival and departure times of trains at various stations along a railway network
Train Path	A scheduled time slot on a railway track allocated for the movement of a specific train
Dispatching	Dispatching in Terminals and Yards is understood as the prioritization of actions and tasks in order to lower downtimes and make the maximum use of infrastructure
Terminal	A location where trains begin or end their journeys and where various operational activities take place. They play a crucial role in the transportation network by facilitating the loading/unloading processes and transfer of passengers or freight between different modes of transportation
Yard	An area where trains are assembled, disassembled, sorted, and stored
Hump yard	A specific type of rail yard designed for classifying or sorting railcars based on their destination
Flat yard	A type of rail yard where railcars are classified and assembled using flat switching (ailcars are moved horizontally between tracks)
Track-Time-Slot	Specifies at which track and at which time a train should be served, e.g. for loading or maintenance
Corridor	A Rail Freight Corridor (RFC) is a designated rail route between two or more countries in the European Union that connects two or more stations along a main route.
TRANS4M-R	Transforming Europe's Rail Freight – The overall goal is to establish rail freight as the backbone of a low-emission, resilient European logistics chain which fulfills end-user requirements to full satisfaction
Railway Collaborative Decision Making (RailwayCDM)	A cooperative process where various participants within a system collaborate to exchange information, coordinate activities, and collectively make decisions to enhance efficiency, effectiveness, and overall system performance.
Functional Requirement	Functional requirements define what a product/system must or should be able to do.

Non-Functional Requirement	Non-functional requirements define how a system should function. They typically tell us something about the performance of the system.
Milestone	The status or geographic position of a train, wagon set or loading unit in the transport process.
Timestamp	The digital record of the time of occurrence of a particular milestone.
FEDeRATED	EU project for digital co-operation in transports based on principles of semantic technology and distributed data sharing.
Block train	A dedicated and direct freight train in most cases for one customer operating from origin to destination with the aim of keeping lead times short
Intermodal train	Freight train that carries *Intermodal Loading Units*
Single Wagon Load train	Freight train transporting individual, mixed class of wagons carrying smaller, diverse shipments from different shippers

4 Background and Objective

The present document constitutes the Deliverable D25.1 “Report on the basic functional and technical specifications for the realisation of the technical enablers of Seamless Freight, also including the final specification input for FP1” (also referred to as “Seamless Freight Specifications”) in the framework of the Flagship Project FP5- TRANS4M-R as described in the EU-RAIL MAWP and contributes as well to the Flagship Project FP1 - MOTIONAL.

The project aims to boost innovation for the European rail freight sector, concretely by developing, validating and demonstrating FP5-TRANS4M-R technical enablers. The work to reach this level of TRL is complex and thus divided into several work packages highly dependent on each other. See WP structure in Figure 1 below.

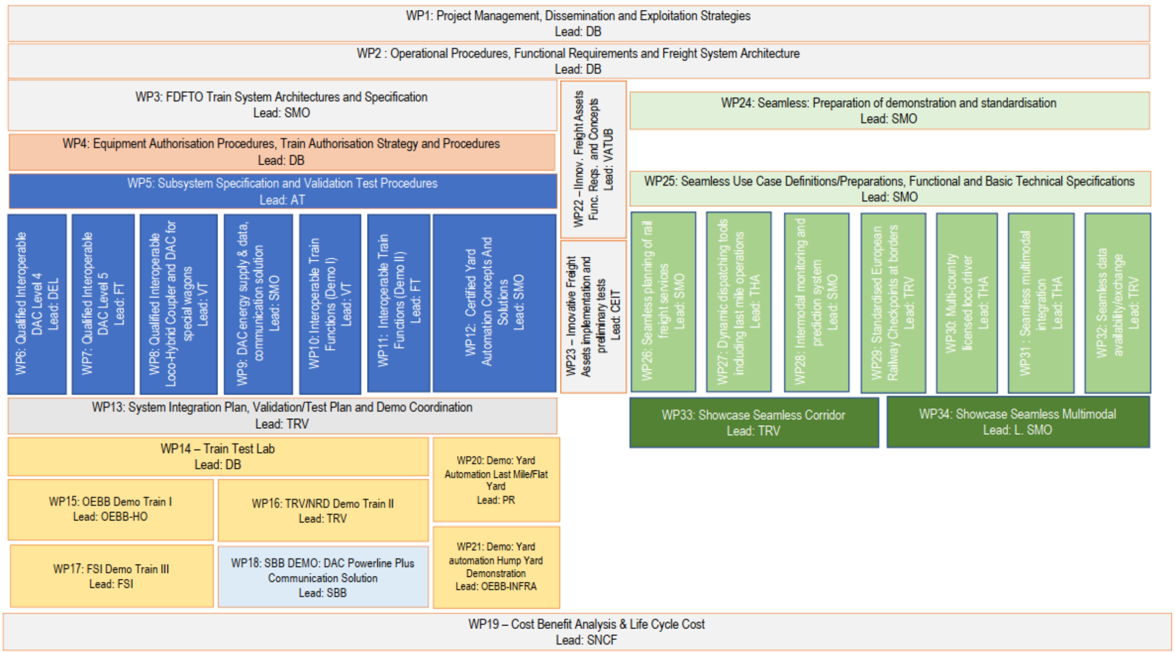


Figure 1: WP structure in FP5-TRANS4M-R

WP25 combines and conducts the specification efforts for the entire Seamless Freight subgroup, therefore giving input to all subsequent developments that will be done in the work packages 26 to 32 and ultimately demonstrated in WP33 and WP34.

To ensure a high degree of interoperability, these specifications take into account as much as possible already existing standards and ontologies as well as the results from relevant projects, such as Shift-2-Rail, and available platforms/data hubs like KV4.0 and RNE TIS. These respective standards etc. will be addressed in the respective relevant subchapters, most notably in Chapter 10 Seamless Data Exchange.

The objective of this document is to provide high-level specifications for a Seamless Rail Freight in Europe. The document was deliberately made public to provide these definitions, requirements and functions not only to the TRANS4M-R project, but also to the sector itself. These specifications will define the basis for the development of the innovations of WP26-WP32 and thus ultimately contribute to the realisation of the technical enablers defined in the MAWP.

The core of this document are the task-based specifications, which aim to fulfil the objectives of the specification phase as stated in the Grant Agreement. Each task/subsequent development work package has its own separate chapter:

- Seamless Planning – Chapter 5
- Dynamic Dispatching – Chapter 6
- Intermodal Prediction – Chapter 7
- Standardised European Railway Checkpoints – Chapter 8
- Multimodal Integration - Chapter 9
- Seamless Data Exchange – Chapter 10
- Multi-Country Licensed Loco Drivers – not included, as the WP is not part of WP25 and will kick off in 2024.

4.1 Link between GA objectives and chapters in the Deliverable

Table 1 links the tasks described in the Grant Agreement for the related WP25 objectives to the respective chabpters of this Deliverable that will feature these elements.

Task (GA)	Task 25.1 Specifications for Seamless Planning	Output of deliverable
Task 25.1	Identify high-level specifications and requirements for the technical functionalities of freight specific cross-border and last mile planning functions and connected systems.	Chapter 5.1
Task 25.1	High level specifications and requirements of information systems for (short-term) operations/capacity planning.	Chapter 5.2 (long-term planning) and 5.3 (short-term planning)
Task 25.1	Capacity view/forecast web frontend for the backend web service developed in FP1.	Chapter 5.4
	Task 25.2 Specifications for Dynamic Dispatching	**Output of deliverable**
Task 25.2	Identify and describe dynamic dispatching requirements and constraints that are specific for last mile operations in terminals/yards to reduce knowledge barrier for operators and freight forwarders to access any terminal or	Chapter 6.2 and 6.3

	yard	
Task 25.2	Relate to a strong demand management from the multimodal industry via a substantial part of market stakeholders in multimodal freight and in strong alignment with other Work Packages and Flagship Projects	Chapter 6.3
	Task 25.3 Specifications for Intermodal Prediction Systems	
Task 25.3	Define the requirements of data needed for a prediction and monitoring system. Definition of functional and technical requirements.	Chapter 7.3, Appendix 14.2 (Seamless Freight Requirements)
Task 25.3	Identification and description of processes of terminals and yards that are relevant for an intermodal prediction system.	Chapter 7.1, Chapter 7.2, Chapter 7.5, Chapter 7.6
Task 25.3	Description of connection points and interface requirements.	Chapter 7.3, Chapter 7.5
	Task 25.4 Specifications for Standardised European Checkpoints	
Subtask 25.4.1	Background description	Chapter 8.1
Subtask 25.4.2	Process analyses for digitalisation and automation at borders or other operational stop points: - Subtask 25.4.2.1. IVG checkpoints at borders, including analysis of inspection agreements in Europe such ATTI (Agreement on Freight Train Transfer Inspection). - Subtask 25.4.2.2. IVG checkpoints at intermodal terminals - Subtask 25.4.2.3. IVG checkpoints at yards - Subtask 25.4.2.4. Connection from IVG checkpoints to traffic management on main lines (alignment with FA3) - Subtask 25.4.2.5. Considered use cases	Chapter 8.2
Subtask 25.4.3	Define new functional and non-functional requirements for standardised checkpoints at borders and other operational stops based on the process analysis in 25.4.2	Chapter 8.3
Subtask 25.4.4	Technical specifications: - Subtask 25.4.4.1. Image processing - Subtask 25.4.4.2. Other identification and detection technologies - Subtask 25.4.4.3. Technical standardisation for image processing and other identification and detection technologies	Chapter 8.4

Subtask 25.4.5	Interoperable IT-systems for data management and processing: - Subtask 25.4.5.1. Data sharing for cross-border transports Subtask 25.4.5.2. Data sharing for internal management of other operational stops - terminals - Subtask25.4.5.3. Data sharing for internal management of other operational stops - yards - Subtask 25.4.5.4. Data sharing for traffic management on main lines. Communication to TMS will be used to provide real-time actions to minimize traffic disruptions. Connection to C-DAS will be assessed. - Subtask 25.4.5.5. Standardisation of data management and processing (give input to 5: Standardisation management (prep of TSI revision), TT and other WP's)	Chapter 8.5
Subtask 25.4.6	Harmonized procedures and regulations	Chapter 8.6
	Task 25.5 Specifications for Dynamic Dsipatching	**Output of deliverable**
Task 25.5	Identification of the different systems and modules of those systems, that are currently under development or already existing in different countries.	Chapter 10.2 and Chapter 11.3
Task 25.5	Examination of customer requirements and user roles of these systems with respect to multimodal freight transport.	Chapter 10.1 and 10.2
Task 25.5	Analysis on how the various systems involved in the offer of an intermodal chain can be seamless combined, how their specific functionalities can be connected or interact and to define further development needs for specific missing functional and technical requirements.	Chapter 10.3
Task 25.5	This includes a high-level preparation of the specifications for these different modules, and how they are aligned between each other, so that they work seamlessly together in order to achieve a seamless multimodal experience.	Chapter 10.4
	Task 25.6 Specifications and use case definition for Seamless Data Exchange	
Task 25.6	Identification of general principles including the administrative barriers in the data exchange processes	Chapter 11.4
Task 25.6	Investigate aspects of data sharing as well as auditing and monitoring techniques.	Chapter 11.8
Task 25.6	Define a Conceptual Data Model (CDM) for a structures data exchange on checkpoints and relations between them.	Chapter 11.12

Task 25.6	Examine the areas where the data exchange is required	Chapter 11.6, 11.7
Task 25.6	Analyse the results from demonstrations of data sharing concepts.	Chapter 11.6, 11.7

Table 1: Tasks described in the Grant Agreement for the related WP25 objectives which are linked to the respective chapters of this Deliverable.

4.2 Seamless freight requirements

One of the main outcomes of the specification phase for Seamless Freight is a harmonized list of requirements. Although the methodology of the specification processes closely follows the connected development work packages (and are therefore separated in different chapters in this report), many requirements are linked across the WPs. These links exist not only within different work packages of Seamless Freight, but also between FP5 TRANS4M-R and FP1 MOTIONAL.

Therefore, experts from FP1 were continuously involved in the process of developing the requirements. This ensures not only that these requirements are useful input for FP1, but also harmonizes the resulting FP1 interfaces and developments with these requirements. This is essential in order to successfully integrate the respective functions and systems from FP1 into the Seamless Corridor demonstration showcase (WP33).

The comprehensive list of requirements can be found in Appendix 13.2.

5 Seamless Planning

Rail freight transport is a complex system that is influenced by a variety of factors, including the transport demands of various logistics stakeholders, the growing environmental consciousness of shippers, and the limited availability of rail related resources like infrastructure, capacity and staff. The main challenge for rail freight transport companies is to bundle diverse logistical requirements of all parties involved and to offer an efficient, designated and customised transport system comprising infrastructure, rolling stock and staff. This is a complex task, as it requires the coordination of a variety of different planning systems and processes.

The goal of the seamless planning initiative in the TRANS4M-R project is to outline the requirements for path planning systems, significantly impacting rail freight transport by addressing constraints imposed by rail infrastructure.

Seamless Planning (Chapter 5) delineates these requirements and serves as input for Flagship Area 1 (FA1). This chapter not only establishes prerequisites for path planning systems but also considers their interfaces with other pertinent planning systems utilized by freight train operators, yard and terminal managers, and those overseeing significant sidings, such as ports, across the entire rail transport chain. Additionally, it acknowledges the interconnectedness between planning and dispatching, especially in scenarios like short-term path planning and adjustments to existing train paths due to factors like line reconstruction or changes on the shipper or receiver side.

Chapter 5.2 concerns long-term planning of the rail freight service on the first and last mile of transport. An end-to-end process map is provided along with descriptions of how long-term planning processes are relevant for different parts of the service chain, focusing on yards and terminals. System requirements, functions and capabilities to achieve more seamless long-term planning are discussed.

Responding to real-time changes with direct impact on transportation implementation, including planned/utilized resources the period is described in Section 5.3. is defined from 12 hours before transport to real time. A description of the process and differences between planning and dispatching with partners (RUs) is provided. The section deals with description of input data from short-term planning for dynamic dispatching. Differences in time horizon between short term planning and dynamic dispatching and also specifying common functions for short term planning and dynamic dispatching are defined.

Planning and operation of trains requires the latest up to date information on the capacity of specific lines and network sections for all involved actors. Chapter 5.6 outlines the development of a web frontend system providing a view on the current capacity and its forecasted development. This includes managing TCRs.

Long-term means a period of time usually limited by the moment when it is possible to establish and make changes to objects such as transport, train and its resources with sufficient lead time before implementation. These objects are not affected by short-term and operational changes or irregularities. This period may represent the preparation of the annual timetable and its regular changes. The minimum time is in the order of weeks before the intended realization of the transport.

Short-term means the time period bounded above by a long-term time period and ends a few hours, maximum 1 day before the realization. In this period, there are changes to already existing objects from the long-term plan, and new objects can be created, which, however, are already affected by the impact of the anticipated changes in this period. In the short-term period, the long-term plan is refined according to the current state of knowledge.

Real-time or operational control represents the period when reactions and changes occur depending on unforeseen facts. This period starts a few hours before the beginning of the transport, through the actual running of the train, until the end of the transport. Most of the processes take place in real time during this period.

5.1 Requirements for path planning systems (input towards FA1)

The planning of train paths is a process that has to consider the individual requirements of several stakeholders, like shippers, operators of ports, intermodal terminals and marshalling yards, as well as rail transport operators and infrastructure managers. The number of stakeholders involved, the type and amount of information required and the plannability of the train paths (long-term and during a timetable period train paths) can vary and depend, among other things, on the type of freight train. A distinction is usually made between:

- **Block trains** – A dedicated and direct train in most cases for one customer operating from point A (origin) to point B (destination) with the aim of keeping lead times short. Such trains have a high transport capacity in terms of length, weight and volume. This trains are aimed to transport large quantities of goods such as coal, mineral products, agriculture products, raw materials, steel products, building materials, industrial products (e.g. cars and supplier products for cars) etc.
- **Intermodal freight trains** – are a type of freight trains that carries maritime containers, swap bodies or semi-trailers, enabling the seamless transfer (horizontal and vertical transhipment) of these loading units between different modes of transportation such as trucks, ships, barges, and trains. The trains are mostly operated between two intermodal terminals and combining standardized loading units to carry cargo of different shippers.

* **Single Wagon Load trains** – refers to a freight train transporting individual, mixed class of wagons carrying smaller, diverse shipments from different shippers. These trains are assembled in marshalling yards and the wagons can be assembled and disassembled several times on their transport route from point A (origin) to point B (destination) to configure efficient trains along the whole rail freight transport.

The path planning of the latter both train types of freight trains is more demanding due to the use of additional infrastructures and the associated consideration of time-consuming services (disassembling and assembling of trains in marshalling yards and sidings, the transhipment of intermodal units in intermodal terminals). The probability for disruptions due to the increased number of handling processes, involved stakeholders, and interfaces between them, requires a more flexible and short-term adjustment of both train types compared to block trains.

Assuming these conditions, the subsequent section describes freight-specific components of necessary technical and functional elements of planning systems based on a rail operator perspective related to sidings, intermodal terminals and marshalling yards, as well as the freight train operator perspective. The main objective is to identify and denominate these elements and to get an overview of what planning systems at this operator level have to consider for efficient rail freight processes, customer requirements, and deductive requirements for the interface with train path planning systems.

5.1.1 Planning of freight train paths

Figure 2 Complete train path chain including intermediate stops" shows a complete train path chain for an international freight train.

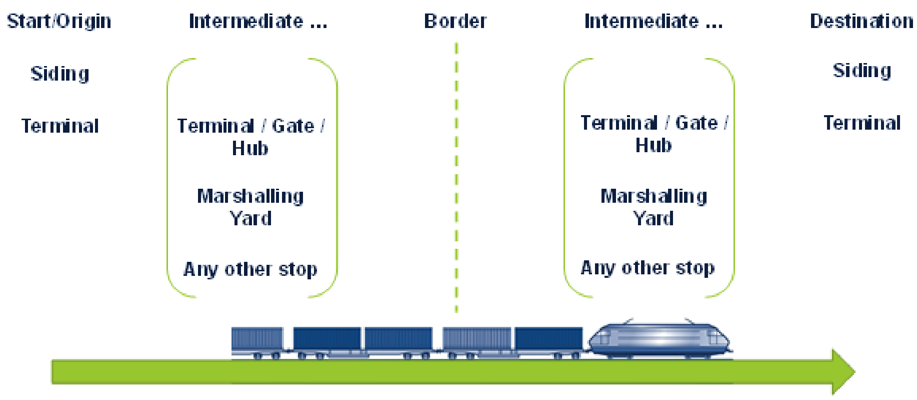


Figure 2 Complete train path chain including intermediate stops

At the interfaces to the planning and managing systems of the several elements, relevant data should be available for an efficient path planning on one hand side and on the other hand side to plan the internal processes (e.g. shunting, marshalling, unloading/loading, wagon inspection, break tests) in sidings, terminals, marshalling yards or other rail infrastructure facilities, where freight trains will have intermediate stops. In general, it should be available the following technical and functional elements to realize the planning processes based on TAF TSI:

- Path request
- Train composition
- Train preparation
- Train running forecast
- Train running
- Driver licence

and others:

- Infrastructure Restrictions

The international path planning process is defined by RailNetEurope and could be accessed by path coordination system a web-platform (https://rne.eu/it/rne-applications/pcs/, last access 21-11-2023). This system is connected by an interface to most national paths planning systems of the IM. But the system is often not connected with freight train operator systems of new or small RU.

In Parallel to the TRANS4M-R project the "Timetable redesign for Smart Capacity Management" (TTR) Project of RNE is ongoing to align the current timetabling processes with the market requirements (see https://rne.eu/capacity-management/ttr/, last access 21-11-2023) One of the requirements of TRANS4M-R part Seamless is to frequently check, the progress of this TTR project. Some general information about the TTR project was already given in deliverable D25.2 (TRANS4M-R D25.2, 2023).

TTR is a project developed in synergy between RailNet Europe (IMs) and Forum Train Europe (RUs), in cooperation with the European Rail Freight Association (ERFA) and shared also with European institutional entities like the European Commission, ministries and regulatory bodies. TTR aims to redesign the timetabling system in Europe in order to meet market requirements, making the process more efficient and adapted to current digital requirements.

The project was born from the need to make railways more competitive, avoiding the waste of capacity and resources, as well as to increase international cooperation with cross-border operations by unifying the timetabling process across the EU. The objective of TTR is to have a process that can respond promptly to the requirements of clients, providing in the passenger business, an annual planning of services (comparable to airline competitors) and in the freight business, greater flexibility and quality for impromptu requests (rolling planning).

Main components for advanced planning:

For the purpose of incorporating long-term and short-term capacity planning, TTR foresees a 5-year capacity planning strategy with long and mid-term tools, allowing the IMs to coordinate and align with different stakeholders to define the way the overall capacity is allocated. There are four advanced capacity planning tools foreseen for the timetabling process:

1. **Capacity Strategy:** It's the long-term capacity planning phase - led by the IM - for the entire railway network, a part of it, or for specific lines. It aims to provide an overview of the future available capacity of the infrastructure and share it with the Applicants and neighbouring IMs.
2. **Capacity Model (with Capacity Partitions):** It foresees the development of a long-term tool for the detailed planning of capacity that models the supply system against the demand based on the identified market needs. It allows for the allocation of capacity between annual timetables, rolling planning, Temporary Capacity Restrictions (TCRs), and unplanned capacity.
3. **Capacity Planning and Publication of Capacity Supply:** Based on the results of the model, a capacity diagram will be built to illustrate the available capacity, including all elements in the supply system and temporary capacity restrictions. The requesters can provide comments to the IMs regarding the capacity model and the capacity allocation schemes (capacity partitions).
4. **International Coordination of Temporary Capacity Restrictions (TCRs):** TCRs may occur in case of maintenance, renewal and construction of parts of the infrastructure, among other reasons. TCRs will have an impact on available capacity of a line or network. TCRs are necessary to efficiently maintain the infrastructure and to allow for its improvement and development. This step aims to obtain better information flows regarding the planning of TCRs at an international level, in order to ensure traffic flows and optimize operations.

Capacity request methods:

There are three main capacity/time-slots request methods set out to ensure that the different market needs are covered through the right capacity allocation processes:

- Annual request: refers to the capacity dedicated to stable transport market requests that are made in advance to the activation of the timetable for commercial use (i.e. for tickets sale).
- Rolling planning request: refers to a flexible method that allows to place requests much closer to the train operations and over different timetables that are reserved for such purpose.
- Ad-hoc request: refers to the unplanned or residual capacity that can be planned in short notice through ad-hoc capacity requests and through appeals for modification, optimization or cancellation of already allocated capacity.

Digital Capacity Management (DCM)

In order to achieve the improvements foreseen in the TTR project, European and national level IT systems must allow for a smooth communication between stakeholders in the complex railway transportation environment. The TTR project has foreseen the development of a new IT environment at a European level called Digital Capacity Management (DCM). DCM constitutes the integral IT System that will support the TTR programme.

DCM aims to digitalise and automize the TTR business processes, reducing manual data entry and using international standards for data exchange (TAF/TAP TSI specifications mainly). The main goals of the DCM are:

- Ensure efficient and promptly information exchange between stakeholders.
- Accelerate the timetabling process by automating certain steps.
- Provide easy access to the process for all stakeholders (with interfaces and web applications).

The DCM is defined as a platform with modular architecture where different applications/IT systems will coexist and communicate/interface in order to facilitate the complete capacity management process, including the mentioned advance planning components and tools, algorithms for capacity optimization within the capacity models, and faster and better communications regarding requests and replies between stakeholders. The DCM will consist of two main blocks:

- A central IT framework, developed by RNE with three central tools:
    - A tool to manage the TCRs and introduce them as negative capacity.
    - A European Capacity Management Tool (ECMT) to public individual capacity models and visualise the available capacity of the IMs.
    - A PCS Capacity Broker to transmit capacity requests at the different levels and provide offers to applicants.
- The national and external IMs' and RUs' systems that will need to communicate with the central IT framework.

For effective coordination, these planning efforts necessitate a business case identifier, ensuring the unambiguous identification of a specific transport throughout the planning and operational phases for potential adjustments. Operators employ their own systems, such as IS HEROS, TIS, ISR, and the consignment note data system IS ORFEUS, to exchange messages among different RUs, covering activities like freight pre-advice and train composition. An additional requirement is that train operators should have the capability to proactively view the anticipated shipments.

A crucial aspect of international freight train path management involves cross-border planning. Freight train paths transition between IMs as part of the comprehensive planning process for an international intermodal service. Concurrently, rail freight transport operators engage in planning activities, including the assignment and alteration of locomotives, drivers (with planned dwell times), and other services such as wagon inspection or braking tests. For effective coordination, these planning efforts require a business case identifier to transfer relevant data in the planning systems of freight train operators. It requests an unambiguous identification of a particular transport, which takes place throughout the planning and operation process in case any adjustments are inevitable.

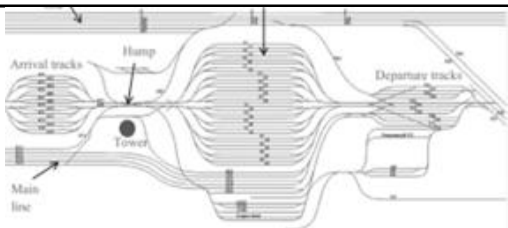
The need expressed by freight train operators is reciprocated by infrastructure managers, who seek timely notification of any delays or rescheduling of planned trains Train operators wish also to have a data exchange standard to apply for the resource planning process.

Further, company related requirements of freight train operation managers and infrastructure managers more on the operational side are highlighted in the following chapters of this deliverable.

5.1.2 Freight-specific overview of necessary technical and functional elements of path planning

The description of the elements of rail freight transport depends on their processes to organise shunting in marshalling yards, loading in sidings and in intermodal terminals including shunting operations, as well as freight train operation. It is distinguished between functional elements – elements which are relevant to rail freight transport based on regulations and operations perspective – and technical elements – derived from technical regulations of wagons, locomotives and infrastructure.

Figure 3 and Figure 4 describe the technical and functional elements, which are relevant to the operation of marshalling yards.

Technical elements: 1. Number of arrival and departure tracks 2. Track lengths 3. Number of shunting locomotives 4. Defined shunting routes	 Layout of Hallsberg marshalling yard own creation upon plans provided (picture [Trafikverket; 2023])	**Functional elements:** 1. Capacity of the hump or other bottlenecks 2. Defined wagon transition times 3. Status information about wagons 4. Data-proceeding of all wagons of incoming and outcoming trains 5. Tracking of freight

		wagons inside the marshalling yard

Figure 3: Technical and functional elements for marshalling yards or local rail yards from the perspective of the yard operator

Rail Yard Management Systems (YMS) are controlling the operational processes inside rail yards. The objective is to ensure the capability and to optimise the timely transition of wagons between incoming and outgoing trains. The availability of existing infrastructure, shunting locomotives, and yard personnel are the constraints which have been considered. The types of shunting, technical wagon inspection, and all existing operational procedures are described in deliverable D2.1 Preliminary Operational Procedures [TRANS4M-R, D2.1 Chapter 6.4, 6.5 and 8.4, 2023].

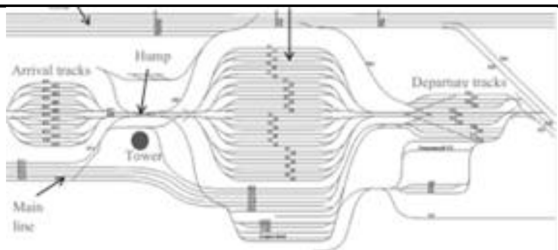
Technical elements: 1. Performance /traction force and traction-mode of locomotives 2. max. train weight 3. max. number of train axles (allowed) 4. Loading gauge 5. max. axle load 6. Technical wagon inspections and braking tests	 Layout of Hallsberg marshalling yard; own creation upon plans, picture [Trafikverket, 2023]	**Functional elements:** 1. Planning of circulation of locomotives and working times of train drivers 2. Departure time 3. Percentage of brake power 4. Intermediate train stops 5. departure and arrival time 6. Wagon data incl. information of dangerous and perishable goods

Figure 4: Technical and functional elements for marshalling yards or local rail yards from the perspective of the freight train operator

The freight train operator is strongly linked to the yard operator’s activities due to all technical elements, which are based on the activities and outputs of the yard operation. Arrival and departure times are the main interfaces between train operator and yard operator for their operational processes, because any deviations are relevant for the other partner and influences its resources and internal costs.

Figure 5 and Figure 6 summarize the technical and functional elements, which are relevant in the operation of intermodal terminals

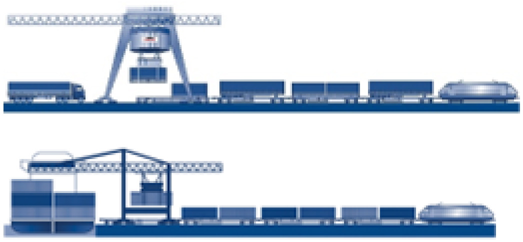
Technical elements:		**Functional elements:**
1. number of arrival and departure tracks 2. track lengths 3. number of shunting locomotives 4. defined shunting routes 5. number of cranes and reach stackers 6. number of tracks and lengths straddled by gantry cranes **7.** technical parameters of gantry cranes and reach stackers	 Intermodals terminals for maritime/rail, road/rail transhipment of standardized loading units, (picture [HUPAC, 2023]) Terminals gate: 1. incoming and outgoing loading units 2. incoming/outgoing data of loading units 3. shipper/customer requirements for logistics (destination, size and weight, time of arrival,...)	1. Capacity of the gantry cranes and reach stackers or other bottlenecks 2. Status information about gantry crane, reach stackers, wagons 3. Data-proceeding of all wagons of incoming and outcoming trains 4. Tracking of freight wagons, inter-modal units, and HDV inside the terminal 5. Sequence of loading units on the train 6. Information of special handling needs 7. time of arrival and departure time

Figure 5: Technical and functional elements for intermodal terminals from the perspective of the terminal operator

In addition to yard management systems described above, Terminal Management Systems (TMS) have to include processes of loading and unloading of intermodal loading units (containers, swap-bodies), the storage of intermodal units (full and empty ones) at the terminal yard, as well as the link to the terminals gate, where incoming and outgoing units have to be registered and checked, as well as dispatching and navigation of the HDV inside the intermodal terminal. Terminal gates are the physical link and the data interface of terminals with their customers and companies realising the pre- and post-haulage on road. Further physical and data-interfaces could exist to maritime transport or inland navigation in case of trimodal terminals.

Terminal management systems consider the coordinated and efficient organisation of all elements (infrastructure, rail wagons, trucks, …) inside the terminal. Further, shunting processes, technical wagon inspection, and other processes, which are often identical with processes in local rail yards, have to be incorporated.

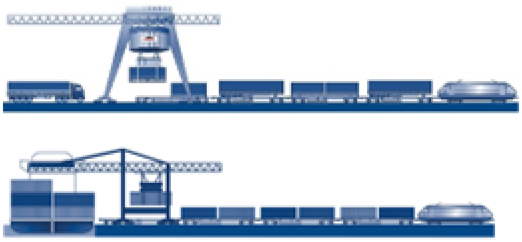
Technical elements:		**Functional elements:**
1. performance/traction force and traction-mode of locomotives 2. max. train weight 3. max. number of train axles (allowed) 4. wagon inspections and braking tests 5. loading gauge, required codification for intermodal freight trains 6. max. axle load	 Intermodals terminals for maritime/rail, road/rail transhipment of standardized loading units (picture [HUPAC;2023])	1. planning of circulation of locomotives and working times of train drivers 2. percentage of brake power 3. departure and arrival time 4. immediate train stops 5. destination and arrival time 6. percentage of brake power 7. wagon and loading units data incl. information about loading units with dangerous and cooled perishable goods

Figure 6: Technical and functional elements for intermodal terminals from the perspective of the freight train operator

As shown in Figure 4 and Figure 6, the technical and functional elements for marshalling yards and intermodal terminals are similar from the perspective of freight train operators. Additionally, the loading gauge or the requirement for 'Codification of lines and wagons for combined transport' [ERA, 2023] has to be considered for the use of railway lines by intermodal freight trains in the EU.

Finally, Figure 7 and Figure 8 describe the technical and functional elements for customer sidings. Costumer sidings are big industrial sidings, ports with own railway network for shunting wagons to different loading/unloading points, small sidings with loading/unloading points at railway stations.

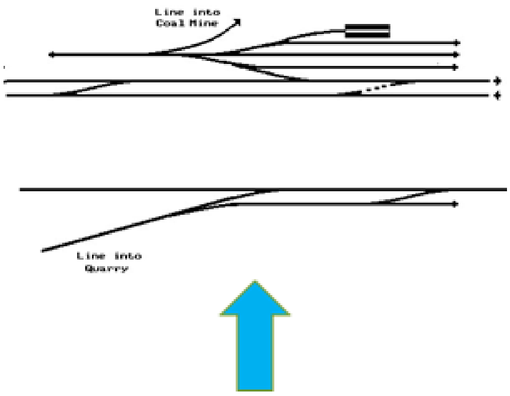
Technical elements: 1. number of arrival and departure tracks 2. track lengths 3. number of shunting locomotives 4. defined shunting routes 5. number of loading and unloading points inside the siding area and their capacity	 Interface to the production and warehouse processes/logistics for incoming and outgoing commodities as part of procurement and supply to the customers Shipment sizes and destinations for single wagon loads and full train loads	**Functional elements:** 1. information of commodities (kind and weight) inside the wagons 2. defined wagon times for loading and unloading 3. status information about wagons 4. data-proceeding of all wagons 5. tracking of freight wagons inside the siding

Figure 7: Technical and functional elements for customer sidings from perspective of the siding's operator

Sidings could have different operational systems which are including aspects with relevance to the processes and the available infrastructure of the siding's operator. Based on the size of a siding processes simple or complex systems with different solutions of data management are still existing. Especially, loading and unloading of wagons at different loading points and the link to internal processes of the costumer require customized solutions with different data requirements and management.

Technical elements: 1. performance/traction force and traction-mode of locomotives 2. max. train		**Functional elements:** 1. planning of circulation of locomotives and working times of train drivers

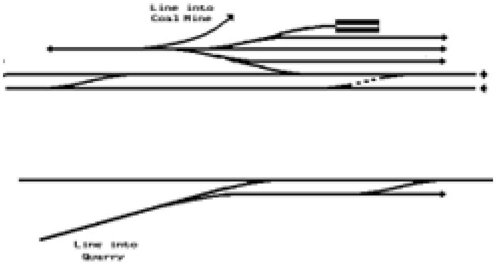
weight 3. max. number of train axles (allowed) 4. loading gauge 5. max. axle load		2. wagon inspections and braking tests 3. percentage of brake power 4. departure time 5. immediate train stops 6. Destination and arrival time (of wagons) 7. percentage of brake power 8. wagon data incl. information of dangerous and perishable goods

Figure 8: Technical and functional elements for customer sidings from the perspective of the freight train operator

Costumer sidings include for the freight train operators also technical and functional requirements. Specials solutions for handing over wagons and responsibilities have to be considered to realize a safe and efficient transport for both partners (customer sidings operators and freight train operators).

5.1.3 Definition of interface and system interaction requirements with other (planning) systems

Efficient and seamless rail operations rely on robust planning mechanisms that facilitate communication between the Yard Capacity Management System (Yard-CMS) and the line-based or national Capacity Management System (CMS). Both CMSs will be controlled by humans in the stage of planning. The coordination between IMs and yard operators ensures that crucial updates to local capacity plans are effectively communicated, enhancing the overall functionality of the rail network. Thus, 4 capabilities have been defined to show relevant communication between the involved systems.

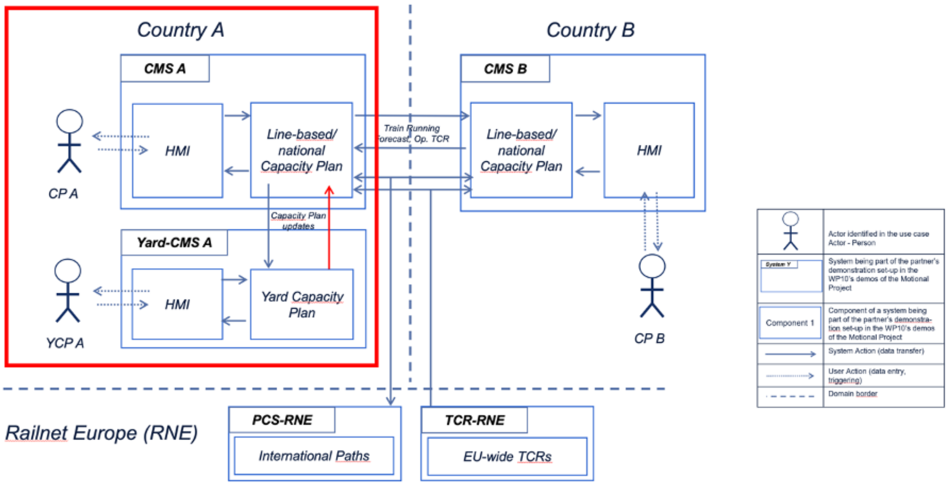


Figure 9: The yard-CMS communicates relevant local capacity plan updates to the (line-base/national) CMS

If a train should be available later or earlier than planned in the departure track of the handover area of a yard, the IM must be informed about the actualized availability time as shown in Figure 9. The IM must consider these actualized planning in their CMS so that they can check the availability of train paths which means that it is less important to communicate earlier availability than to communicate a delay. An information about a changed departure track in the handover area must also be transmitted to the IM so that they can adjust their plans. Furthermore, the yard operator must inform the IM about changes in the planned train consist. This is particularly important if the train will hit the route restrictions for overload/oversize with the new plans. In this case, the IM must choose another route for the train in their CMS.

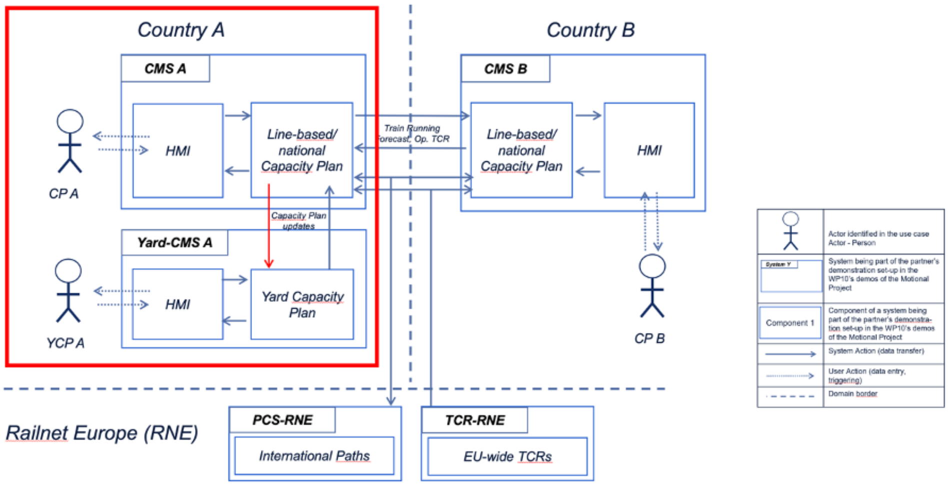


Figure 10: The (line-based/national) CMS communicates relevant capacity plan updates to the yard-CMS

Conversely, the IM must provide information from their CMS to the yard operator in some cases. In case the IM plans a later departure from the handover area, this information must be also considered in the yard operators CMS. However, if they plan an earlier departure, they must inform the yard operator only in some specific cases. Vice versa, the IM's CMS must provide information on a changed arrival track or arrival time (earlier or delayed). If the train consist in the yard will differ from the original train, the yard operator must get information on this to their CMS before the train is moved to the arrival track.

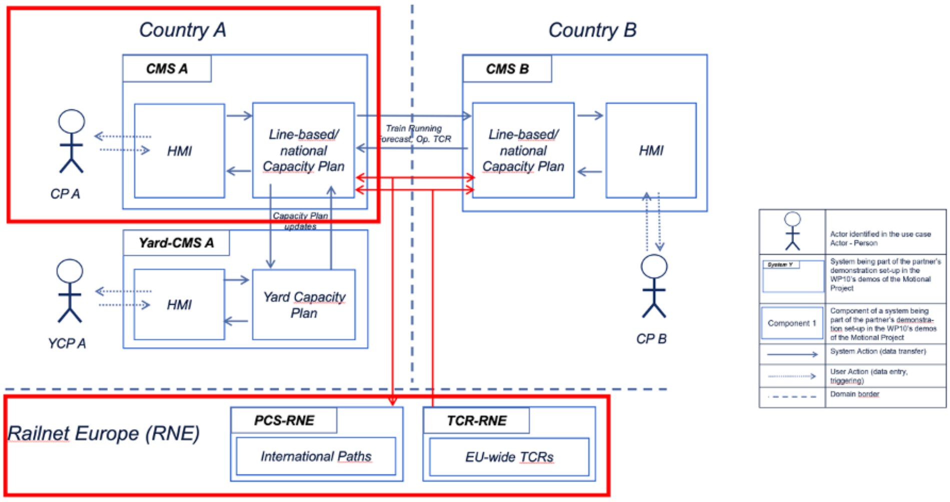


Figure 11: The (line-based/national) CMS exchanges planned capacity objects with EU-centralized applications

To enable international planning, information on train paths must also be exchanged with RNE (Railnet Europe) which is shown in Figure 11. Freight path requests must be sent by the CMS to RNE's path coordination system (PCS-RNE) according to the TSI TAF standard. Information on temporary capacity restrictions will be provided by the RNE TCR tool. The CMS must receive and proceed this information to consider the TCRs in the timetable planning.

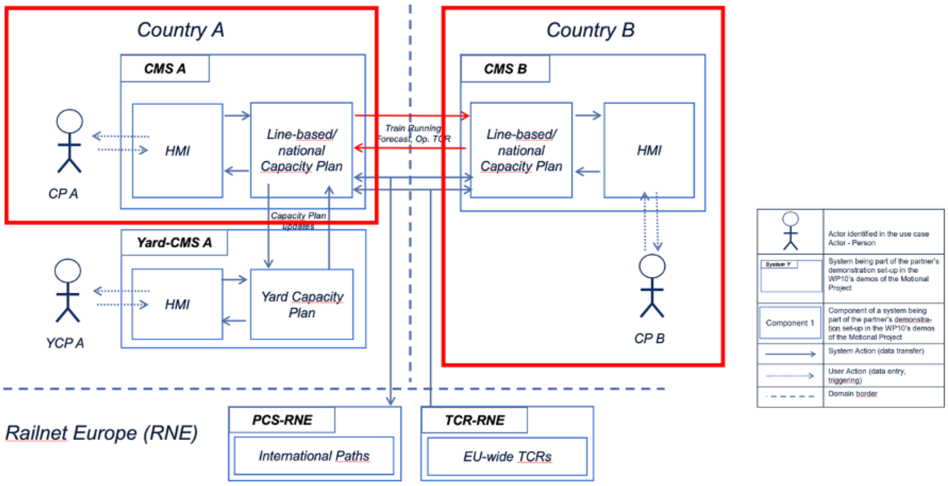


Figure 12: A line-based / national CMS exchanges relevant capacity plan updates on the local network with the neighboring line-based / national CMS behind the border for defined line sections.

In addition to international planning involving RNE, international planning must also be coordinated between neighboring IMs. For this purpose, IMs have to exchange new, changed, and cancelled train paths for cross border trains and trains on defined line sections towards the border with the other IMs involved so that each IM can consider these train paths in their CMS. This is shown in Figure 12. The train paths added by other IMs will trigger the path validation and conflict detection processes so that the responsible IM will receive a confirmation or rejection of the path. Besides cross border train paths, also relevant TCRs must be exchanged between the IMs to consider them in their CMS. This is to be applied for new, changed, and cancelled TCRs on defined line sections towards the border.

Beyond that, an interface between the line-based CMS and the train planning system is necessary. The definition of this interface is described in deliverable D25.2 'High-level specification of requirements, challenges and a future target state for freight cross-border planning and operations from an operator perspective as input for FA1' [TRANS4M-R D25.2, 2023].

The data requirements to get train paths are defined by the railway infrastructure manager or the one stop shops for international train paths on then TEN-T network (subdivided in several corridors). The data that are necessary are documented and are communicated to data portals. A registration is mandatory. The Customer Information Platform (CIP) of Rail Net Europe is the current step in for freight transport operators to request trans-European rail paths on TEN-T corridors [RNE; 2023]. Train paths for national freight trains could be requested on the websites of the responsible rail infrastructure managers. The general framework for paths allocation is described in national network statements.

5.2 Long-term first- and last-mile planning systems and functions

FP5 TRANS4M-R aims at developing the necessary functions, tools or supporting systems needed to ensure that seamless planning covers the complete end-to-end rail service. The first-mile processes in rail freight involve transport from production facilities to the terminals, while the last-mile operations consider the journey from the freight trains out to the end customer and distribution centres (warehouses). All activities and processes in this range are planned in some way, either at an operational or more long-term level. This section presents long-term planning decisions related to different parts in the freight service chain.

Section 5.2.1gives an overview and process map of the end-to-end rail freight service and the actors and decisions involved here. Section 5.2.2 lists some long-term planning processes related to the different parts of the rail freight service. Section 5.2.3 describes some planning systems currently in use for planning, with an emphasis on long-term planning systems. Section 5.2.4 describes general requirements for planning systems. Finally, Section 5.2.5 discusses functions and capabilities enabling more integrated planning of the rail freight service, and an enhanced operational planning.

Table 2 explains symbols used in this section.

Symbol	Meaning
Ac-	Actor (physical object or people) or Activity (area or operation) involved in the rail freight related processes
P-	Processes and times of activity where capabilities and functions concerning planning are needed
S-	Planning system
	Links users to systems

	Flow of time
	Involves some planning processes
	Information flow to/from a system

Table 2: Symbols used in Section 5.2.5

5.2.1 End-to-end process map

In order to state the need for planning processes and planning systems on the first and last mile, an overview of the operations in a rail freight terminal and yard will be useful. This process map will visualize how trains and cargo flow through a terminal, and thereby enlighten the need for proper planning processes for different actors and operators.

The map in Figure 13 gives a simple overview of areas in and flows through a terminal. Here, the blue boxes represent some actor or activity relevant in the terminal processes. We have joined the "Ac"s relevant for arrival and departure as the involved planning systems and processes mostly remain the same. The orange boxes with "P"s represent processes. A process can be viewed as a place or time where a set of milestones are achieved. Planning is needed for the different processes, i.e., some problem of timetabling, sequencing, storing, path planning, booking, crew scheduling, etc. must be solved both long-term, short-term and in real-time to enable seamless processes.

Please recall that this section emphasizes *planning* process and systems, and that process maps for e.g. the physical execution of these processes are given elsewhere in this document and/or in other deliverables in the TRANS4M-R project. Note also that we in this section simply refer to "terminals", and then mean general rail freight terminal. We do not separate large from small terminals, or consider stations or hand-over points specifically in this section. The same holds for "yards", which for simplicity here are placed inside a terminal in the figure.

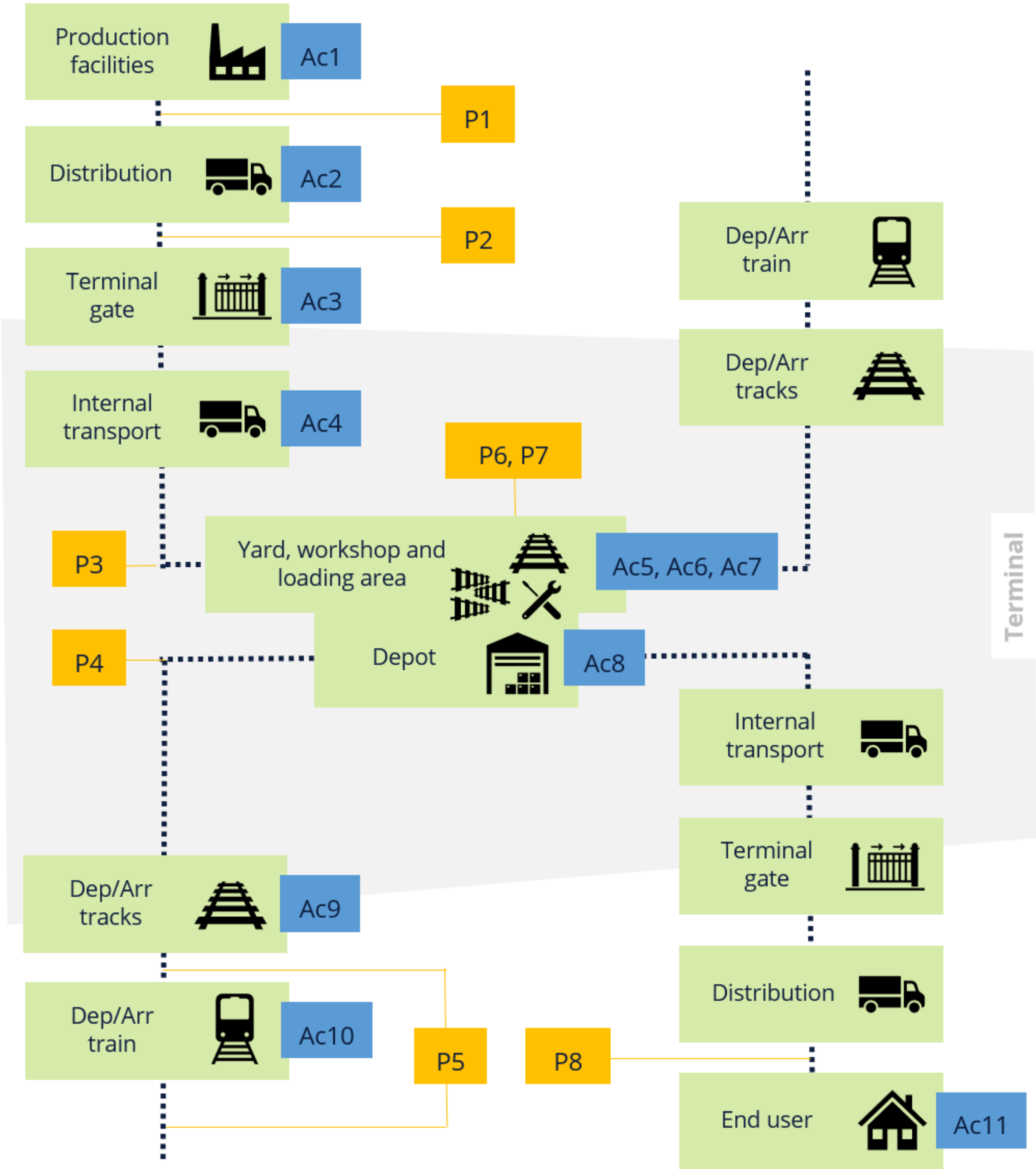


Figure 13: Process model of end-to-end areas and related planning processes in a rail freight terminal and yard

Location	Ac1 - Production facilities
Related processes	P1
Systems in use	S1
Specified actors	Customers, production facilities, merchants
Activities	Selection of transport subtractor, booking train operator and cargo transport

Location	Ac2 – Distribution
Related processes	P1, P2
Systems in use	S1, S2
Specified actors	Road-based transport, courier, trucks
Activities	Driving from/to customer, through gate and to the depot

Location	Ac3 – Terminal gate
Related processes	P2
Systems in use	S2
Specified actors	The physical terminal gate, road-based transport
Activities	Controlling traffic through the terminal

Location	Ac4 – Internal transport
Related processes	P1, P2
Systems in use	S1, S2, S3
Specified actors	Trailers, semi-trailers, cargo, cars
Activities	Transport from gate to depot inside the terminal

Location	Ac5 – Loading area
Related processes	P3
Systems in use	S4, S5
Specified actors	Operators, reach stackers, trucks, portal cranes, cargo
Activities	Loading and unloading trains, shunting trains onto/off tracks, inspections and tests, cargo carrier movement

Location	Ac6 – Workshop and maintenance area
Related processes	P7
Systems in use	S6

Specified actors	Broken wagons, workshop, tracks, workers
Activities	Repairs, maintenance

Location	Ac7 – Yard
Related processes	P4, P6, P7
Systems in use	S3
Specified actors	Train dispatchers, operators, shunting men, locomotive drivers, IMs
Activities	Splitting and assembling trains, removing broken wagons, tests and inspections, snow removal, parking and stabling, movements to loading tracks, sequencing of wagons, humping

Location	Ac8 – Depot
Related processes	P2, P3
Systems in use	S4, S5
Specified actors	Terminal operators, cargo carriers, trucks, cranes
Activities	Storing cargo, moving onto/off trains, cargo carrier movement, depot management

Location	Ac9 – Departure and arrival tracks
Related processes	P4, P5
Systems in use	S3, S7
Specified actors	Inbound and outbound trains, locomotive drivers, IMs
Activities	Tracks for trains to/from the terminal

Location	Ac10 – Departing and arriving trains
Related processes	P4, P5
Systems in use	S7
Specified actors	Train operators, Train dispatcher, locomotive drivers

Activities	Trains departing from or arriving at the terminal, trains passing through the terminal

Location	Ac11 – End user
Related processes	P10
Systems in use	S8
Specified actors	Customers, companies, postal offices, private persons
Activities	Delivery status updates, receiving goods, end of chain

Location	Ac12 – Managers
Related processes	P3, P4, P6. P7
Systems in use	S3, S4, S5, S6
Specified actors	Yard-, terminal-, infrastructure managers and leaders
Activities	Managing terminal operations, dispatching, maintenance, shifting and yard operations

Location	Ac13 – Terminal operators
Related processes	P1, P2, P3, P4 P6, P7, P8
Systems in use	S3, S4, S5, S6
Specified actors	Terminal operators at the terminal and yard
Activities	Distribution, loading and unloading, shunting, tests and inspections, depot management, maintenance

Location	Ac14 – External planning systems
Related processes	P5
Systems in use	S3, S7
Specified actors	Route planners, IMs, timetable makers, other terminals and stations, train line
Activities	Planning routes and timetables, capacity planning, track assigning, traffic management, data exchange

Below, Table 3 shows how the planning processes from the process map relates to the EDICT milestones. Further information about what the planning processes mean, contain and which actors are involved, is given in sections 5.2.2 (long-term) and section 5.3 (short-term).

Process	**Related EDICT milestones**	
	Long-term	Short-term
P1		D03
P2		D03, D12
P3	D11n2, D14n2, A09n2, A13	D11n, D14n, A09n1, A12
P4		D16n1, D10, A03, A04, A08n3
P5	D10, A03	D10, A03, A04
P6		D11n, D14n, D16n1, A04, A09n1, A12
P7		
P8		A05, A06, A10

Table 3: Relation between planning processes and EDICT milestones.

5.2.2 Overview of planning processes

The following subsection describes long-term planning processes related to the activities from the process map in section 5.2.1 in more detail. Although the process map springs most areas of a yard and terminal, not all areas use long-term planning as this is hard without near- or real-time data, and the level of uncertainty might be large. This fact limits the scope planning realistically may have. Also, planning processes differ from terminal to terminal, yard to yard, and the state of the art differs between European countries depending on technology, ownership and political considerations. This subsection seeks to give a general overview of how long-term planning processes look.

5.2.2.1 P1 From production and customers to transport

The first-mile of a freight supply chain involves distributing the goods from the merchant's warehouse or production facility to couriers like truck companies or other logistic service providers for further transport. From this starting point, cargo is transported to a freight rail terminal, potentially via other terminals like airports, seaport terminals, truck terminals or goods stations.

Most trucking companies are not using any standard process or system when it comes to the long-term planning of this first-mile transport. Trucks are planned based on the planned train departures, and pickup is decided on-demand with the customers in accordance with these long-term plans. Once the freight train timetables are set, regular pickups will be scheduled visiting all customers in a way enabling fast and secure transport in the start of the supply chain.

5.2.2.2 P2 Road-based transport to/from terminal

Active terminals have a high amount of road-based traffic entering or exiting the loading area with cargo. All these vehicles (trucks, semi-trailers, etc.) need to pass through the terminal gate. The actual number of cars is dependent on the long-term plan for the load of cargo being transported through the terminal, as well as the placement of the relevant customers. When the route plans are determined and the train operators know which customers will be using their services, the number of cargo carriers needed to be distributed into or out of the terminal can be estimated. In some cases, the train companies themselves transport the cargo, in other cases the customers, and in still other cases external transport companies.

A car entering the terminal is planned by request, sent in as soon as route- and track plans are created and altered if changes to this occur. There is one request per container number containing information about depot placement and time of pick up. Gate operation systems will have an overview of such requests and monitor the car traversal through the terminal.

5.2.2.3 P3 Loading and unloading processes

Inside the terminal, trucks and freight trains need to be loaded or unloaded. These operational processes involve assigning loading tracks, routing the trains to this track and the trucks to the nearby depot, and then lifting of containers between truck and train which can be done via the depot in between or directly. The planning of these activities is done short-term by the terminal operators.

Long-term planning processes of loading and unloading activities is about where and when the operations should be performed. In general, there is no standard process for planning this as terminal layouts and activities vary greatly. This also causes differences in the actual need for long-term planning.

5.2.2.3.1 WP26 Use case environment: Loading track assignment in Oslo Alnabru, Norway

In WP26 of the TRANS4M-R project the research providers will examine how long-term planning of loading track assignments can be done in a terminal. In a terminal, the loading and unloading processes of a train are done on assigned loading tracks. The plan showing where (which track) and when (which timeslot) the trains should be loaded/unloaded is drawn up on a long-term basis and shared between all terminal operators.

Figure 14 shows an example of a loading track assignment in Alnabru, the largest freight rail terminal in Norway. This plan is created with a one-year perspective. Here, the colours represent arriving/departing trains served by different terminal operators. The plan is for one week and the relevant days are specified within the boxes, which represent track-time-slots (TTSs). Each column represents a track, and the rows represent time.

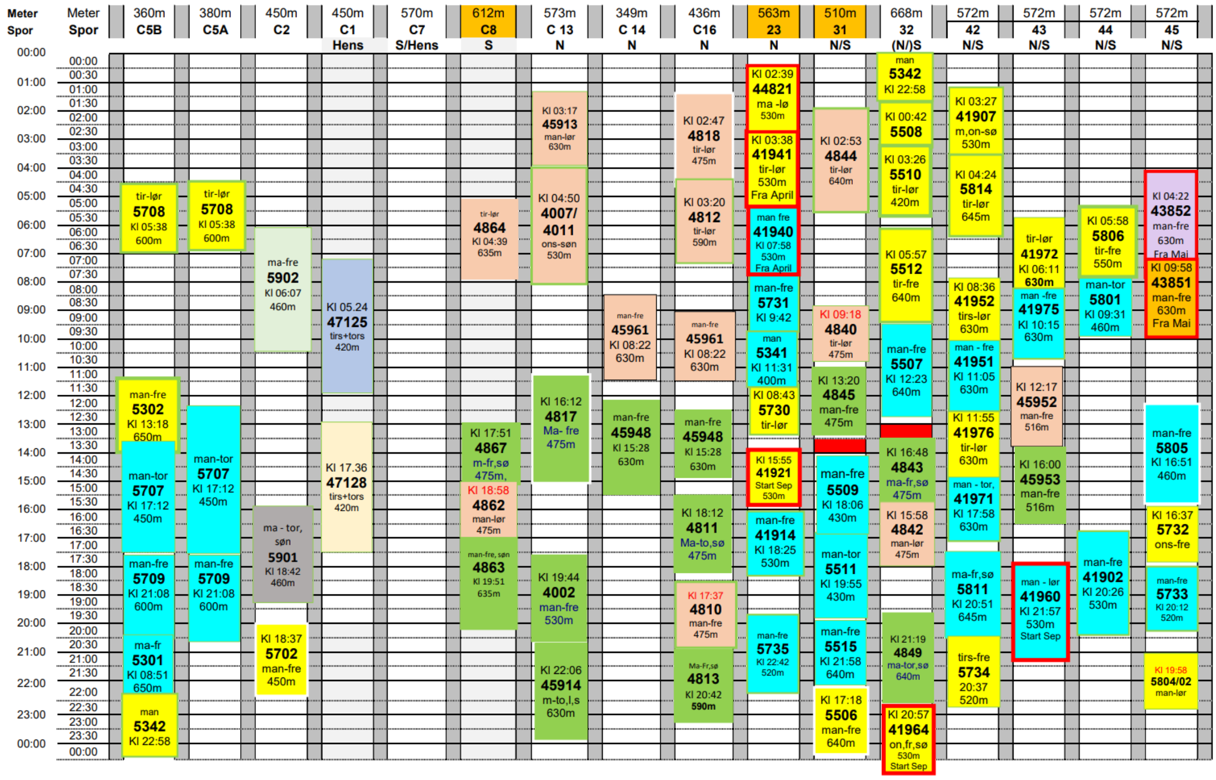


Figure 14: Current visualization of a loading track assignment plan at the Norwegian terminal Oslo Alnabru [Bane NOR, 2023]

The train operators apply for paths through the railway network (see process P5). For each of the train operator's trains, the relevant terminal operator applies for a TTS at Alnabru. Once these trains have been assigned paths and times for arrival and departure to/from the terminal, the terminal loading tracks planner receives these applications. At this time each train has also been assigned a terminal operator. The planner then needs to assign the loading tracks such that all trains can be served (if possible). This is not an easy task for several reasons:

- Some time slots are more desired than others, like mornings and afternoons.
- The tracks may have different lengths, and the actual lengths of the trains are unknown at this time. The same holds for the number of wagons and which cargo is carried in each train unit.
- Some tracks have easier access to e.g. portal cranes and depots.
- The terminal owner must ensure fairness between the different operators. There are rules and practices related to the communication and sharing between the different operators.
- Arrival- and departure times given in the train timetable must be met.

There are also other aspects which must be taken into account. A train operator applies for a track for a specific train, but it is not guaranteed that this train will be existing. Nevertheless, the track assigner needs to consider the train in its plan.

It might, and does, happen that multiple operators apply for the same TTS. As it can only be used by one operator, the track assigner has to deny some applications and suggest alternatives instead. The generation of the final plan is an iterative process, where the terminal owner comes with a suggested plan and discusses that with the terminal operators and then applies changes accordingly. One of the big challenges is to find a plan where all operators are happy in the sense that the plan is considered fair.

The status quo for loading tracks assignment is that the plan is made manually in several terminals. Information about the trains' times of terminal arrival and departure are received and used as upper and lower bounds for the possible time slots. The interfaces used for creating the plans are different in different countries. As an example, the Norwegian plan shown in Figure 14 is made by only one person using Excel sheets. This has several draw-backs:

- No possibility of drag-and-drop.
- No functionality for notifying about violations or errors.
- Rules and thoughts about how the plan should look are internalized in the plan maker's head through years of experience. It is tough and time-consuming for other people to take over the task of making a plan.

New and/or updated systems and functions for planning loading track assignments are needed in order to cope with increasing flow of freight trains and more requests in peak times. Digitalization and support are two main keys here. A better long-term plan for loading tracks will also make it easier to replan when situations occur in real-time, like delays, missing crew or cancelled trains. The expected tool developed in this use case environment will therefore be useful for both long-term and short-term planning of track assignments. With a generic interface, the to-be-developed planning system is intended to be easily adaptable to also other Norwegian and European terminals.

See the system description in section 5.2.3: Track Assignment Optimizer.

5.2.2.3.2 Depot planning

The long-term planned track- and loading track assignment plan includes specifications about depot placements – a depot plan. Each loading track has an assigned primary and secondary depot. In a terminal with several terminal operators, specific geographical areas are assigned for their depots. Some area is put aside as transit depot. Besides safety regulations and rules for e.g. where dangerous cargo may be placed, the internal depot control is operator specific. In the context of long-term planning, it is desirable to place depots and assigned loading tracks as close to one another as possible to prevent long truck routes and unnecessary traffic crossings.

Maximum depot capacity is calculated by simple formulas, and some slack is often added as cargo may be placed along fences, slid in between other containers or placed elsewhere with free capacity. As several intermodal terminals experience that this maximum capacity is reached, long-term planning of traffic through a terminal must integrate depot considerations.

5.2.2.4 P4 Shunting departing and arriving trains

Inside a terminal, trains may need to be loaded or unloaded as described in process P3. Other operations on a train involve splitting, rearranging and assembling wagons; see process P6 – Shunting movements. This is done in the yard. When all necessary operations are performed on a train the outbound train is ready for the final steps before departure.

5.2.2.4.1 Assigning departing and arriving track

Departing (arrival) tracks for all outgoing (incoming) trains are planned along with the route plans, as this plan includes the specifications of which departing (arriving) tracks the trains should have at each terminal. The relevant manager at each terminal looks at the suggested long-term route plan and gives feedback on the feasibility of the plan. In this way, local route planning processes integrate and interact with terminal track planning processes by means of iterative communication and feedback. The extent to which this happens varies between nations.

5.2.2.5 P5 Transport on the main line

After all checks have been made, the train departs from the terminal as given in the freight train timetable, and moves on to the main line. The freight train *timetable*, along with the train's *path*, is planned for the long-term. See also section 5.1 for information on this.

5.2.2.5.1 Path planning process

The path and timetable for a train can be planned in multiple ways. The standard one is that the RU sends a path request to the IM for the yearly timetable. This request contains the operational and/or commercial stops, desired arrival/departure times and train characteristics. The IM completes the requests to form a train path including all planned locations and intermediate timings, as well as the complete route. If there are conflicts with other paths or restrictions, these are resolved. After receiving the resulting path from the IM, the RU accepts or declines the offered path. If declined, an alternative path must be negotiated. This whole procedure can be performed in parallel for multiple trains at a time. The desired departure and arrival tracks at the start/end terminal can be provided optionally through the request as well. This enables linking the long-term terminal planning and track assignments to the train path planning.

Linking path planning to terminal planning is, unfortunately, rarely done in practice today. The general European experience is that long-term planning of trains paths and timetables to a large extent assumes that internal planning of terminals and yards will be feasible. The (inter)national IMs may "not care" about local terminal planning. As the number of terminals and yards along a train path might be large, such an incorporation of the microscopic planning considerations would make the macroscopic long-term planning practically impossible. An alternative, practiced in some countries today, is the iterative planning process, where terminal managers provide feedback on the suggested path plans and timetables.

Another way the path and timetable for a train can be determined is by using so-called rail freight corridors. Here, trains may use international Pre-arranged Paths (PaPs), which are pre-constructed and used for more efficient handling of path requests. These are generated yearly, and published eleven months before the start of the relevant timetable period. Some countries also have priority routes based on one-year or multi-year agreements for critical freight transports, e.g. automotive industry (just-in-time) or critical resource supply (e.g. coal in the UK).

A short, but detailed video summarizing the process of international path planning and time tabling through the PCS system (section 5.2.3.7) made by RailNetEurope can be found at their website [RNE PCS; 2023]. Here, the full process from RU applications to the finalized timetable is introduced, specifying which actors are involved.

5.2.2.5.2 Main line planning

Outside the terminals and yards, and apart from road-based or other transport, the remaining part of the freight journey is the transport on the main line. Here, the cargo is transported from one terminal to another on the line, cross regions and cross borders. While the process of actually driving of the train is simple, the concrete processes at a handover point vary and do not necessarily reflect a seamless exchange, see Chapter 7.

For long-term planning of the main line, the central aspect is the abovementioned path planning and time tabling for each train and terminal, but also macroscopic view of the main line and freight corridor as a whole. This involves planning solutions and sequences in points of train intersections (tracks, stations), considering minimum time lags and maximum capacity at parts of the main line, planning procedures at handover points and so on. Also included here is the planning of the main line itself; where to place tracks and intersections, installing sensors and video gates etc. Such long-term planning involves many actors from different countries, and the decisions to be made are often politically influenced.

5.2.2.6 P6 Shunting movements in a yard

Shunting movements involve all moving of wagons and cars inside a yard and a terminal. Due to fluctuations in the level of daily activity, high level of uncertainty and unforeseen events many shunting operations are planned short-term or simply performed by request in real-time. The concept of long-term planning of shunting operations is hard to realize. For this reason, use cases and use case environments related to shunting are primarily related to the dynamic dispatching work package.

One long-term planning area relevant for shunting is what concerns capacity; number of operating tracks, workers on ground, machine and resource availabilities, yard infrastructure etc. Long-term changes to the yard infrastructure will affect the performance of shunting operations by, e.g., increased track capacity. Long-term investments in new digital systems or efforts made in updating already existing ones will enhance procedures operationally, but also to a larger extent enable the possibility of long-term planning specific operations related to the terminal operations.

Some countries have processes to plan shunting long-term. In Italy, a process for planning shunting operations in the long-term has been introduced for some of the terminals managed by Terminali Italia. The process is based on the concept that the RU is able to request the shunting operations at the same time as they request the track for a freight train run through the Italian Piattaforma Integrata Circolazione (PIC). The request is transferred to the Piattaforma Integrata Logistica (PIL) where it is received by the terminal manager. He can accept or refute the request, which includes the time slot and the additional services requested. The planned shunting operations are then transferred to the Shunting Management System and are incorporated into the daily shunting operations program at the terminal, which is defined six months in advance. The daily shunting program is reviewed and updated every day to also process short term shunting requests.

5.2.2.6.1 Inspections and tests

There are sets of manual, standardized and required tests, procedures and inspections that must be done before a train ready for departure may actually depart. These are described in more detail in section 6.3 “Procedure before departure”. The execution of these operations is done at a suitable time between when loading is finished and the ETD, and is planned in the sense that the list of required operations is fixed and that estimations on the duration of these operations are given. The involved actors are yard locomotive drivers, break operators, shunters, wagon inspectors, and finally the line locomotive drivers.

5.2.2.6.2 Assignment of yard-track

Trains or sets of wagons may need to be parked or stabled in the yard for a longer or shorter amount of time. The track on which (parts of) a train could be placed for such purposes is in some terminals decided long-term as a part of the train path generation. Based on history, planned flow of trains to the terminal, direct questions and applications, the train dispatcher and terminal operators agree on plans for the yard track assignments. Some extra tracks are kept free for shunting purposes and as buffer tracks for damaged wagons or locomotives. It is up to the terminal operators to decide on the realised track assignment for each train they operate, but the long-term planning of assignment is meant to be followed the entire route plan period unless circumstances demand otherwise.

5.2.2.6.3 Shunting from yard to loading tracks

In a terminal, the yard is used for both parking rolling stock and for shunting operations. One type of shunting operations concerns moving trains to the loading/unloading area. This type of shunting is rarely formally planned, meaning that the timing and actual route for moving the wagons are not set long-term, but are rather decided on site. The starting track (in the yard) and the ending track (loading track) are planned annually, as well as tentative times for loading/unloading. The actual movements are done by a foreman shunter or locomotive driver requesting a route, and getting a yes- or no-signal from the shunting manager or train dispatcher. A hypothetical long-term planning process for these movements should consider bottlenecks in time and tracks, and prioritize movements according to assigned loading times, as well as ETAs and ETDs. A use case environment related to this issue is described in Section 6.4.3.

5.2.2.6.4 Rearranging wagons, splitting, assembling

Given the long-term track assignment, it can be seen whether or not a train needs to be split e.g. due to the length. As trains become longer, but tracks remain the same, it is necessary to plan that trains may or will be split. Decisions can be made regarding track assignment, routing and a time window for performing the splitting and reassembling. The actual procedure, with which shunting locomotive and with which personnel is harder to plan long-term, and is decided by request at the operational level. This currently holds also for the routing and timing decisions, unless internal processes exist for long-term planning. Such processes could be related to e.g. hump sequences as a hump yard, which may be long-term planned when the required information about inbound and outbound train, along with the timetable, is given.

5.2.2.7 P7 Workshop processes

The task of repairing and maintaining both rolling stock and tracks contains several aspects of long-term planning. Regular preventive maintenance can be planned ahead based on previous experiences on e.g. expected living years of a track. However, most maintenance will have to be adjusted to short-term needs like suddenly broken-down wagons or damaged tracks.

The long-term aspect of workshop planning requires interaction with the train operators long-term rolling stock planning, in order to know when which rolling stock is both available and in need for a check-up. Maintenance planning can be coupled with long-term personnel planning, both in composition of expertise as well as in planning shifts and working schedules. The necessary shunting operations for routing and moving rolling stock in and out of the workshop can only partially planned long-term, as these need to be coordinated short-term with the remaining shunting operations in the yard and the short-term needs of repairing broken down rolling stock.

5.2.2.8 P8 Transport to end-user

The final part of the last-mile of a freight supply chain involves distributing the goods to the end user. The logistics service provider transporting goods from the final terminal (via postal offices etc) to the end customer uses historical data to predict e.g. the number of trucks needed in different regions in order to transport the expected amount of goods. Long-term planning of the end user transport thereby involves such resource placements decisions and route assignments based on market knowledge and previous experiences. The actual order for the transport of goods to one specific end user is done on-demand or on a daily basis.

5.2.3 Overview of planning systems

The following subsection describes some of the planning systems which are the status quo for European yards and terminals today. These systems are used by the actors through the process map in 5.2.1 to plan the processes in 5.2.2. This section emphasizes planning systems relevant for long-term planning. For systems mainly relevant for short-term planning, requests and dynamic dispatching we refer to Chapters 6, 8 and 10.

Figure 15 visualizes the connections between the planning systems for a general terminal and yard, and includes the relation to the on-line freight train network and the road-based transport to and from the terminal. The "Ac" boxes represent the actors from section 5.2.1, and the new green boxes are planning systems "S" relevant for the associated parts of the terminal.

The freight rail service is an area under constant digitalization and technological developments. While large European terminals may have well-developed digitalized planning systems, studies show that many terminals mostly plan their activities and allocations *manually* given the necessary input data. Systems for planning and visualizing plans do exist, but the amount is limited and the user scope is mainly on a regional or national level. An increased level of digitalized information, both in short- and long-term planning, is necessary for generating seamless plans in an integrated fashion. The large variations in systems and interfaces used in Europe make it impossible to list every current long-term digital planning system in this section. For this reason, we list the planning systems on a general level and refer to only some specific systems relevant for each part of the process map in section 5.2.1. The underlying idea behind the mentioned and not-mentioned systems will be the same, as well as their users and use.

The planning system of "S0: Oral communication" is the most important planning system in 2023. Little can or will ever replace the experiences and knowledge living inside train dispatchers, IMs and terminal managers about how a good long-term plan should look. Although empirically founded, well-agreed and steered by the best suited people, the oral, manual communication may result in fragile, isolated and highly person-dependent planning processes. TRANS4M-R finds it vital to enhance and spread already existing, and introduce new digital planning systems for both short- and long-term planning to increase level of overview, stability and integration with other processes.

The planning systems considered in this section are S1: Train operator booking systems, S2: Gate operating systems, S3: Terminal management systems, S4: Yard management systems, S5: Depot management systems, S6: Loading and unloading systems, S7: Workshop management systems, S8: Path planning systems, S9: End-user systems.

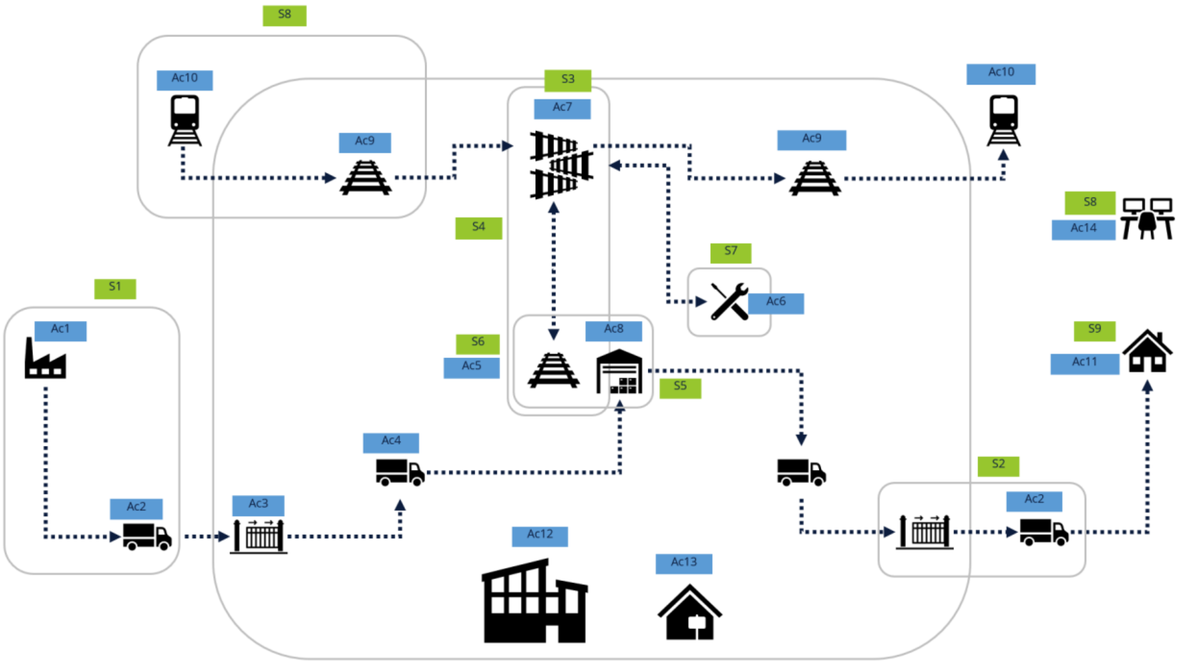


Figure 15: Overview of planning systems in a terminal and yard

5.2.3.1 S1 Train operator booking systems

The first-mile of rail freight transport brings goods from the producers, merchants or customers to logistic service providers, distributors or other subcontractors. As mentioned in process P1, there is no standard system for the planning of such transport. Operator specific systems for transport booking exist, like OnRail's PICit system or CargoNet's GTS system which are used in Norway. Such systems book transport on-demand and are relevant for short-term planning. The long-term planning aspect in a transport- and booking related system is minor.

5.2.3.2 S2 Gate Operating Systems (GOS)

A terminal's Gate Operating System (GOS) is a digital system for controlling transport through the terminal gate. When a truck approaches the gate, the registration number is automatically scanned, as well as other information as time and potential damage on the carried cargo. GOS is an intelligent system ensuring seamless movement through the terminal gate. GOS feeds input to and interacts heavily with TOS and other terminal management systems.

For long-term planning, historical data from GOS will contain valuable information, e.g., knowledge on terminal activity in different seasons and times of a day. This provides planners knowledge on capacity usage, bottlenecks and areas where development should be prioritized.

5.2.3.3 S3 Terminal Management Systems

By Terminal Management Systems (TMSs) is here meant all systems related to monitoring, overviewing and planning the terminal as a whole, as visualized in Figure 15. Such systems are primarily related to real-time information and overview of the terminal status, by gathering information about ongoing processes and storing information about equipment and cargo in the terminal. With respect to long-term planning such as capacity distribution and track assignment, terminal management systems may be used as a source for relevant historical data.

5.2.3.3.1 Terminal Operating System (TOS)

The Terminal Operating System (TOS) is a software platform that manages the movement and storage of various types of cargo in a terminal. It provides a centralized system for the efficient handling and monitoring of vessels, equipment, trains and crew, and seeks to achieve a more efficient planning of the terminal activities. Data is continuously shared between TOS and GOS as new information arrives, e.g. when a new truck enters through the terminal gate. The TOS can be adapted to manage the flow of cargo in and around rail terminals, including the movement and storage of cargo, inventory management, and scheduling and planning.

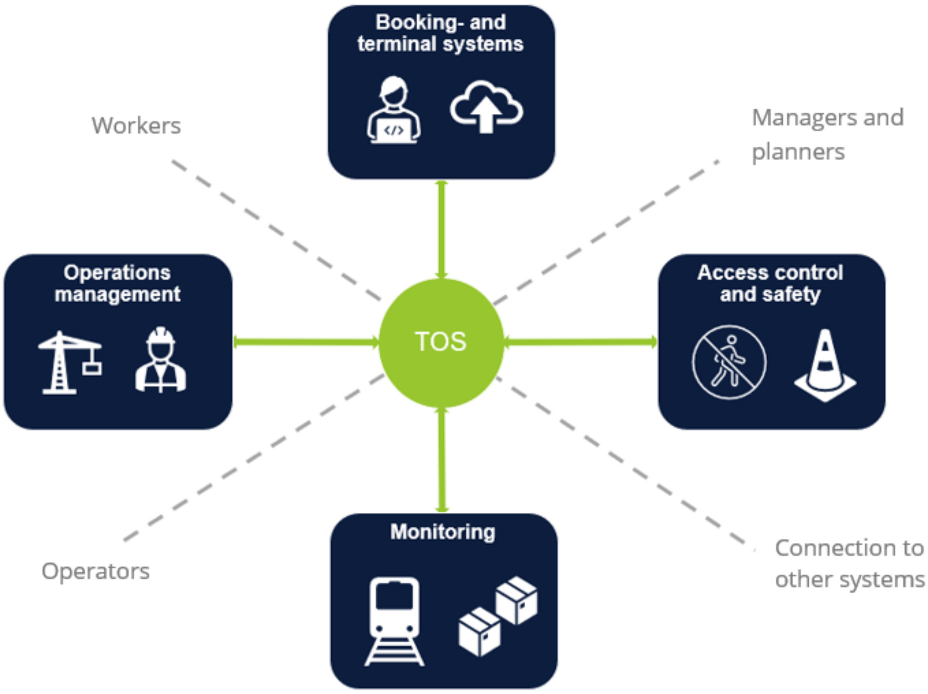


Figure 16: TOS and connected services, applications and users

5.2.3.3.2 DISC-M

The DISC-M system, mentioned in Section 7.6.1, is an example of a system similar to a TOS, but with more emphasis on reservations and alterations. DISC-M is an application used to plan train utilization. It includes all transport types (single wagons, complete trains), such as loaded or empty wagon movement. Key functions are the planning of wagon journeys according to the current plan, capacity reservation for wagons in trains, the definition of wagon handover in the marshalling yard, the monitoring and evaluating of the wagon transport plan, and responses to irregularities. The capabilities and data communication of this system may be used also for long-term planning of the relevant activities by creating e.g. drafts and seeing consequences of choices.

5.2.3.4 S4 Yard Management Systems (YMS)

In general, a Yard Management System provides information about assets and activities within a yard, enabling overview, access control and real-time insight. Such a system interacts with TMS and GOS for seamless data sharing. Depending on the actual system, a YMS may provide functionalities and capabilities concerning asset tracking, appointment scheduling, track booking, mobile integration, cross-platform communication, real-time notifications and visualizations and integration with other management systems. The system can relate to long-term planning by e.g. the capability of visualizing yard overview and thereby supporting what-if analyses.

5.2.3.4.1 Yard Coordination System (YCS)

The YCS is a tool for coordinating the planning of the track allocation for the arrival/departure yard of a larger marshalling yard. This tool is used in real-time and for short term requests, but the visualization, communication with other systems and level of overview for different operators may be useful when long-term planning the relevant activities. See the system explanation in section 6.3.

5.2.3.4.2 Yard Dispatching System (YDS)

As a use case environment for dynamic dispatching, algorithms for dispatching within the yard will be developed. The related system, YDS, should enable overview and planning of movements within a yard. See a further description in section 6.3. For long-term planning, the YDS will be useful for generating suggestions to shunting plans when the train paths and timetables are given. The plans may be easily adapted as new or updated information arrives.

5.2.3.4.3 Examples of systems used in Italia

As mentioned in process P6, some terminals in Italy have processes for long-term planning of shunting operations. For this, some digital systems are used, which are also relevant for other long-term planning processes.

Piattaforma Integrata Circolazione (PIC): It's a modular platform that seeks to guarantee the integration between management and information systems related to the circulation of trains in the infrastructure managed by Rete Ferroviaria Italiana (RFI), in addition to connecting with other systems related to rail transport in general (commercial, monitoring, logistics, etc.). PIC is used to request paths, share path details, share train compositions among other important communications between RUs and the IM. The system allows to request long-term shunting operations at the terminals managed by Terminali Italia, at the same time that the RU requests the track for the operation of a freight train.

Pattaforma Integrata Logistica (PIL): It's a platform created to support the FSI Group in Italy in the development of the freight transport sector from an intermodal point of view, with a focus on business processes and the integration of railway transport with all other actors of the supply chain. It is an open and modular hardware and software platform aimed to manage logistics processes and freight transport, and it is directed to provide real-time services to intermodal terminals through the interaction between actors and processes of the supply chain. PIL includes the management IT systems for shunting, handling, freight transportation and logistics, providing services that include digital booking, supply-demand matching, control and monitoring, data exchange and information.

Shunting management system: It's the IT system for the management of shunting operations at the terminal. It is an implementation of a Warehouse Management System and supports the end-to-end management of shunting operations at complex logistics nodes. The system covers the planning, execution, and reporting phases, allowing for the integration of all the actors (RU, IM and terminal/yard manager). The shunting management IT system is part of the PIL integration framework.

5.2.3.5 S5 Depot management system

For depot management and planning inside the terminal there exists no standard system. Real-time information and overview can to some extent be gathered from TOS. The actual overview of containers and depot content is, however, terminal operator specific. The systems they use are bespoke systems for their own needs, mostly at the short-term and operational level. In general, there do exist specialized RU systems connecting depot management to, e.g., workshop management. Such systems combine infrastructure and support data exchange and information flow between the two processes.

For long-term planning of depot activities and management the systems in use are limited. Most terminals plan their depot assignments and sizes manually when information on train paths and timetables is provided.

5.2.3.6 S6 Loading and unloading systems

In practice, the same applies here as for S5 Depot management system. Systems in use concern real-time information, and long-term planning is rather related to the assignment of loading tracks and possibly timeslots for performing the loading or unloading operations.

5.2.3.6.1 Track Assignment Optimizer (TAO)

As mentioned in section 5.2.2.3, the Norwegian Alnabru freight terminal will be a use case environment to inspect how to optimize the long-term assignment of loading tracks to terminal operators. Assigning trains to track-time slots (TTSs) for loading and unloading is a lengthy process, to which the to-be-developed Track Assignment Optimizer (TAO) will assist the track assigner and terminal operators in communicating and decision making.

The TAO takes as input the terminal operators' long-term applications for TTSs for all their planned trains. Currently this data is provided as part of an Excel file, with the relevant columns described in Table 4. This data input routine of course needs to be adjusted if the way the input data is provided changes.

The TAO is envisioned to approach seamless planning by supporting the following features:

- **Visualizing assignments:** The current system for visualizing track assignments is shown in Figure 14 in Section 5.2.2.3. This is a static, manually made figure. The TAO will display a dynamic timetable enabling, among other features, the drag-and-drop of TTSs (boxes in the figure), splitting a box (splitting a train over several tracks), and being notified of infeasible drops (e.g. two boxes on the same track overlapping in time on the same day).
- **Suggesting feasible assignments:** In addition to the applications in Table 4, the TAO will know information about the terminal topology, as well as safety rules and other restrictions which limit the set of feasible track-time-assignments. Algorithms will be developed for automatically suggesting and displaying assignments to the user on request.
- **Finding an optimal assignment**: Given some objective agreed upon with the relevant stakeholders which measures what a good assignment is, the TAO will use mathematical optimization algorithms for finding an optimal assignment beneficial for all actors.
- **Making a plan feasible**: Given a manually made but infeasible assignment, the TAO can find and display the feasible assignment most similar to the original one.

The TAO will be developed with different horizons in mind. Mainly, the tool will be developed for long-term seamless planning but some added features will also make the TAO useful for dynamic dispatching:

- **Long-term planning:** The TAO will assist the planners in the yearly making of the loading tracks assignment in Alnabru by being a relevant and easily available digital tool in the iterative planning process, enabling the abovementioned features.
- **Short-term planning:** In times of changed activity (e.g. summer), the TAO can take in updated information and find suggestions for assignments more suitable for the new scenario.
- **Real-time adjustments**: The TAO will be able to demonstrate the possibilities and potentials of enabling more frequent replanning, up to real time adjustments of e.g. updated times of arrival, changed train lengths etc. Additional (relaxed) constraints and conditions will then need to be discussed and added to (removed from) the system.

Regarding real-time replanning, an innovative vision for the TAO is its potential to interact with the timetable generating software used in Europe's Rail project FA1, MOTIONAL. The TAO can provide feedback to the timetabling software in terms of constraints and suggestions with information about whether a certain track assignment is possible in Alnabru or not, and if not why. In this way it may facilitate an iterative process of generating a timetable that can not only take the network but also the yards at the ends into consideration, assuming similar information is available about the other yards.

Column Name	Data Type	Description
Index	string	Unique Id for application.
Arr/Dep train number	string	Train number of arriving/departing train for which unloading/loading is applied for.
Operator	string	Train operator for the train.
Arriving/Departing	string	String indicating whether train is arriving or departing from Alnabru.
Outbound terminal	string	Name of terminal the train is leaving from.
Ending terminal	string	Name of terminal the train is ending at.
Arr/Dep time	time-string [hh:mm]	Time the train arrives/departs from Alnabru.
Arr/Dep day	weekday-string	Weekday the train arrives/departs from Alnabru.
Train length	integer	Train length in meter.
Loading track	string	Loading/unloading track that is applied for.
Loading/Unloading time: From	time-string [hh:mm]	Desired start time for loading/unloading the train.
Loading/Unloading day: From	weekday-string	Desired weekday for starting loading/unloading the train.
Loading/Unloading time: To	time-string [hh:mm]	Desired end time for loading/unloading the train.
Loading/Unloading day: To	weekday-string	Desired weekday for ending loading/unloading the train.
To/From train number (Day)	string	If relevant, the train number of connected train (If this train is departing, then the train number under which the same rolling stock arrived. Similarly, if the train is arriving, the train number under which the same rolling stock shall leave.) Weekday for connected train is added in parentheses.
Yard track	string	Desired yard-track for parking.
Notes parking	string	Comments about parking.
Notes	string	Other comments

Table 4: A terminal operator's application for a yearly TTS in the loading tracks assignment, here specified as currently provided in the Norwegian Alnabru freight terminal.

5.2.3.7 S7 Workshop management systems

Specialized RU systems for managing and controlling the terminal workshop exist and are used on the operational level by the workshop employees. Such a system may be workshop specific or a functionality integrated in systems with a larger terminal or yard scope, e.g. RAILBASE, which links maintenance and management of railway vehicles to the railway infrastructure. As the planning of workshop-related maintenance activities is mostly short-term related and on-demand, the long-term planning aspects are limited and rather related to track assignments, personnel planning, equipment management and regular maintenance, which are planned in other systems.

5.2.3.8 S8 Path Planning Systems

The international and national path and route planning systems assist in the yearly and long-term planning of train paths, which again affect the train timetabling process. Technical and functional elements of related systems are described in section 5.1.

5.2.3.8.1 Path Coordination System (PCS)

The Path Coordination System (PCS) is a system used for harmonized international path planning, by gathering new, late and ad-hoc path requests [RNE PCS; 2023]. This system has over 1000 daily users, such as national IMs and applicants. In PCS, trains are presented as dossiers, containing information about composition, basic data and other parameters and comments. The PCS systems supports the path planning process from the starting point of adding a new dossier through requests, booking and timetable drafting to final offer and closing the active timetable.

5.2.3.8.2 National path planning systems

Communicating with the PCS, some European countries and IMs have their own national system for planning paths, routes and generating timetables. This system takes input from PCS for the international trains, and can also be used as an interface for providing applications to the PCS system. The national planning system provides information to operational systems like the S3 systems used for operational management and overview, and for other terminal and infrastructure related planning.

5.2.3.9 S9 End user systems

The end user, who receives his goods at the end of the freight chain, uses distributor related applications for monitoring the transport status. The distributors and logistic service providers again have their own systems for such monitoring and internal planning of resources based on the (forecasted) demand. These systems are in practice unrelated to any (long-term) planning systems of the freight train chain or other terminal systems besides the ones potentially used by the distributors themselves.

5.2.4 Requirements for long-term planning systems

The two previous subsections explained some processes (5.2.2) and systems (5.2.3) related to the planning of a terminal with an emphasis on long-term planning. Long-term planning is essential for several stakeholders in the rail freight industry. *IMs* need planning for capacity management, path allocation and timetabling. This planning helps to check the stability of the timetable for user groups across the freight train line, but also enables the IM to prepare other timetables in case of strikes and line interruptions. The freight *train operators* may plan long-term together with their costumers to optimise the use of their own resources. *Terminal operators* may benefit from planning by safe, robust and reliable freight service. Inside a *terminal* and *yard*, long-term planning enables overview, forward-thinking and integrated processes in an otherwise often pressured and traffic-filled environment.

However, long-term planning cannot fulfil the full requirements of the shippers and logistics transport market. Flexibility is a challenge for train operators as they compete with road-based transport companies that are able to organise transport units and transport service from one hour to the next one. Thus, shippers and logistics companies perceive that the rail freight transport service has a disadvantage compared to road freight transport. Train operation companies will have to meet this challenge by offering better services and advantages in other characteristics like availability of customized wagons and loading units, opportunity to transport higher volumes and weights, short times for loading and unloading etc.

The inevitable need for on-request planning and dispatching for the rail freight service, especially on the last-mile, makes requirements for long-term planning systems hard to state in a concrete manner. Below, we refer to some general technical and functional requirements for planning systems which are considered necessary to achieve seamless long-term planning. Some specified requirements were mentioned in the relevant "S" subsection in 5.2.3. Non-required, but desired functions and capabilities are discussed in 5.2.5. For a more concrete list of requirements, also including requirements for short-term planning, we refer to the attached Excel document *"Seamless Planning Requirements"*.

User groups

- Clearly and suitably defined system user groups.
- Clearly and suitably defined access policies.
- Clearly and suitably defined planning areas, geographically and in time.
- Differentiated and defined user responsibilities.
- Definition of input provider system/user and output receiver system/user of the different system functionalities.

Information processing

- Separating between estimated, planned and actual data information.
- Possibility of storing a pool of relevant data (trains, operations etc) that should be planned, but have not yet been.
- Defined agreement on the access to historical plans created by the system
- Defined agreement on the access to historical plans and information relevant from other related systems

Interfaces for shared planning systems

- The systems must have a clear scope for which actors and other systems it should communicate and share information with.
- Open, not proprietary, interfaces when relevant.
- Clearly separating open from confidential information between the actors.
- Common and standard interfaces across terminal areas.
- Common and standard interfaces across regions.
- Common and standard interfaces across nations.
- National planning systems must implement interfaces from the relevant international planning systems, e.g. PCS for path planning.
- National planning systems must properly translate national data into format required for international data sharing by the specified interfaces.
- Standardized message-sharing format across terminal areas, regions and nations. See e.g. chapter 7.4.

Planning

- Possibility of drafting plans.
- Possibility of storing the final plan.
- Appropriate visualization of the final plan.
- Sharing the final plan with all defined users in an agreed-upon time horizon.

- The system must have properly detailed information about the planning environment, e.g. correct information about relevant track lengths.

5.2.5 Functions and capabilities for integrated planning

FP5 TRANS4M-R aims, among other goals, at enhancing yard and terminal planning systems. A desire is to increase the level of interaction with network planning systems, so that the systems can process data in an efficient and agile way for a better internal planning of the resources. The information presented in 5.1 and 5.2.1-5.2.4 founds the basis for this section, which in a general way seeks to describe functions and capabilities that can improve planning processes and systems.

5.2.5.1 Improving planning in yards and terminals

The Seamless Planning use case environments have discovered the following aspects relevant to consider to enhance the long-term and operational planning:

5.2.5.1.1 Prediction models

Long-term planned times of arrival and departure will naturally be generated with some level of uncertainty due to the timespan and lack of finalized information. Based on previous knowledge planning systems may use artificial intelligence for predicting suitable times for each train. Prediction is also relevant for the dynamic dispatching and operational planning level as exemplified through the use case environment in sections 7.5 and 5.3.

5.2.5.1.2 Automated decision-support

FP5 TRANS4M-R will develop digital systems that can interact with the users and automatically visualize feasible plans and schedules when the proper input data is provided or updated. Such systems incorporate, e.g., optimization and prediction models. This innovative functionality will be groundbreaking for the field of both the operational and long-term planning processes. Decision support raises the level of overview in time, geographical area and between different actors, and will shorten the way towards the future's integrated and seamless planning processes.

5.2.5.1.3 What if-capability

Automated digital systems with decision-support should also include the possibility of performing what-if-analyses. This capability will ease planning processes by coping with insecurity and visualizing to the planner what will happen if this or that action is chosen. This capability can answer questions like: What happens in the loading area if this train is delayed? What happens if that track is out of order? Intelligent decision-support systems may also assist planners by answering: When *should* this train be loaded if it is delayed? Where *should* that train be routed through the terminal if that track is out of order?

5.2.5.1.4 Collaborative planning and decision making

To a larger extent, stakeholders and actors at the terminal should interact and plan their activities through increased level of communication. Plans should be cocreated in an interactive and iterative way, ensuring that the scheduling of some activity (e.g. loading, portal crane movement, depot rearranging) is related to the scheduling of some other, different activity (e.g. shift locomotive movement, stabling trains). The future development of systems should to a larger extent focus on collaborative decision making.

The use case environment developing the Asset Warehouse exemplifies how collaborative cross-operational short-term planning can be achieved. See sections 5.3 and 7.6.1.

5.2.5.1.5 Data access and sharing possibilities

Different systems in use by the actors involved in planning processes must allow a transparent share of the relevant data. In order to accomplish integrated planning, the scope of processed input must exceed the direct output of the relevant planning process. Drafts for plans must be communicated as early as possible so that processes depending on this knowledge may adapt their planning in an optimal way. For more information on this matter, see chapter 11.

Challenges will arise with respect to data access regarding competition, regional boarders, update frequency, software interfaces, reliability, format etc. The development of the future software for the freight rail system must grasp these at an early stage, and strive to enable safe and honest communication for the greater good.

5.2.5.1.6 System overview

There is a need for sharing access and information to some terminal system overviewing the activities happening at a terminal, but also the planned activities. A bird view of the present and planned terminal operations should be available for the key managers active at different parts of the terminal; train dispatchers, terminal operators, IMs etc. An objective, common overview makes real-time decision making easier despise different interests, and ties together processes which may in practice be viewed as isolated.

5.2.5.1.7 Operationalisation of long-term plans

If long-term plans exist, e.g. for assigning track-time-slots for the loading/unloading of a train, the experienced truth is that these plans are rarely followed by the practitioners. The important constraints may be satisfied, like on what track some train should be unloaded, but the time and order with other trains may be very different from what is planned. To achieve more seamless terminal operations the long-term plans should be attempted to be followed by all actors. If there is a significant gap between plan and performance, then the performance should be reconsidered and the plan updated. A reliable and realised plan gives a common knowledge of what is actually being done at the terminal at each time, strengthens the possibility of smart reactions when delays occur and will, ideally, ensure that all operations are performed at the most suitable time slots. Optimizing long-term plans is of no use if the plan is not used on a day-to-day basis.

5.2.5.2 Integrated end-to-end train path

All parties along the rail freight line are benefited from a more integrated planning process. What happens in a yard will affect a train's travel on the network, and vice versa. A fully integrated end-to-end planning process is, by our experience and due to the information in this section, believed to be very hard to achieve. Some reasons are the following:

- **Different time horizons** in the planning processes, from one year to real-time decision making.
- **Different scope**, macroscopic planning of a line or microscopic planning of activities within a yard.
- **Uncertainty:** How can end user transport be planned if timetables are not generated? Can other terminals rely on one terminal performing its activities within the deadlines? Uncertainty makes intermodal planning hard.
- **Interest conflicts**: With respect to, e.g., time being spent on operational processes, as well as resources.
- **Competition**: Sharing systems and processes may be undesirable due to this.
- **High pressure**: Burst capacity and constant high traffic volume makes routine changes hard to realise.
- **Political aspects and policies** may limit the amount of planning it is possible to integrate with other stakeholders.

- **Handover points:** Seamless data exchange at points of different transport.

In addition to what was mentioned in section 5.2.5.1 are below some functions and capabilities which could ease the above problems and guide the future freight rail towards more integrated planning.

5.2.5.2.1 Sharing data on times and location

Operational planning will be enhanced in all parts of the supply chain by a proper share of timestamps, milestones and updated information. This is discussed in detail elsewhere in the deliverable, e.g. chapter 8 and 11.

5.2.5.2.2 User and role management for common systems

Integrated planning may be achieved by using integrated planning systems, where different stakeholders may provide information, parameters, suggestions and ideas relevant for different plans, or to plan their own operations. Such integrated planning raises high demand for cyber security, monitoring and data protection. In some way, anonymization of data and correct accesses must be addressed.

5.2.5.2.3 Data warehouse

Planning will be enhanced by relaunching the use of existing or developing new common data warehouses. In this way, reliable, specified information may be shared among actors for better operational planning. This may involve actors working from managing locomotive inspections to routing end-user transport. The Asset Warehouse (see e.g. sections 5.4 and 7.6.1) exemplifies precisely this.

5.2.5.2.4 Iterative processes

Parts of the end-to-end freight service chain should be planned in an iterative process. This enables different stakeholders and actors to share their views and suggestions, while also altering them when input from other actors is received. Such processes do exist today, but we see the potential for expanding this way of working further: Network – terminal – yard – distribution. As a start, iterative planning processes should be implemented for use by “neighbours” in the supply chain. From there, workshops and tests should demonstrate how such planning communication can benefit larger parts of the service chain.

5.3 Short-term requests and changes in the current timetable period regarding the first- and last-mile planning systems and functions

Freight specific definition of use cases/applications when short-term planning is necessary. Based on previous analyses of the operational and commercial activities of RUs in the field of cooperation were identified several serious deficiencies which unnecessarily increase the capacity requirements on cross-border lines, especially at neighbouring stations. There are very fundamental constraints that consist in inadequate transport information. Due to lack of information RUs have to stop trains at hand over stations to complete the information (besides other things for the needs of its own customers).

Related EDICT milestones, resp. processes involved are following:

- P1 From production and customers to transport,
- P2 Road-based transport to/from terminal,
- P3 Loading and unloading processes,
- P4 Shunting departing and arriving trains,
- P5 Transport on the main line,
- P6 Shunting movements in a yard,
- P8 Transport to end-user.

5.3.1 Identified shortcomings

Along the transport chain, insufficient and/or lack of immediate information on delayed trains may result in interruption of operating processes or a lack of supply. This can have a strong impact on the suitability of rail transport for specific commodities which rely on just-in-time production. The project deals with the solution based on improved train running information, with the time saved proxy in each RFC by a smooth handover of the Estimated Time of Arrival (ETA) and an active transport planning and management.

The identified shortcomings and their solutions are mainly in insufficient communication between railway freight RUs (missing or wrong information), in information exchange about planned train running and capacity planning of other resources (engines, drivers, other staff), and train composition. The train planning processes are significantly interconnected between RUs due to the mutual use of resources (locomotives, drivers, wagons). Data exchange standard is not applied for the resource planning process. With the measure of trains, it is not possible to effectively perform the coordination of processes among RUs without IT support. The most common reason for stopping trains at border or handover stations is in order to replace engine or the driver, due to impossibility to coordinate shifts and timetables of resources and therefore share them. To streamline the operation process and eliminate idle times at borders, the RU needs train data of partner RU right during planning process to adapt its own plans. At the same process, it is possible to define the requirements for the return of resources back from the cooperating RU. The development of new data interfaces of the information systems ELITE and DISCOR is assumed. It would lead to a data exchange of the train plan, its requirements and composition between the systems.

5.4 Requirements on short-term planning systems different from long-term planning systems

Preparation of resources for a specific transport is based on the requirements of e.g. the customer at the time of the transport order. Also, at the time when the transport is in progress, but the plan can still be planned/refined.

Short-term planning data is an input for the dynamic dispatching (preparation of the shift plan). Time of input is, for example, period from 10 days to approx. 12 hours prior to execution on a specific transport section/responsibility.

Determination of resource requirements (including local resources) is depending on the refined plan (short term). The resource requirements are entered into the Asset Warehouse. Results are based on demonstration shifts.

Outcome of the process are data on planned transports (route/path, shipment, timing, physical properties) during a defined short-term period, which requires partial data acquisition also during implementation on the foreign section and identification of deviations in transport characteristics compared to the long-term plan – changes in times and route/path as well as changes in shipment and physical properties. Current data form long-term planning systems are not complex and reliable. Due to that is proposed usage of multiple data resources.

Proposed Asset Warehouse system receives regular ETA updates from the connected ETA prediction system. This input supports and enables some of the key functions of the Asset Warehouse, such as the reassignment of planned resources. In turn, the ETA prediction system receives data from the dispatching management systems.

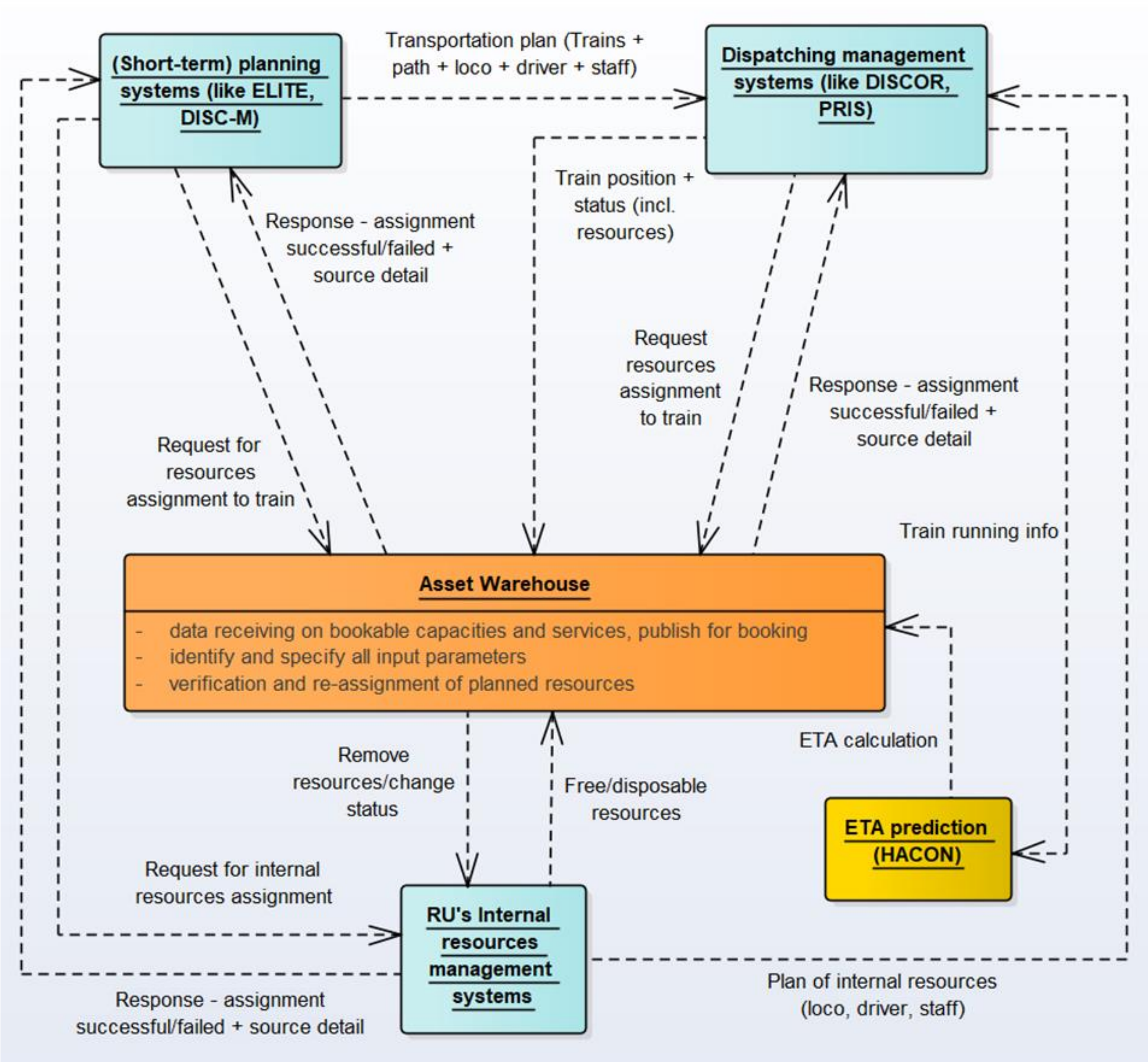


Figure 17: Asset Warehouse - Resources assignment for Short-term planning/Dispatching systems

5.4.1.1 Identifying requirements for establishing reliable planned time of arrivals from yard/terminal departure predictions

Train path planning, especially long-term planning, is partially based on information with inherent uncertainty, such as the actual yard/terminal arrival and departure times. This uncertainty for the required resources promotes the gap between planning and operations, which naturally interferes with the reliability of the planned time of arrival to the following yard/terminal.

Currently, deviations between the planned train departure from the yard/terminal and the actual one is addressed by the infrastructure manager's dispatcher, whose objective is to decide the actual departure time of the train from the yard/terminal into the mainline. This decision is made based on the real-time capacity conditions on the mainline, which limits the reliability of long-term planned times of arrival that were established at earlier stages. A train's planned time of arrival is reliable as long as the path plan is robust to delays, and the actual train departure from the yard/terminal is aligned with the reserved path plan. As freight trains in general have lower dispatching priority on the mainline (Crozet, 2014, p. 28), they are exposed to a higher risk of delays in case of network disturbances, and the reliability of their planned times of arrival becomes also a product of unplanned conflicts and the possible dispatching decisions from the infrastructure manager.

As the timeline transitions from long-term planning to real-time operations, more information that become available can be used to improve seamless planning. Previous studies have shown that data-driven approaches can improve the predictability of yard departures (Minbashi et al., 2023). Improved predictions of yard/terminal departures can identify the mismatch between long-term or ad-hoc train path planning with the actual operational requirements. An identified mismatch can become valuable for the provision of short-term planning for the train transition from yard/terminal (FP5) to mainline (FP1). Such short-term plan can improve the seamless planning between two yards/terminals in two aspects. First, by improving the resources utilization on yard/terminal as well as on the mainline. Second, by improving the reliability of the planned time of arrival by incorporating the effect of possible dispatching decisions from the infrastructure manager when adjusting the train's path plan.

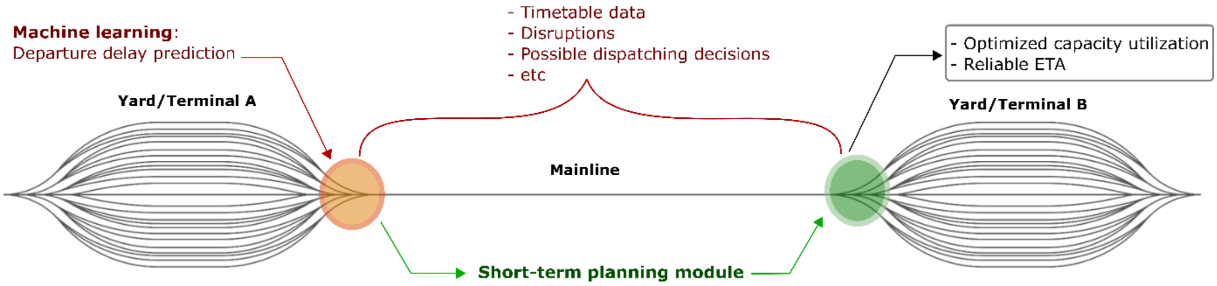


Figure 18: Integration of departure prediction model with the short-term planning module

This work requires integrating departure prediction model with short-term departure planning module as shown in Figure 18, which will be part of the Malmö and Alnabru demonstrator. This integration work serves as a proof of concept on how to implement early predictions to improve planning in short-term, therefore, the concept can be applied with basic input requirements, which can be developed further with more information that is available. The requirements for the prediction model are identified in Section 7.5.1.

The objective of the short-term departure planning module is to identify a train's departure time from the yard/terminal to the mainline that balances between the capacity utilization in the yard/terminal and the mainline. Therefore, the following requirements are identified for establishing a reliable planned time of arrivals:

- The machine learning model must provide predictions of freight trains' departure times. These departure predictions will serve as an input for the short-term departure planning module as it will be used to identify possible mismatch with long-term planning. Trains that are identified to have such a mismatch will then be selected for evaluation and planning in the short-term departure planning module.

- For each of the selected trains, two capacity utilization functions will need to be constructed as suggested in the illustrative example in Figure 19. The first function is based on the capacity utilization for yard/terminal waiting. This time function will need to be based on the occupancy of the yard/terminal after the predicted departure time, i.e. the penalty of waiting in the yard/terminal. The objective is to identify if the train should wait further in the yard/terminal before the IM dispatcher allows it to enter the mainline. This offers the possibility for the train to avoid entering the mainline if it is too congested and the yard/terminal is relatively less congested. Therefore, this function requires information of the last updated plan of yard/terminal resources usage.

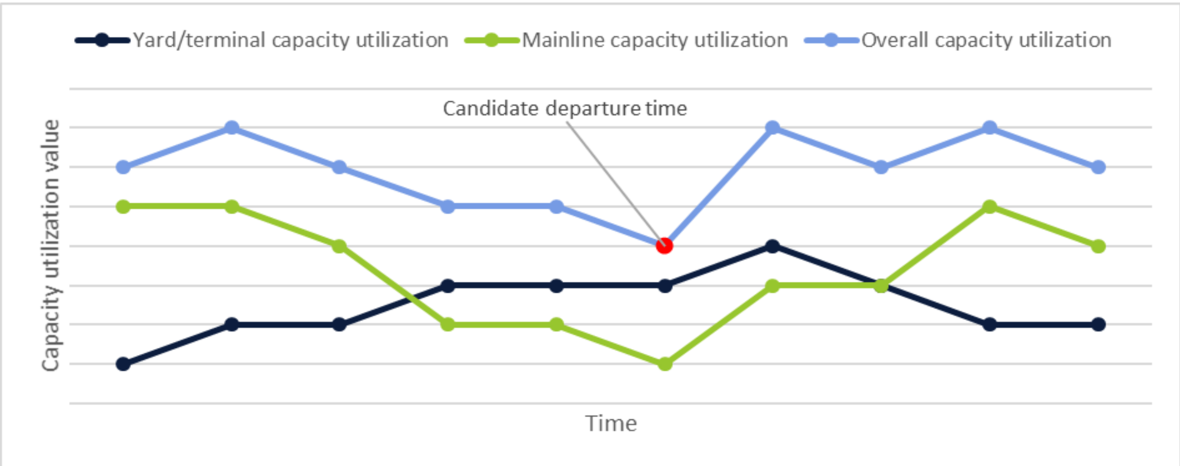


Figure 19: Illustrative example on the suggested departure time from the yard/terminal

- The second function is also part of this departure decision, where this function will need to be based on the capacity utilization condition on the mainline, i.e. the penalty of allowing the train to enter the mainline rather than waiting in the yard/terminal. Therefore, this function requires information of the last updated plan of main line's resources usage between the two connected yards/terminals, this can be for instance the last updated timetable. The overall capacity utilization function is the summation of the two functions, which will identify the time that has the minimum utilization to be the suggested/planned departure time. This planned departure time balances between the capacity utilization in the yard/terminal and the mainline.

- To ensure that a reliable planned time of arrival can be achieved with the planned departure time, the mainline capacity function should be based on the last updated timetable, and should be reflective to the main line's capacity occupancy, maintenance work, runtime of the train to the next yard/terminal, and the risks of potential events or dispatching decisions that may cause delays for the train. Therefore, a simulation tool with dispatching logic will be used in connection with the predicted departure time to evaluate the associated delays with each departure alternative.

5.5 Short-term cross border planning system based on unique transport identification

The above-mentioned shortcomings either directly or indirectly extend idle times or otherwise seriously affect the quality of rail freight transport as well as the cost-effectiveness of individual transport operations. Shortcomings affect not only the planning and operation on cross-border sections but also on the national sections. Regarding the RU, it is therefore about the development of a communication system. Regarding the solution, it is about developing an interface for existing information systems and about the development of a new tool for (small) RUs (both based on TAF TSI communication). Standardised communication is also not affected by information systems individual organisations are equipped with. Proposed solution developed within the project meets condition of accessibility for use by all operators, it means on a non-discriminatory basis and may be available for use by all freight carriers.

The aim is to provide railway RUs a comprehensive tool (information system/component) helping them increase competitiveness and thus help effectively change modal distribution. Developed tools will not only help to improve the quality of services offered but will also help to speed up data interchange among external systems, resulting in a synergistic effect that will result in shorter delivery times, greater volumes of goods transported and manipulated, and greater flexibility of services provided.

Implementation significantly rationalizes the processes of planning and utilization of resources, integrates maximum information into a comprehensive package with transport identification. It will also enable the coordination of plans between partners in the specification of transport parameters (especially critical transport times of handing / taking over of resources used during transport). All processes are linked to the shipment initiation process and use the shipment information came up from the precise planning.

Implementation will significantly accelerate the process of cross-border transport and check-in at the initial and end points of transport. It will remove unnecessary downtime to the transport. The result of the proposal is a new interface enabling the coordination of plans between transport partners, including notification of expected changes.

The train planning and dispatching system components match route needs with resources (allocation, validation) in the short-term and ad hoc, including path requirements (FP1), see Figure 20.

Short-term planning based on Asset Warehouse has following features:

- Redesign of a short-term process regarding cross-border path requests, cooperation on implementation, including an interface for harmonising transport planning of business cases (consignment/train) between railway undertakings.
- IMs' planning information systems (FA1) define route coordination based on TAF TSI (for example PCS, TIS etc.).
- Relevant partners, such as small RUs (project partners or others not participating in the project) are willing to synchronise business cases, transport planning, and code lists.
- Introduction of multilateral communication between RUs based on the unique identification (reference case, TSI TAF attribute) of the transport with emphasis on the confirmation of the reservation of the resources allocated to the transport/train.
- Harmonization of the resource allocation process on a cross-border section with implications for the last mile and CZ sections (related to the reference case).

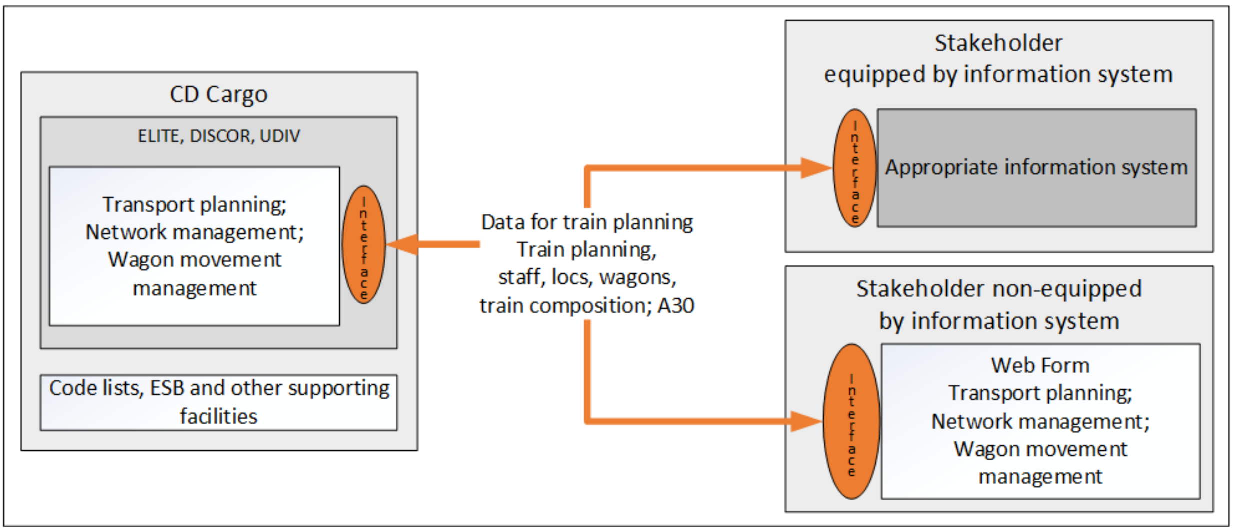


Figure 20: Short-term planning and cross border harmonization incl. small RUs from the perspective of CD Cargo

Abbreviations used: TMS = Transporting management system, ELITE = System for short-term resource planning, DISCOR = Information system for support of operational management, ESB = Enterprise service bus

5.5.1 Interface description

The interface between the short-term planning system and dispatching systems will process the collected information to put them into a useful standard. This processing requires additional information on the trains described in the dispatching systems which can be taken from TAF TSI messages. Those message types that are relevant for the interface will be described in the following section.

TrainStatus

TrainStatus is a message about the current position of the train. The request is expected to include the whole TrainStatus message. TrainStatusRequest is called by dispatching management system providing actual Train Status. This request will be set up by Asset Warehouse.

Use case specification of an inter-railway cooperation in planning

The use case specification of an inter-railway cooperation plan in the context of FA1 processes is defined and demonstrated through two case studies.

Train planning/dispatching from/to the terminal/yard, operated by CDC

This use case focuses on coordination of planning and dispatching processes during transport. The primary challenge lies in supporting the processes by relevant data exchange among all stakeholders involved. Everything begins in the planning phase, where information about the planned transport is available to coordinate future data exchanges (demonstrated in WP 26). This entails sharing details from the owner/keeper/leader of the transport with each partner, primarily for transmitting the unique identification number (UID) of the transport. The planning process constitutes a crucial step where specifics about the transported goods or materials are refined collaboratively, enabling effective information exchange among all parties involved. In initial phase of information exchange, establishing a clear line of communication from the owner/keeper/leader of the transport to each partner lays the foundation for seamless collaboration. The communication channel, particularly concerning the UID of the transport, forms the backbone of subsequent interactions among stakeholders. The aim is to coordinate planning at the level of paths and resources. It is necessary to accept different time milestones for each partner. For example, when the terminal operator finishes its process, the first RU starts its dispatching phase and the next RU is still in the planning phase. Progress stages among partners, particularly the RUs, require adaptable strategies. For instance, while the terminal operator completes their processes, the first RU enters the dispatching phase, creating a dynamic workflow. Flexibility in timelines becomes crucial, ensuring a synchronized approach despite diverse stages of particular transport. An adaptability is vital in harmonizing the efforts of different railway undertakings, allowing them a seamless transition through various stages of the transport process. In such a complex process, effective communication and data sharing are crucial for a smooth operation. The RUs need to have access to real-time information about the status of resources and schedules to make qualified decisions.

Real-time access to crucial information is pivotal in ensuring that RUs can make timely and informed decisions. Access to up-to-date data regarding resources and schedules empowers RUs, enabling them to optimize their decision-making processes.

Assets Warehouse features

Dispatching phase is closely linked to ETI/ETA calculation process (WP 28). Every change in an agreed plan must be checked against the resource availability. In case of conflict the reallocation process has to be started. As a support it is used the Asset Warehouse tool, which is able to offer available resources of another stakeholder (WP 27).

The Asset Warehouse tool plays a vital role in the data exchange, as it provides a centralized platform for RUs to access and reserve resources from various stakeholders. This simplifies the process of reallocating resources when conflicts arise.

Finally, in case of reallocation process, it is necessary to check the availability of the requested services (marshalling, shunting, brake testing, technical inspection, etc. – WP 31).

During the reallocation process, a thorough examination of the availability of requested services becomes essential. Services like marshalling, shunting, brake testing, and technical inspection (as outlined in WP 31) are scrutinized, ensuring that each service is available when needed, maintaining the fluidity of the transport process.

Requirements:

- Innovated data interchange of connected items to ensure proper information at the appropriate time and with the right IDs, based on TAF TSI – particularly the unique identification of trains as they go through each country and IM. In this particular instance, it refers to the interchange of data between the ČDC planning and dispatching system (ELITE, DISCOR) and any other system used by another RU.
- New data exchange for sharing available resources, which refers to resources planning systems (like ELITE on ČDC) and transport and activity planning (like DISCOR and PRIS on ČDC). The provider of data exchange will be the Asset

Warehouse system which provides service booking process among different stakeholders.

- A centralised database and point of access for conducting queries on locally accessible public information (such as the location of access to sidings, the terms of such access, and the time slots for deliveries).
- The creation of an identifier for the object's owner in order to facilitate data interchange (transport, train).

Data providers:

It requests data related to the transport (with any unique ID) in real time mode, e.g. transport announcement in planning phase (leading RU -> terminal operator and participating RUs), preparation process in terminal (terminal operator -> 1st RU and leading RU), ETI/ETA calculation (RUs) and inputs for marshalling (RU -> marshalling yard operator).

State of the art (data exchange):

- RU -> Customer/terminal (in CZ) only dedicated non-standard data exchange
- RU -> RU old fashioned UIC Hermes data exchange (A30 Train pre-advice, A31 wagon movement, A40/41 consignment message)
- RU -> MYO internal ČDC data exchange
- ETI/ETA is solved only in internal ČDC systems.

The use case underscores the critical role of efficient planning and data exchange in the realm of railway operations. The coordination between various stakeholders, including RUs, is pivotal in ensuring the smooth and reliable transportation of goods. The innovative data exchange, resource sharing, and real-time access to crucial information are central to this endeavour. The utilization of tools like the Asset Warehouse system facilitates the process and minimizes disruptions, while adherence to TAF TSI standards enhances interoperability across borders. The adoption of such practices and technologies is necessary to meet the growing demands of the transportation landscape.

Use Case Hamburg – Prague

The first case is the transport of containers between selected terminals, where the distribution of containers occurs before and after the use of sea transport.

Type: Unit train								
Comodity	Combi - container			Planned resources				
Route 1	Route	RU	State	Licence	Track	Loco	Driver	Staff

Departure	Hamburg-Waltershof	ČDC DE	DE	ČDC DE	Terminal	ČDC DE	ČDC DE	Terminal
ETA decisive point	X km / X min	ČDC	DE	X	X	X	X	X
Handover point	Bad Schandau	ČDC DE/ČDC	DE	ČDC DE/ČDC	DBN	ČDC DE/ČDC	ČDC DE/ČDC	X
Via	Ústí nad Labem hl. n.	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC DE/ČDC	X
Destination	Praha-Uhříněves	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC	Metrans
Comodity	Combi - container			Planned resources				
Route 2	Route	RU	State	Licence	Track	Loco	Driver	Staff
Departure	Hamburg-Waltershof	ČDC DE	DE	ČDC DE	Terminal	ČDC	ČDC DE	Terminal
ETA decisive point	X km / X min	ČDC	DE	X	X	X	X	X
Handover point	Bad Schandau	ČDC DE/ČDC	DE	ČDC DE/ČDC	DBN	ČDC DE/ČDC	ČDC DE/ČDC	X
Via	Ústí nad Labem-Střekov	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC DE/ČDC	X
Destination	Česká Třebová	ČDC	CZ	ČDC	Metrans	ČDC	ČDC	Metrans

Table 5: Use Case Hamburg - Prague

Use Case Nymburk - Emden

The second case is the transport of cars from the Škoda Auto car factory (Mladá Boleslav, Solnice) with collecting in MY/terminal Nymburk (CZ) to Emden terminal.

Type: Unit train

Commodity	Automotive			Planned resources				
Route 1	Route	RU	State	Licence	Track	Loco	Driver	Staff
Departure	Nymburk hl. n.	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC	ČD
ETA decisive point	X km / X min	DBC DE	CZ	X	X	X	X	X
Via	Ústí nad Labem-Střekov	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC/DBC DE	X
Handover point	Bad Schandau	ČDC/DBC DE	DE	ČDC/DBC DE	DBN	ČDC/DBC DE	ČDC/DBC DE	DBC DE
Destination	Emden	DBC DE	DE	DBC DE	Terminal	DBC DE	DBC DE	Terminal
Commodity	Automotive - empty			Planned resources				
Route 2	Route	RU	State	Licence	Track	Loco	Driver	Staff
Departure	Emden	DBC DE	DE	DBC DE	Terminal	DBC DE	DBC DE	Terminal
ETA decisive point	X km / X min	ČDC	DE	X	X	X	X	X
Handover point	Bad Schandau	DBC DE/ČDC	DE	DBC DE/ČDC	DBN	DBC DE/ČDC	DBC DE/ČDC	DBC DE
Via	Ústí nad Labem-Střekov	ČDC	CZ	ČDC	SZCZ	ČDC	DBC DE/ČDC	X
Destination	Nymburk hl. n.	ČDC	CZ	ČDC	SZCZ	ČDC	ČDC	ČD

Table 6: Use Case Nymburk - Emden

Above-mentioned use cases are aligned with the description of Loading Tracks Assignment presented in section 5.2.3.6. These use cases are also relevant for short-term planning and subsequently in dynamic dispatching. Resources assigned in long-term plan will be reassigned through Assets warehouse algorithms. The reassignment must by coordinated on both sides of border (it is necessary to establish using of unique identification of transport).

5.6 Capacity view and forecast web frontend

In recent years shippers have to a large extent organised their production with a reduced level of storage/stock, using just in time or just in sequence logistic procedures. This goes in hand with a high dependency on the quality of the services, but especially also with the requirement to recognize early enough if in the coming weeks and months their transport mode of choice for their production plants will be affected by relevant capacity restrictions. Nowadays even their service providers (intermodal operators / RUs) do not have a full picture about the available infrastructure in the coming weeks and months and must cancel their services on short notice. Short notice is in this case to be understood as a time span which does not allow to prepare sustainable mitigation measures.

If for example a shipper is usually transporting spare parts or raw material 3 times per week from one plant to another and has a maximum stock for 2-3 days of production, the shipper is highly affected if more than one of the trains must be cancelled without sufficient early notification. Then there is either the (limited) chance to run a respective number of additional trains on short notice to increase the stock level before the track closure starts, which is mostly not possible, on one side as the resources of the RUs might not be available on short notice or as the capacity limitation of a line or network section will affect / has affected not only their trains but also others which have to be re-scheduled. Therefore, it is often the only chance to switch a reasonable amount of transport volume back to other modes of transport, which leads to higher additional costs and a loss of environmental performance of their supply chain.

If certain temporary capacity restrictions (TCRs) on the European network would have been visible for either internal or external logistic management departments in a simple and easy way, these could have prepared mitigation plans and could have increased the stock volume for the respective period by ordering additional trains or additional capacity on trains early enough in the time period before the capacity limitation, so that the emergency usage of road could be prevented.

The relevant information enabling to prepare, initiate and implement such alternative solution, is in several cases available only in a scattered way in the various systems of the IMs, is only partly processed by the operators, and is not easily accessible. Consequently, there are several constraints and reasons for a limited proactive usage of the information for the logistic departments of the shippers.

Even if the information is partly available it is not accessible transparently or at least not in an effective way. Searching in various data sources, requesting and exchanging information via phone or mail, and repeatedly updating this to stay up to date on a dayly or weekly basis is burdening or even preventing any pro-active management of the supply chain and storage concept.

The required information must be available at least clearly assigned to specific lines and network sections and should include the period during which the capacity restriction will be effective. Detailed information about the limitation (full track closure, single track operation, speed limitation, …) should be provided. The basic system accessing the data framework must be capable to manage TCRs in an appropriate way, to feed a respective web-frontend with filtered/merged/processed information. The users should be able to enter origin and destination, as well as a time period or specific date, and should receive filtered information on TCRs for these settings, shown on a map and/or in a list to be downloaded. In this step, the approximate effects of the TCRs can be calculated based on the existing information which allow a categorisation of TCRs. If timetable data should be connected to the system, this calculation will show the effects of TCRs on single train runs with a higher precision. This information might also be pushed following an abonnement to the service. The system might allow to register and to safe certain settings and favourite filter combinations (e.g. for regular transport relations, …).

In a later second version, an interface to the LTP (daily) or effective daily timetable could allow to enter a train number and to receive a result of limitations affecting this train during a period or a specific date. This enables to check whether the restrictions for the maximum number of TCRs affecting a single train run have been violated. Additionally, the forecasted daily run time extension for all affected train will be given. Besides the mainline, also TCRs on sidings or loading points could be considered in a second version.

6 Dynamic Dispatching

6.1 Overall target

Dynamic Dispatching is the combination of two major elements. On the one hand it is the operational know-how about how to optimize tasks and actions in Yards and Terminals, thanks to digitalization to visualize it and there for to support effective decisions. The second and most important part about it, is the integration of dynamic information. Dynamic updates about estimated time of arrivals in order to minimize unproductive actions and to maximize the use of existing infrastructure.

The objective of dynamic dispatching is to implement a harmonised real-time interface between Railway Traffic Management System and the yards and the terminal management systems, in order to dynamically adapt planning and tasks in yards and terminals according to real-time evolution of traffic and availability of assets. Overall objective to enable harmonised yard operations and terminal operations across Europe to further ease interaction between different yards or between different terminals or in between yards and terminals.

The specification part reflects the ambitions stated in the grant agreement. It is split between 6.2 with the focus on Terminals and 6.3 with the focus on Yards.

In preparation for Workpackage 27 it was the common objective of the project partners to identify where today real time information is either missing and or received too late in either Terminals or Yards and where this missing information is leading to unefficiencies. It was therefor agreed in several Workshops, that the Workpackage 27 wants to focus on different use cases to show with practical and real examples, where live information is either increasing efficiency or maximizing the use of existing infrastructure. This led to the five different use cases described in 6.4. which are the fundamental basis for the envisaged developments with Workpackage 27.

The description has been coordinated by the joint parties and was aligned with a strong demand management from the multimodal industry via a substantial part of market stakeholders in multimodal freight.

6.2 Dispatching process in Terminals

According to various interviews with different terminal operators, the dispatching process in terminals is today a very demanding task. The demanding part is not coming from the complexity of the tasks and operational procedures as such, which are relatively simple and well structured. The complexity arises of the permanent, short term adaptions of tasks in order to respond to events and delays.

The processes described in D2.1 was established in close interaction with the stakeholders of Workpackage 27 and does therefor align well with what is described here. Whereas the processes in D2.1 focus clearly on the coupling and uncoupling and the related tasks in the yards and terminals, the processes in preparation for Workpackage 27 do focus on the operational and commercial procedures around the dispatching in terminals and yards.

Below graph shows the process steps of intermodal services with goods entering and leaving the Terminal, with a special focus on the most common intermodal service, truck to rail and vice versa.

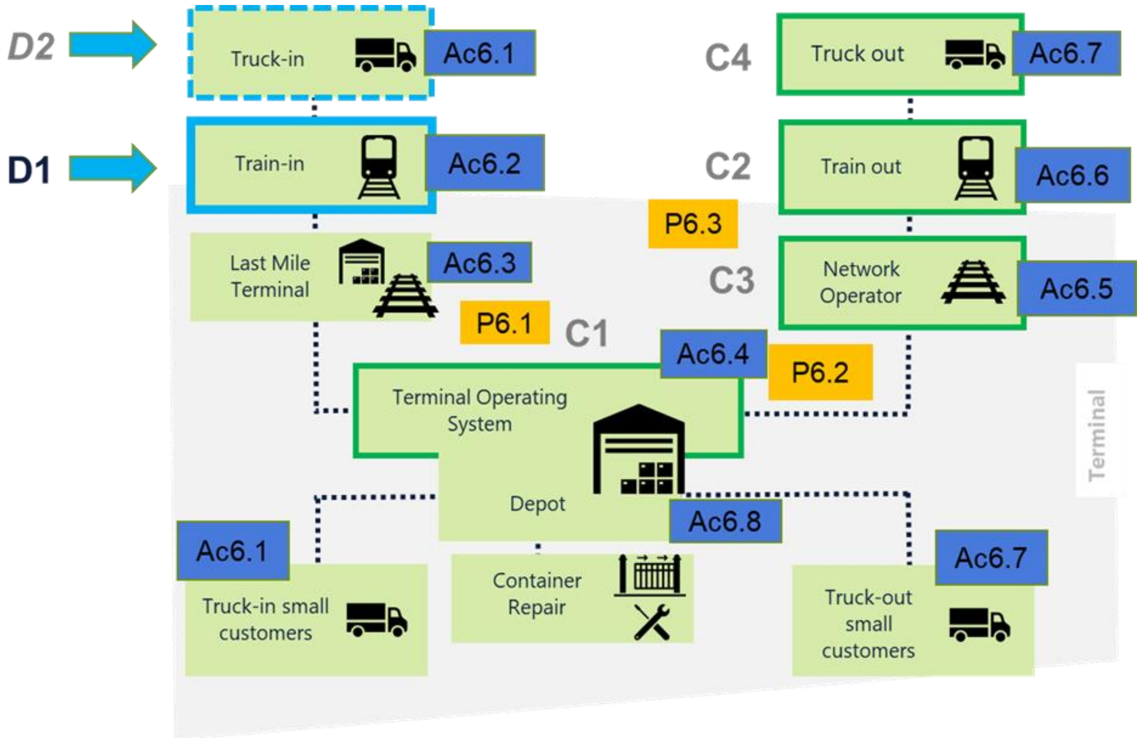


Figure 21: Intermodal sequence in terminals with process steps and actors, respectively locations

D1 Dynamic Input 1 – latest Train estimated time of arrival
D2 Dynamic Input 2 – delays of truck arrivals (optional)

C1 Consequence 1 – dynamically adapted tasks
C2 Consequence 2 – dynamically shifted departure time
C3 Consequence 3 – potential new train composition
C4 Consequence 4 – dynamically adapted pick up time for trucks

Location	Ac6.1 – Terminal Truck Gate
Related processes	P6.1 Container in
Specified actors	Terminal operators, cargo carriers, trucks, cranes
Activities	Truck delivers container, terminal receives Container, controls weight, documents, enters data into terminal system, checks for damages on container

Location	Ac6.2 – Railway Network
Related processes	P6.1 Container in
Specified actors	Terminal operators, cargo carriers, cranes
Activities	Train arrives, waggon consist and estimated time of arrival are announced, loading units are pre-announced, container, terminal receives train and container, checks waggon consist and loading units against what was announced, controls weight, documents if available/necessary, enters data into terminal system, checks for damages on container

Location	Ac6.3 – Terminal Railway (Last Mile)
Related processes	P 6.1 Container in
Specified actors	Terminal operators, cargo carriers
Activities	Train is split into two if track is too short, train is sorted for departure, waggons are checked for damages

Location	Ac6.4 – Depot
Related processes	P 6.2 Container Storage
Specified actors	Terminal operators
Activities	All Containers without direct reconnection are stored in depot according to envisaged priorities

Location	Ac6.5 – Terminal Railway (Last Mile)
Related processes	P 6.3 Container out
Specified actors	Terminal operators, cargo carriers, infrastructure manager

Activities	Waggon consists, loading units and estimated time of departure are announced to infrastructure manager

Location	Ac6.6 – Railway Network
Related processes	P6.3 Container out
Specified actors	Terminal operators, cargo carriers, cranes
Activities	Train is split into two if track is too short, Train is sorted for departure, Containers are loaded according to contracts or priorities, loading distribution according to waggon restrictions, dangerous goods restrictions, track restrictions, destinations, waggons are checked for damages, Loading is checked for safety

Location	Ac6.7 – Terminal Truck Gate
Related processes	P6.3 Container out
Specified actors	Terminal operators, cargo carriers, cranes
Activities	Truck picks up container, controls weight, documents, forwards data to cargo carrier, final check for damages on container, terminal receives acknowledgement of pick up

Location	Ac6.8 – Depot
Related processes	P6.2 Container storage
Specified actors	Terminal operators, cargo carriers, cranes
Activities	Container damage is detected, check with Container owner about repair and commercial details

In theory as highlighted above the dispatching process is a series of not exhaustively complex tasks where basically the available loading units in the terminal and the available capacity on road and rail to transport the loading units within the pre-defined timetable slots are compared and optimized.

The large amount of short-term influences make optimal decisions difficult or even sometimes nearly impossible.

Short-term influences are on the one hand the market demands, such as short-term priority shifts of loading units due to customer wishes. Such short-term priority changes are difficult to change or eliminate.

On the other hand, it is all about availability of resources. The most obvious and straight forward short-term cause for dispatching is train delays. Those are the major part of the whole Seamless group to try to avoid them where possible and where not possible to announce them as early as possible and in a standardized format to all relevant stakeholders.

Other short-term influences on the pre-defined dispatching processes are damages on waggons or loading units and wrong waggon loadings or waggon consists. The main objective of the interaction between Workpackage 27 and Workpackage 32 is to have a standardized data transmission of a minimum set of data from Video Gates and also here to make this information accessible for the relevant stakeholders. Minimum data would be waggon type, waggon number and Loading Unit identifier (ILU Code). If this information is completed, this could erase a general process step in a terminal or Yard - the "waggon check" - and it could again help to plan accordingly in advance if a different waggon composition than planned is approaching the terminal.

Last but not least, it is the surrounding transportation modes, such as Trucks and the maritime world, that this Workpackage will try to address who to best forward latest information about estimated time of arrivals and potential delays.

Marshalling yards are large railway yards where waggons from inbound trains are sorted into new outbound trains. There are often multimodal terminals in connection to marshalling yards, which means that the yards are not only the hubs of the railway network, but also for the transportation network as a whole. This makes yards an important point of interaction for many different actors, which brings some challenges and opportunities. (ARCC, 2018) presents the results from an analysis of the line-yard interface in Sweden, and identify a number of problems that occur during operations. For example, coordinating shunting movements in the yard, managing trains that run early or late and identifying foreign cars.

6.3 Definition of interface and system interaction requirements with other (planning) systems for Yards

To ensure that all data relevant for dispatching decisions are available to the dispatcher to consider them in the search for the best decisions. Thus, the IM's CMS has to translate the capacity plan and all further updates that will be provided by the yard manager to an operational plan. New updates provided by the yard operator to the IM must also be translated for the IM's TMS. Vice versa, updates from the TMS must be available to the CMSs to check them for necessary rescheduling. To show the relevant communication between the involved systems, 5 capabilities are defined.

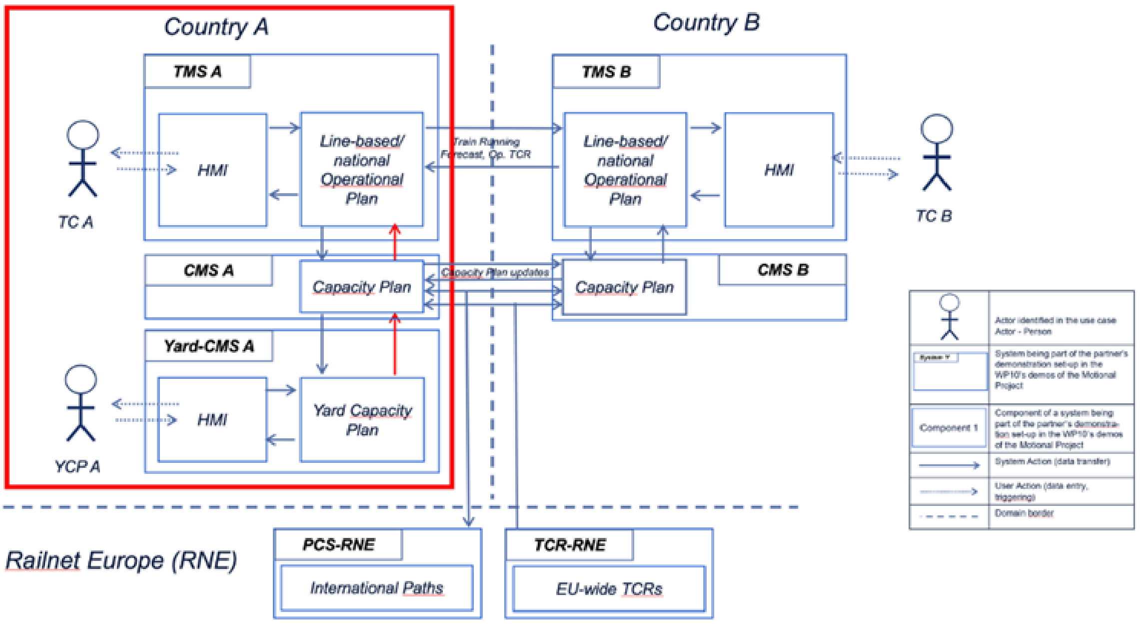


Figure 22: The line-based/national CMS and the yard-CMS communicate relevant capacity plan updates to the line-based/national operational plan

According to the capabilities described in chapter 5 on seamless planning, the Yard-CMS communicates relevant local capacity plan updates to the (line-based / national) CMS. Hence, these updates will need to be translated to the Operational Plan delivered by the CMS to the TMS. This applies to all information on new planned, changed, and cancelled train paths, on new planned, changed, and cancelled TCRs, new planned departure and arrival tracks, and on earlier or later planned availability times in the departure track of the handover area of a yard.

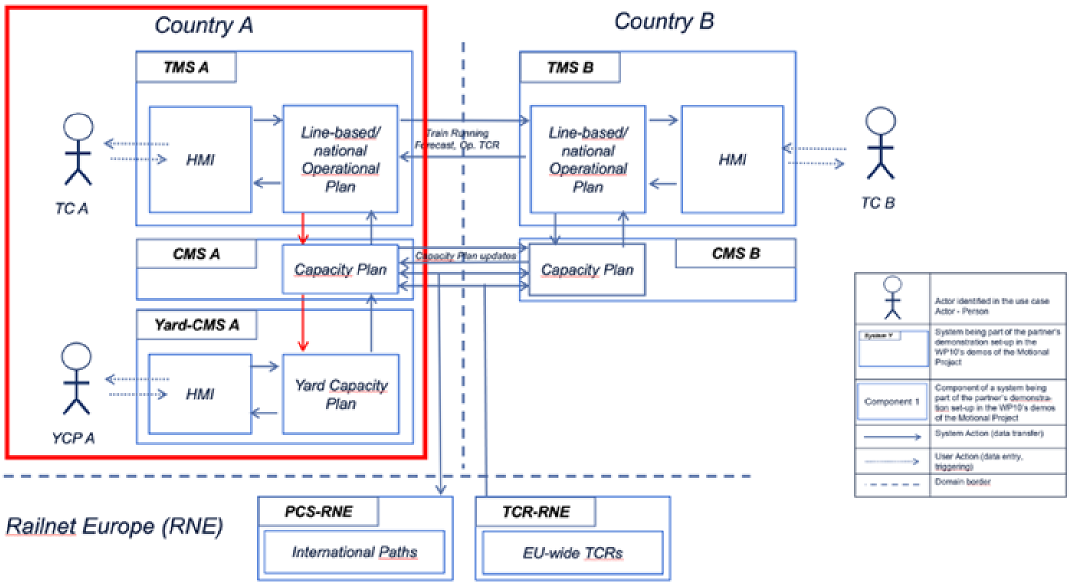


Figure 23: The line-based/national TMS communicates relevant operational plan updates to the line-based/national capacity plan which is connected to the yard capacity plan

Conversely, the (line-based / national) CMS communicates relevant local capacity plan updates to the Yard-CMS which is also described in section 6.3. Hence, any changes of the Operational Plan requested by TMS based on train running status, forecast and train controller decisions will need to be translated to the Capacity Plan managed by the CMS. It must be possible to provide information on trains that are cancelled due to train controllers' decisions, changed arrival tracks in the yard, changed arrival or departure times, changed arrival tracks, and on new planned, changed, or cancelled operational TCRs.

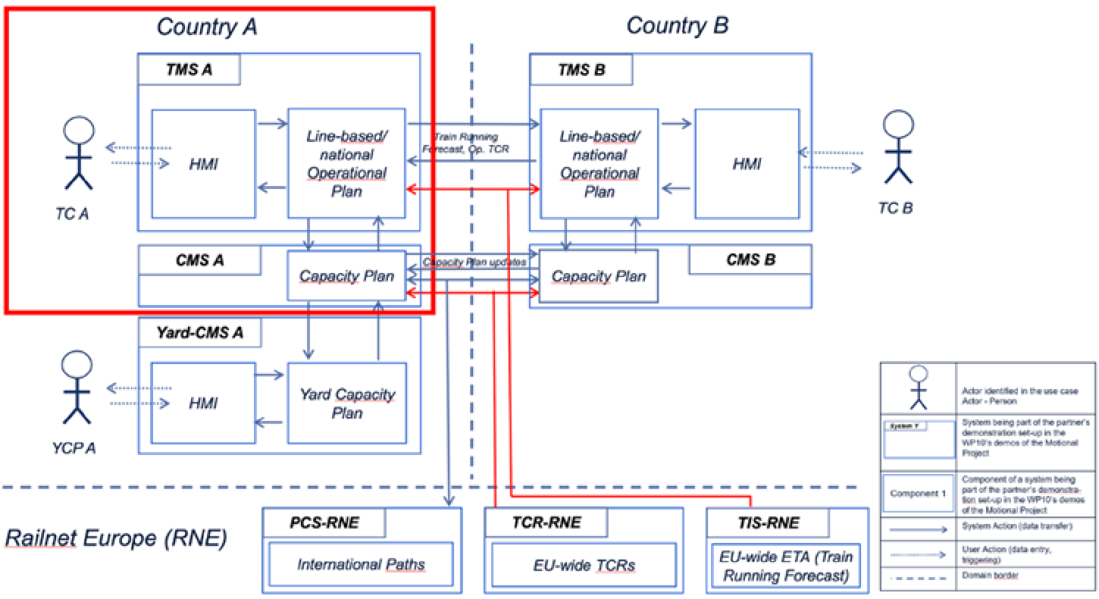


Figure 24: The EU-centralized applications communicate relevant updates to the line-based/national operational and capacity plans

The IM needs real time information on the estimated times of arrival at handover locations of borders that can be extracted from TAF TSI messages provided by RNE. Information on TCRs behind the border is also received from TAF TSI messages. To also update the CMS, the information is transmitted to the (national / line-based) CMS and the Yard-CMS. Based on the ETH data, the TMS must calculate a forecast for the local network and provide it to other clients and RNE as TrainRunningForecastMessages.

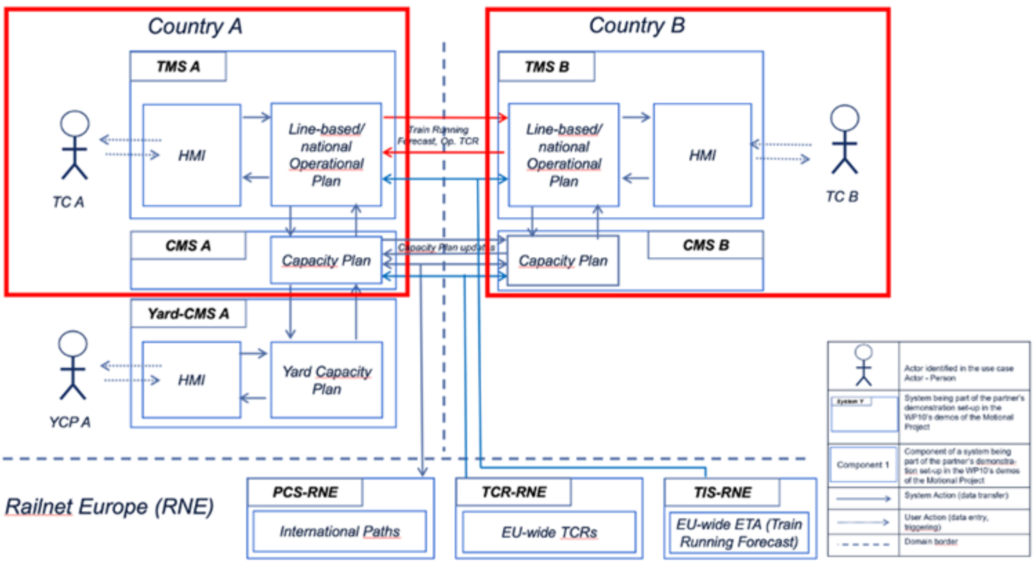


Figure 25: A line-based/national TMS exchanges relevant operational plan updates on the local network with the neighboring line-based/national TMS behind the border for defined sections

The (line-based/national) TMS exchanges relevant updates of Train Running Forecasts and operational TCR information on the local network with the neighbouring (line-based / national) TMS behind the border for defined line sections. The neighbouring IM needs this information in its TMS to calculate estimated delays at handover points in the neighbouring network and to determine necessary timetable adjustments. Train Running Forecasts and operational TCR status information for cross-border freight trains are exchanged on defined sections to detect conflicts.

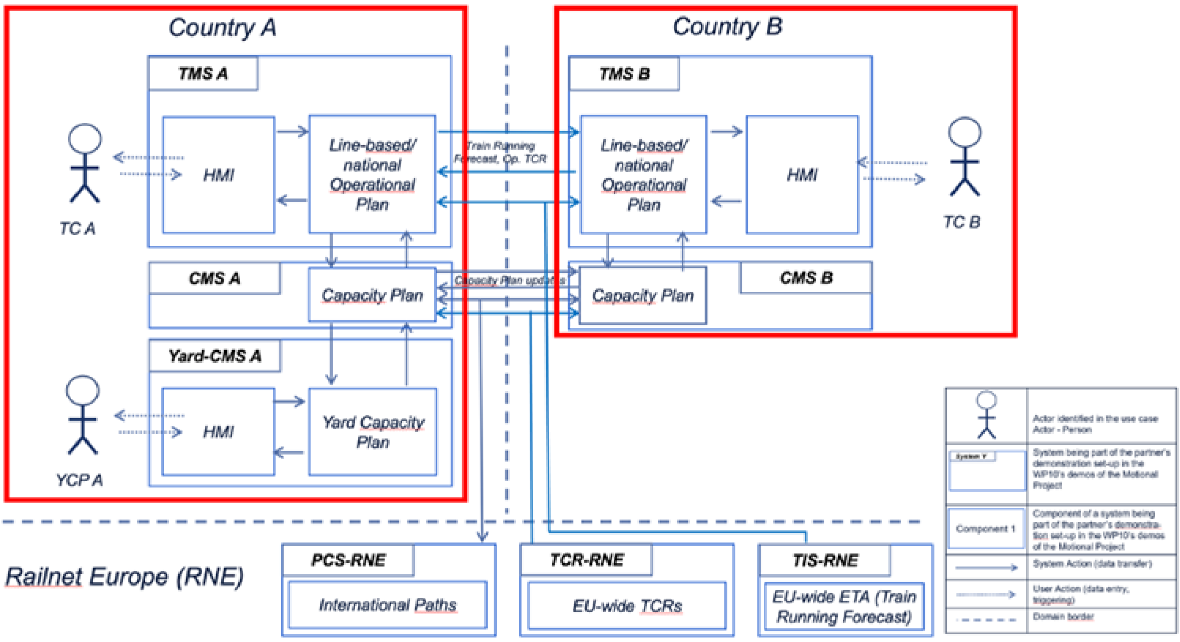


Figure 26: The TMS deals with situations that typically occur in the cross-border context

The TMS must analyze the impact of incidents that occur specifically in the cross-border context. In case of TCRs behind the border, the impact must be identified and managed by identifying related conflicts with cross-border freight paths, indicating decision options on the local network, and implementing required decisions for handling these conflicts. If there should be one TCR on each side of the border, the TMS must show the impact of these TCRs if they are not coordinated. In general, conflicts of international trains impacted by TCRs on both sides of the border must be identified and solved, and connected shunt-moves to the yard must be featured. Knock-on delays due to the planned vehicle exchange at handling locations must be taken into account if they are caused by delayed inbound trains. If the conflict resolution at a handover location leads to changes in the train sequence, these changes must be considered and implemented in the operational plan.

6.4 Dynamic interaction the envisaged Use Cases

The group of Workpackage 27 has focused on 5 different Use cases to demonstrate the advantages of how seamless real-time data exchange can accelerate process and stimulate for more freight on rail. The first show case focusses on a dynamic terminal operating system, dynamic task adaptions thanks to real time data from the traffic management system and sophisticated intermodal prediction.

The second use case demonstrates how the interaction with real time data from video gates can enhance operational procedures.

The third Use case elaborates on how the dynamic information from traffic management systems and intermodal prediction can support a decision support functionality for the various tasks and conflicts in a yard.

The fourth Use case demonstrates the booking for marshalling yard services in order to analyze the impact of change requests by reordering activities in the last mile, terminals and Marshalling yards with a support of dynamic scheduling.

The last Use case focusses on the prolongation of the promising works that have been accomplished during the Shift2Rail project YCS around dynamic dispatching requirements for yard coordination system in Malmö, Sweden.

All Use cases want to demonstrate as the Key Performance Indicator how processes could be accelerated with a before and after comparison, with or without dynamic data to help make processes and decisions faster and more accurate.

All Use cases are focussed on real applications, in order to avoid theoretical work, that finds no application in the real intermodal world. But the focus of the use cases is to demonstrate the benefits in order for them to become blueprints for the European intermodal sector.

6.4.1 Dynamic Dispatching in an Intermodal Terminal in Germany (Industriestraße 1, 36269 Philippsthal (Werra))

This is the specification of the Use Case 1 as a result of Workpackage 27 dynamic dispatching and the associated developments, respectively the challenges to overcome.

The use case has the objective to demonstrate a dynamic interaction of a terminal operating system and therefor the dynamic adaption of tasks to be performed on a given day with the objective to avoid empty spaces on freight trains, reduce delays in departure of both truck and trains and to reduce unproductive craning. Reduction of time in terminal of a truck and reduction of time in terminal of containers.

A typical intermodal terminal has containers coming in via rail or road (train in and truck in) and Containers going out via rail or road (train out and truck out). Most effective transports are the once where truck in goes directly on train out and train in is directly loaded on truck out. Such direct operations have the least craning movements and fastest change over time. In larger terminals such direct operations are nearly never operated as trains are much faster unloaded and processed. Therefor the Container depot acts always as the in between buffer. In smaller terminals a train sometimes is in the terminal for 24h which allows such direct operations in some cases, but also in smaller terminals the majority of Containers are first stacked in a depot and then processed further.

With this use case the ERJU partners want to use case that the more dynamic information flow into a terminal operating system, the better the operations can be planned and optimized. Containers in Depots are stacked above each other, sometimes up to 5-7 containers high. This implies in itself the consequence, that many reachstacker or crane movements are not to load or unload a truck or a train, but are to restack containers. The restacking of a container is the definition of an unprofitable movements. An ideal planning would lead to no unprofitable movements.

Figure 27 shows planned tasks to unload a train. Objective is to dynamically adapt tasks thanks to latest estimated time of arrival and waggon load.

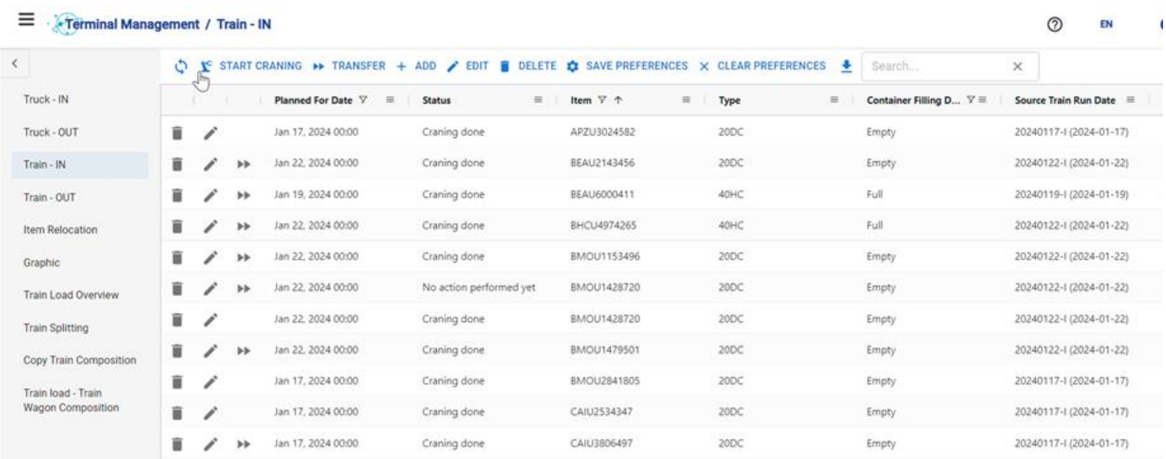


Figure 27: Task Overview for Incoming Trains

The use case shall therefor demonstrate how a terminal operating system dynamically adapts the planned craning tasks (item mission tasks) in terminals based on real time information from Railway Network (in close alignment with WP28) *(TAF TSI format).*

The use case shall furthermore demonstrate how a terminal operating system can support optimized movements in a Container Depot in order to avoid unproductive craning tasks inside the depot, based on information, which Containers are planned to depart on Rail.

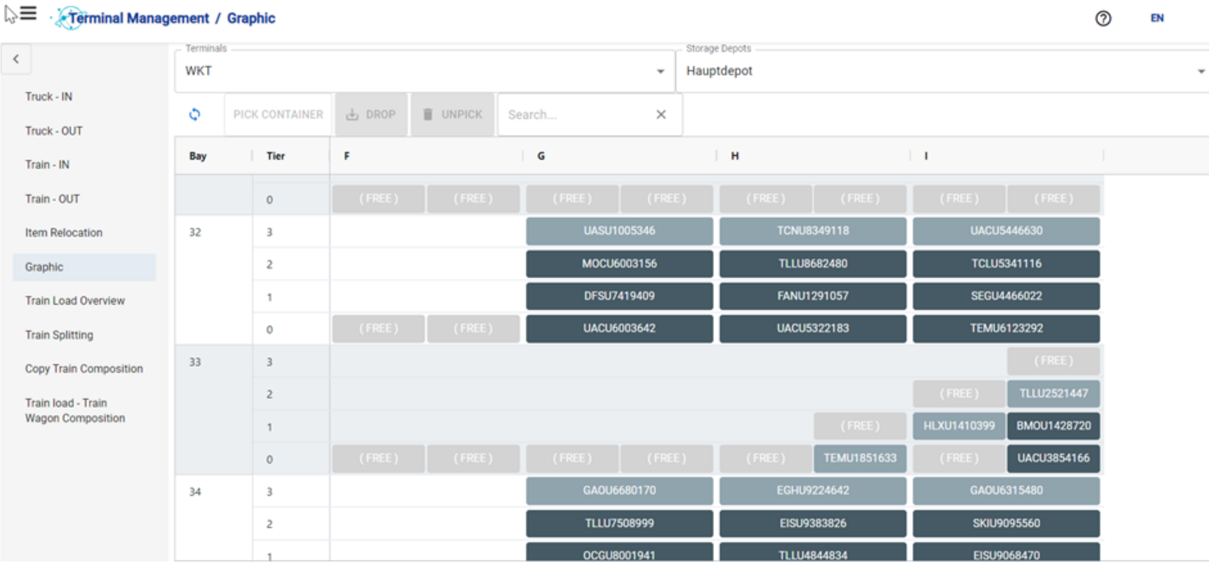


Figure 28: Graphical Depot Overview

In addition to this the use case shall demonstrate Road Traffic information road e.g. linked to a sophisticated booking system (Google Maps, Here, format to be checked) and loading constraints in maritime world, changed schedules etc. (e2open, cargosmart or direct interface to shippers (MSC, Hapag etc.) lead to new ordering of tasks in a terminal.

Last but not least the use case has the aim, to demonstrate the advantages of a dynamic train load overview, which supports the reachstacker driver or the crane operator in loading the train based on destinations and the above mentioned dynamic task allocation in the depot.

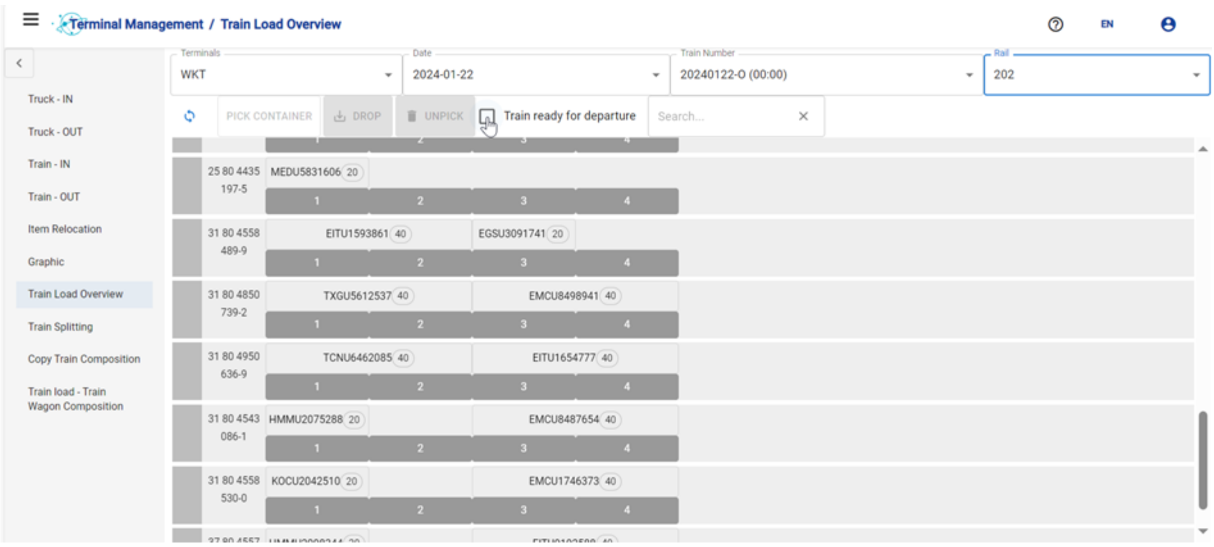


Figure 29: Dynamic Train Load Overview

All these dynamic adaptions of tasks shall have the objective to reduce or where possible to eliminate unprofitable movements.

Developments are mainly to enable existing terminal operating systems to have multiple data sources and to develop the according interfaces and user interface features. Furthermore, terminal operating systems must be able to categorize and cluster this information, to prioritize interfaces in the sense that there shall be information that is classified as the master information that e.g. overrules information received from interfaces with lower priority.

In addition, terminal operating systems must be able to treat a sophisticated multi tenancy, so several stakeholders from different legal entities able to access but with own restricted access. All dynamic information must be processed by the terminal operating system in near real time and made visible to all involved stakeholders in almost real time.

Two main constraints have been identified by the project team members so far. First is to be solved together with other Workpackages of FP5, the constraints about data availability of TSI TAF/TAP. It is today not so obvious for a terminal to get data from a railway undertaking (RU). To receive the data via interface means, at least with some infrastructure managers in Europe, that the terminal receives all train run information

- Train Running Information Message
- Train Running Forecast Message
- Delay Cause Message

of all trains of the RU. Also some of the European infrastructure manager can, as of today, only transmit this TSI data to only one IP address. So if the TSI data of a railway undertaking is already transmitted to an e.g. IT service provider of this railway undertaking, the data needs to be forwarded which is as of today not possible free of charge.

Another significant challenge or constraint when speaking about optimization of tasks and movements in a terminal, are the contractual and commercial constraints. Constraints in the sense of a terminal being a contracted service provider, that cannot fully freely decide to reprioritize loadings even if this would be more optimal for all involved players, as it could lead to contractual penalties.

The project partners assume, that during the course of the ERJU project, more challenges and constraints will be identified.

Three open topics have been identified so far, that for the moment are not yet specified but with a collective aim to tackle them:

1. The optimization of wagon-consists, which is as well not always under the control of a terminal but shunted in a shunting yard from a third party.
2. Second is to optimize thanks to a dynamic interaction between two terminals.
3. Third is to optimize thanks dynamic interaction with Yards and taking into consideration an optimum year plan (WP 26)

The project partners assume, that during the course of the ERJU project, more open topics will be identified.

6.4.2 Dynamic Integration of the Terminal Operating System with Intelligent Videogate

REAL TERMINAL IN SPAIN

This is the specification of the Use Case 2 as a result of Workpackage 27 dynamic dispatching and the associated developments, respectively the challenges to overcome.

Intelligent Videogates are a reality in the railway industry, and are set to support operations by capturing real-time information on day-to-day train journeys. Their applications are not only relevant in the field of freight transport, but also in the field of passenger transport, and at border crossings they can also be very useful.

This use case will be in close alignment with Workpackage 29, the intelligent video gate as part of the standardized European checkpoint.

One of the most relevant applications in the freight environment is to provide as much information as possible to the terminals about the train composition, and the order in which the loads are arranged on each of the platforms that make up the train.

Currently, this information can be provided in several ways. At the terminal of origin, a document must be sent to the rail network manager, indicating the platforms and the loads carried by each of them. This document, in Spain, is called Pie de tren, and has a list of all the cargoes and all the platforms that make up the train. This is comparable to the "Wagen-Liste" in Germany. Those lists, need in many countries to be checked by a real person in order to get approval of the national safety bodies for a train to depart, but establishing the list can be digitally supported.

However, many times, this documentation is handwritten, it is not automated, and sometimes, discrepancies arise between the theoretical information and the real information. This means that when the train arrives at the terminal, it has to be rechecked and registered in the management systems of the terminal, which containers have actually arrived. This check is done manually, and must be registered in the terminal Operating System.

Another less serious problem than human errors when transcribing the information manually (typos) are the errors in defining the order of the platforms and the containers that are on them, which causes that, at certain times, when picking up a container to deliver it, which was expected in a specific position of the train, it is not really positioned there. This entails checking which is the real position of the container, leading to the loss of operation time.

Taking into account all the above, our intention is to carry out a use case with the integration of the Video Gate with the terminal Operating System, so that the processes to register the goods as the platforms of the train is automatic, and also shows all the inconsistencies between the information received from the terminal of origin, or from the systems of the infrastructure manager.

On the other hand, the Intelligent Videogate will serve as a checkpoint for the information generated from the terminal, which must be sent to the infrastructure manager before the train is ready to leave the terminal.

The information that the terminal operating system will receive from the IVG is proposed to be the following:

1) Train ID and direction of travel, (incoming or outgoing).

2) ID of the platforms and the order in which they make up the train (train composition)

3) ID of the container plates, and the order in which they are arranged within each platform.

4) Identification, for each container, of the type of dangerous goods, if any.

5) Damage that each container may have

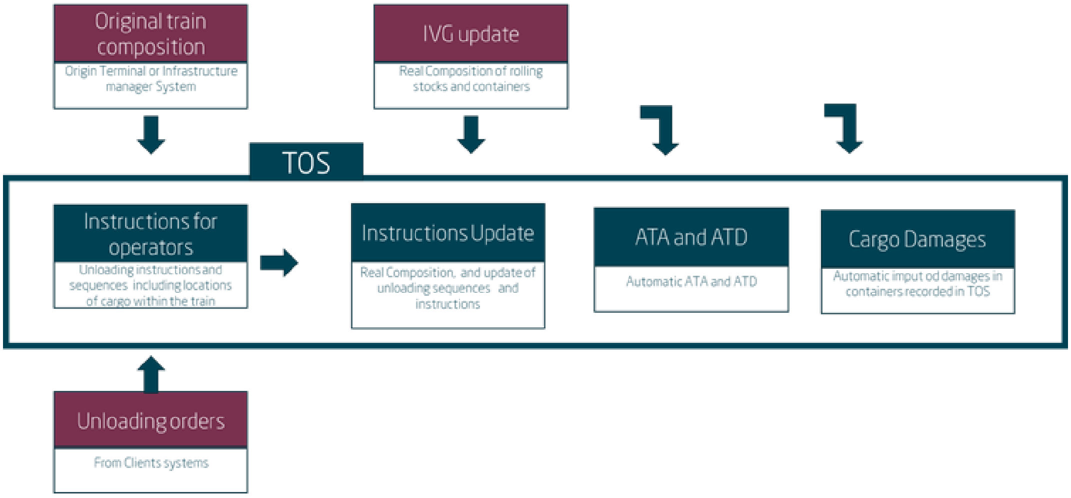


Figure 30: Stepwise Information Flow

The terminal operating system will make the pertinent checks by comparing the information received from the video gate with the theoretical information that the system may have stored from other actors or systems. If the checks are satisfactory, the goods and rolling stock transmitted by the IVG will be registered in the TOS. If inconsistencies are found in the information received, the evidence collected from the IVG will be accessible (for each container or platform) through the terminal operating system, to verify that the information received by the IVG is correct, and that the theoretical information received is not accurate.

6.4.3 WP27 Use case environment: Decision support for shunting operations and yard dispatching at Alnabru (Oslo, Norway)

This is the specification of the Use Case 3 as a result of Workpackage 27 dynamic dispatching and the associated developments, respectively the challenges to overcome.

In the Norwegian Alnabru terminal there are four main track areas, among them the loading tracks (C-tracks) and the yard (R-tracks). See FigXX. The yard is used for both parking rolling stock and for performing shunting operations, such as splitting trains and removing broken wagons. In the flat yard Alnabru, the planned shunting seldom consists of completely rearranging the wagons to new trains, as is done in classic hump yards. Most planned activity consists of splitting trains and moving trains from and to the C-tracks. In such movements, the routing of the wagon sets from R to C must be decided. Dispatching within the yard and terminal is relevant here in real-time.

Another prominent unplanned activity we are aware of is the need to take broken wagons out of a train and move them to the workshop. Bane NOR explains that currently those unplanned activities are called in to the dispatchers at Alnabru, who then must adjust their plans of how the trains should move and when. Most of these changes are done manually.

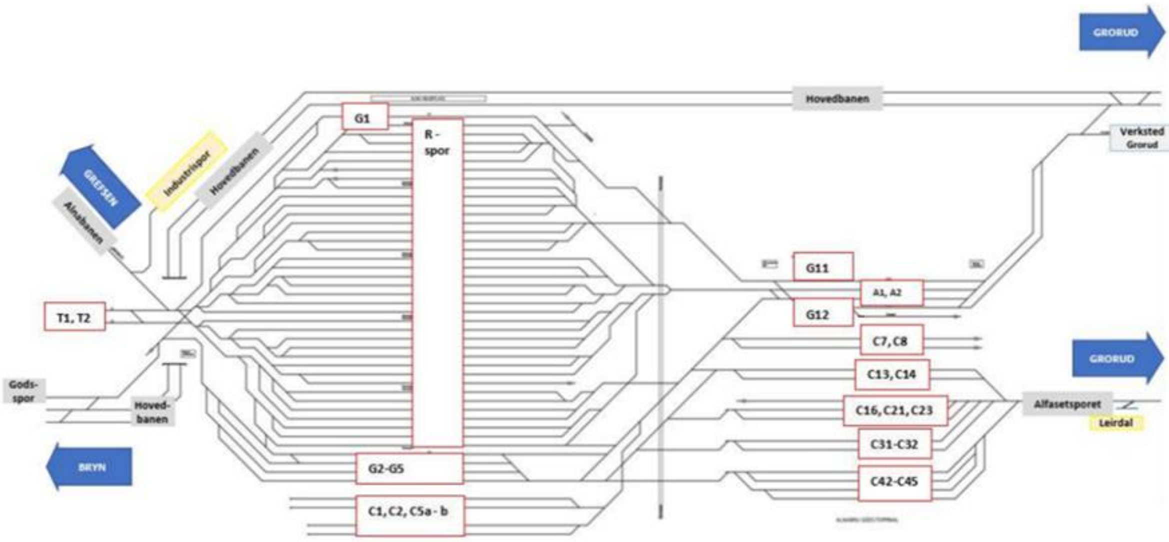


Figure 31: Schematics of track plan at Alnabru. The “R” tracks make up the yard and the “C” tracks are the loading and unloading tracks.

The Norwegian research partner in TRANS4M-R, SINTEF, will look into the development of a tool that helps the dispatchers at Alnabru terminal plan shunting and the movement of the rolling stock in real-time using optimization and automation. We call this a Yard Dispatching System (YDS). Planned yard activity can be loaded in from the relevant existing yard systems. Current, ad-hoc activities can be entered into the YDS directly. The YDS should take updated real time information about planned activities from the terminal, line and yard into account. The tool can then, based on optimization algorithms, present suggested plans of the rolling stock movement to the dispatcher, making his task of deciding on a plan much easier.

SINTEF is currently working together with Bane NOR and developing a dispatching tool that eases the task of the dispatchers at Oslo Central Station, which is a passenger station. It uses real-time data and creates train plans for the next two hours for the trains for all lines around Oslo. It displays a train graph that is updated continuously with the real time data and the suggested plan of how to dispatch the trains. SINTEF will create the necessary algorithms for supporting a similar tool, YDS, at Alnabru, but adjusted to the specific needs and challenges for that terminal.

For this use case environment there is a link to FP1 Motional with respect to real-time updates of information on the line. Algorithms developed there for dispatching on the line will be adapted to a terminal view, and implemented in the YDS. Mandatory and optional requirements for the YDS are given in the common list of requirements:

The YDS must

- know the yard and terminal topology and information about safety regulations (minimum time lags, maximum speed etc.)
- know the trains' arriving and departing times form the train timetable
- know the assigned arrival and departure tracks from the track assignment plans
- get information about train information (length, number of wagons etc)

The YDS should

- return either a feasible shunting plan or an infeasibility notification
- receive information about updated ETAs to the terminal
- include an algorithm for finding not only feasible, but optimal shunting plans
- have information about preferred sequence of routes for shunting operations, or about tracks not preferred, either at a general or area specific level.

6.4.4. Booking system for Marshalling yards

This is the specification of the Use Case 4 as a result of Workpackage 27 dynamic dispatching and the associated developments, respectively the challenges to overcome.

Analyzing dynamic dispatching requirements involves identifying real-time traffic restrictions, assessing resource availability (using functions of Asset Warehouse), and evaluating un/loading, handling, and train formation services (IS VESTA functions developed in Dynamic Dispatching WP), all while determining crucial data inputs from the dynamic planning process and understanding their impact on the RU's operational processes.

In order to achieve the objectives, it is necessary to develop functions that take into account the impact of change requests by reordering activities in the last mile, terminals and MY. Additionally, it is desirable to implement dynamic scheduling, including rescheduling as necessary, and to enable ad hoc dynamic resource allocation, particularly of shared resources among RUs. With regard to interfaces, the focus should be on establishing interfaces with personnel and locomotive shift planning systems, as well as integration with the traffic management system (FA1). Consideration should be given to the basic factors and functionality required to accurately calculate ETAs (WP28) and train composition, particularly from terminals, MY and sidings. Especially for the shift planning system and crew rostering optimization, this Use case can also give valuable Input to Workpackage 31.

To achieve these objectives, comprehensive data on resource and service availability and information on usage conditions are required. Outputs from the FA1 traffic management system to support our decision-making process is essential. In addition, it is essential to have thoroughly tested interfaces that are ready for implementation to ensure seamless integration and functionality.

6.5 Operation in a marshalling yard

All planned sources are matched to activities that are arranged in a precise sequence. A common sequence is explained below.

The trigger for a procedure in a marshalling yard is the notification of train arrival that is provided by the "Dispatcher information system of operational management" information system – DISCOR or another relevant system. The plan of activities is updated by input from the information system of IM (FA1) or the dispatching information system of RU based on the train composition taken from the operational information system (PRIS).

The decision about the sequence of trains to be processed (marshalled) depends on the railway undertaking's dispatcher who uses information from the "Operational information system" – PRIS to decide. PRIS contains complete information about a train unit. PRIS does not provide optimization support. The optimization function is developed in WP27 in IS VESTA.

6.6 Inbound train and the marshalling procedure

The procedure begins with the arrival of the train (train head reaches the entry signalling). After arrival, the train unit is secured by a wheel chock or by tightening the wagons' hand brakes. Next, the mainline locomotive is uncoupled. The average time for this procedure is 3 minutes. Uncoupling is performed by the line locomotive driver. After that the line locomotive is shunted to the line locomotive sidings. A signalman sets up and locks the shunting route. Commands from the railway undertaking's dispatcher to the line locomotive driver are given by radio and by signalling. The main activities of the inbound train procedure are shown in the Table 7.

Inbound train procedure	**Time (min)**	**Performed by**
Moving train from the surrounding network to the yard – arrival	X	X
Handing over the train and shipment documentation (loco driver hands it over to the wagon inspector)	1	Transport agent / wagon inspector
Braking the train unit with wheel chocks	1	Line loco driver
Tightening the hand brakes of the first five	6	Line loco driver

wagons		
Command to uncouple the line locomotive and to shunt	0.5	railway undertaking's dispatcher
Uncoupling the line locomotive	3	Line loco driver
Shunting from the arrival track to the line loco siding	3	Line loco driver

Table 7: Inbound Train Procedure

The hump locomotive driver receives the information about the track on which the train unit is to be marshalled on. The hump locomotive is coupled to the rear of the train unit. Screw couplings of wagons are loosened by the shunter and the head shunter in accordance to the sorting list. The hump locomotive moves the train blocks to the hump per commands from the signalman and the head shunter. Loosened couplings are taken off by a coupler using a special rod. If any of the wagons is not allowed to be humped, such wagon is decoupled and shunted to the siding track next to the hump during the process of pushing the groups of wagons to the hump. After all the blocks are humped, the hump loco moves to the siding track with the non-humpable wagons, couples them and shunts them to the classification yard on a dedicated track. The main activities of the marshalling procedure are shown in Table 8 below.

An interaction with Workpackage 2, for the coupling and uncoupling processes will further enrich this Use Case and the Workpackage 2 works.

Marshalling procedure	**Time (min)**	**Performed by**
Notification to the hump loco about the track of the unit to be marshalled	0.5	railway undertaking's dispatcher
Notification about dangerous goods	0.5	railway undertaking's dispatcher
Shunting the siding loco from its track to the arrival track	3	Yard/hump loco driver
Coupling the train unit	3	Shunter
Loosening the wagon hand brakes	6	Shunter

Releasing the train unit (takinging the wheel chock away)	0.25	Shunter
Preparing for humping (e. g. loosening the screw coupling)	25	Shunter
Command to shunt blocks of train	0.5	Head shunter
Shunting a block of train	5	Yard/hump loco driver
Cutting and humping blocks into the classification yard	30	Coupler, brakeman, signalman
Shunting the non-humping blocks into the classification yard	6 per shunting	Shunter / coupler, Yard/hump loco driver
Securing the train blocks against movement (wheel chocks and hand brakes)	0.5	Brakeman
Shunting broken wagons	10 per shunting	Shunter / coupler

Table 8: Marshalling Procedure

6.7 Procedure before departure

After one of the tracks has been completed, the procedure to prepare the train to depart begins. The decision to begin this procedure is taken by the railway undertaking's dispatcher. All operations on the departing train can be completed because the time norm has been reached, the weight norm has been reached, or there is no other wagon to be matched to the train in the dedicated direction. During humping, the brakemen push the wagons or blocks to one another and tightens the handbrakes of the wagons. Pushing the wagons is done manually by breakmen. If it is necessary to push blocks manually due to weight or bad weather conditions, the blocks are pushed by a yard locomotive. When the wagon shunting on the track is completed, brakemen couple the blocks of train together. Afterwards, the yard locomotive is coupled. Hand brakes of wagons are loosened and wheel chocks are put away. The brake system of the train unit is filled and a brake connection test is performed. According to the command of railway undertaking's dispatcher, the yard loco shunts the train unit to the departure yard.

The train unit is then again secured against movement on the dedicated track and a wagon inspector performs a technical and shipment inspection. From Table 4 it is apparent that this activity takes the longest. It takes about 60 minutes and its duration, besides the number of wagons, depends on the type and the length of the wagon. Optimisation proposal has to consider this attribute while calculating the necessary time for this activity. The listing activity of the train vehicles is performed by the transport agent and it takes approximately 35 minutes. It is performed at the same time as the technical and shipment inspections. Then, the RU dispatcher gives the command to shunt and couple the line locomotive. The command is given over radio and signalling. The line locomotive driver and shunters release the wagon hand brakes and put the wheel chocks away. Next command given is to fill the brake system by compressed air and the line locomotive driver in cooperation with the wagon inspector perform a full brake test. Then the line locomotive driver receives the results of the full brake test verbally from the wagon inspector. After that, it is necessary to receive and sign relevant documents. The last activity performed is to send a “Ready to depart” text message by line locomotive driver to the DISCOR system. Afterwards, at the appropriate time according to the timetable and the situation on the surrounding network, the train leaves the departure yard. Departure is an activity managed by the infrastructure manager's dispatcher in coordination with the RU's dispatcher at the station and the RU regional network dispatcher. The main activities of outbound train procedure are shown in Table 9.

Outbound train procedure	**Time (min)**	**Performed by**
Pushing (manually + yard loco)	20	Brakeman, yard loco driver
Coupling train blocks	30	Brakeman
Shunting the yard loco	5	Yard/hump loco driver, shunter
Coupling the yard loco	3	Shunter
Filling the train unit brakes	4	Yard/hump loco driver
Shunting the train unit	5	Yard/hump loco driver
Technical and shipment inspection (in general)	60 (2 min per wagon)	Wagon inspector
Technical and shipment inspection (2/4/6/8 axle wagon)	1,5/2/2,5/3	Wagon inspector
Listing the train vehicles	35 (1 min per wagon)	Transport agent
Command to couple the line locomotive to train unit	0.5	railway undertaking's dispatcher
Shunting from line loco sidings to	X	Line loco driver

departure track		
Coupling the line locomotive to train unit	3	Line loco driver
Command to fill the pressure brake with air	0.5	railway undertaking's dispatcher
Loosening the wagon hand brakes	6	Line loco driver, shunter
Releasing the train unit (takinging the wheel chock away)	0.25	Line loco driver
Placing wheel chocks beside the track	0.25	Line loco driver
Full brake test	30 (1 min per wagon)	Line loco driver, wagon inspector
Notification of full brake test results	0.5	Wagon inspector
Handing over the train and shipment documentation (car inspector hands it over to the loco driver)	1	Line loco driver, wagon inspector
Signing the international train braking report	0.1	Line loco driver, wagon inspector
Handing over commands for route	1	Line loco driver, wagon inspector
Signing the commands for train running	0.1	Line loco driver, wagon inspector
Train readiness to depart notificaton (text message)	3	Line loco driver
Departure	X	X

Table 9: Outbound Train Procedure

Description of scenarios

The process of transport realization is a process of specifying the requests for wagon transfer from a particular train, including specifying the required activities on the train, if offered by the marshalling yard. The wagon transfer is specified when the train forecast is updated and in case of failure to comply with the conditions of the plan (e.g. loss of the connecting train, ordered wagon transfer with an impact on the delayed departure of a follow-up train).

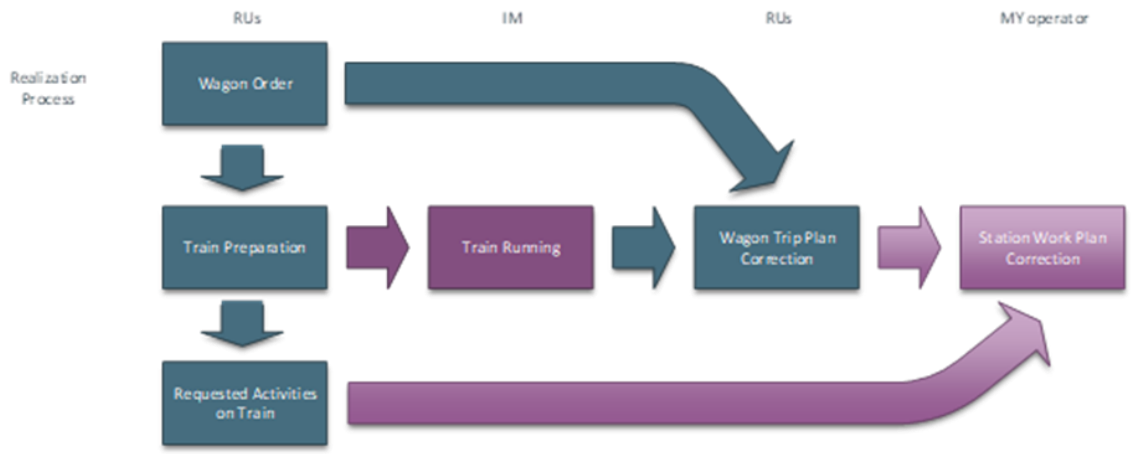


Figure 32: Process Flow

This process assumes the following communication interfaces:

- Wagon transfer in the station (update - RU > MYO)
- Required activities on the train (RU > MYO)
- Train composition (RU > MYO and vice versa)
- Train ready for departure (MYO > RU)

The last two interfaces already exist, it is only necessary to edit the header for forwarding the message to MYO. The definition of the interface for wagon transfer in the station is given above.

Scenarios of communication between IM, RU and MY

For clarity, we present several possible scenarios and their impact on communication between key stakeholders in the single wagon load shipment process. Individual scenarios have been selected based on operational experience and represent a basic set of situations and communication proposals in these situations. The individual scenarios are as follows:

- train running without interruption,
- inability to reach the marshalling yard at the scheduled time, unloading on route,
- train delayed on arrival at the marshalling yard, the wagon transfer ensured,
- train delayed on arrival at the marshalling yard, the wagon transfer is not observed,
- non-compliance with the wagon transfer schedule on the part of MY,
- inability to depart from the MY to the network at the scheduled time, departure to the intermediate station,
- change in routing of the wagon or change of operations with the wagon during the marshalling in MY.

Trouble-free trip

The first scenario describes a trouble-free trip of a wagon with no delays and other disruptions. This scenario considers a situation, in which operation in MY and on the adjacent network is carried out according to the timetable with minimal disruption. In this scenario, the train terminating in the marshalling yard is running on time, the marshalling yard ensures wagon transfer to other trains as scheduled, and the default freight trains leave the MY to the network according to the timetable. It is clear that this is a scenario in which the proposed communication is quite simple.

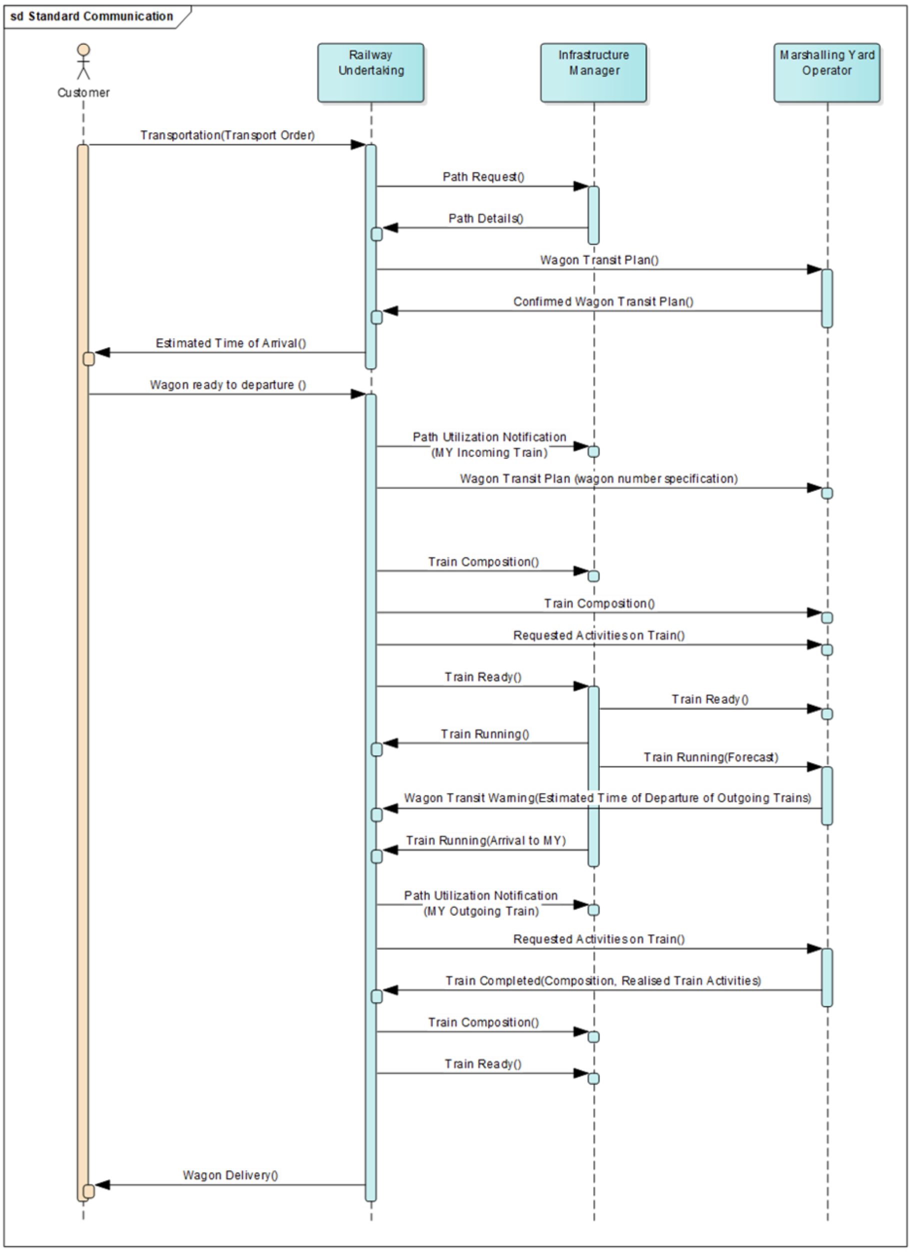


Figure 33: Scenario Overview

Inability to reach the marshalling yard at the scheduled time, unloading on route,

The second scenario describes the overfilling of the entrance track of the MY and the stopping or idling of arriving trains at stations before the MY.

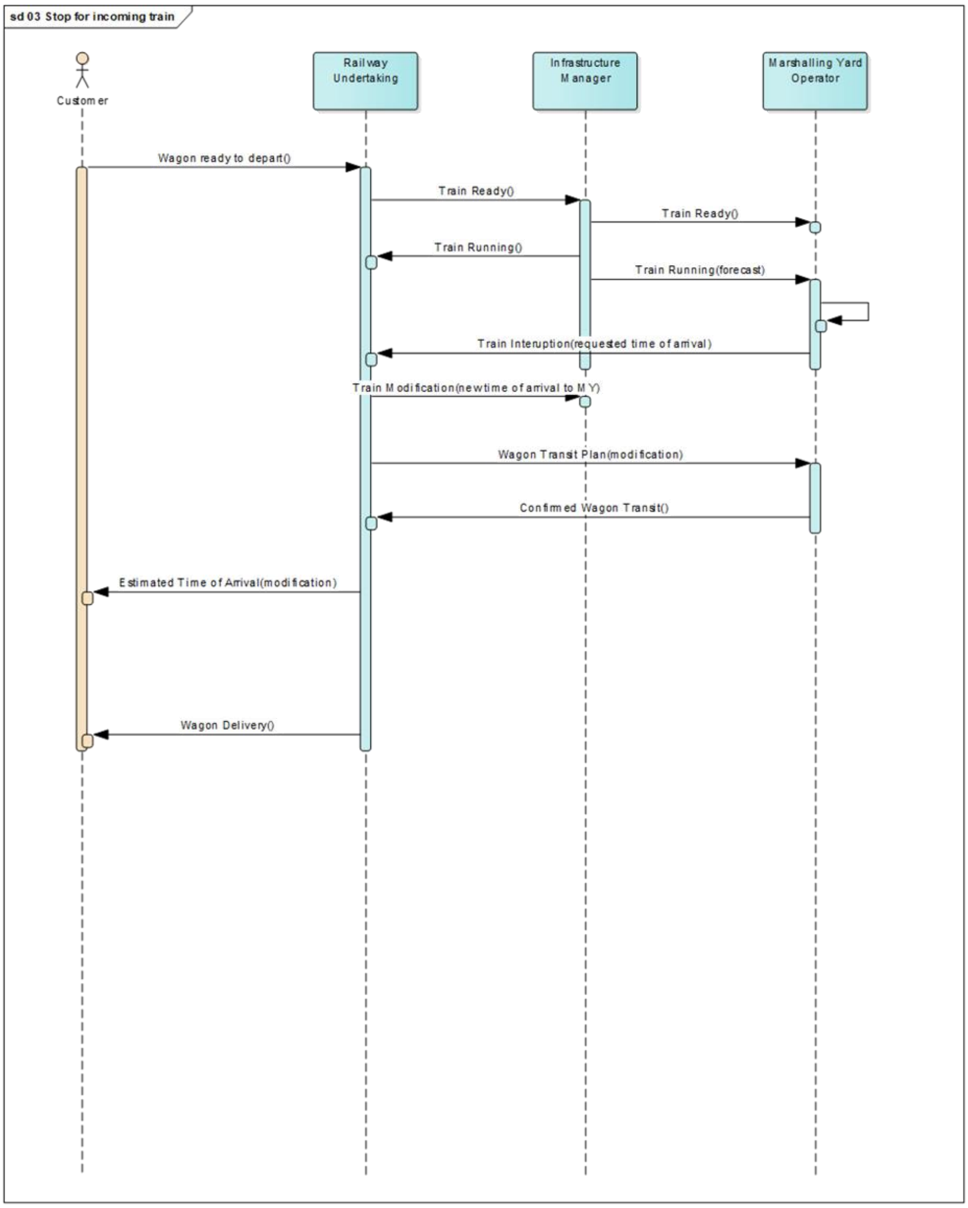


Figure 34: Second Scenario

Train delayed on arrival at the marshalling yard

The third scenario describes the situation where the train arrives late at the MY for reasons beyond the control of the marshalling yard operator.

- wagon transfer ensured
- wagon transfer not ensured

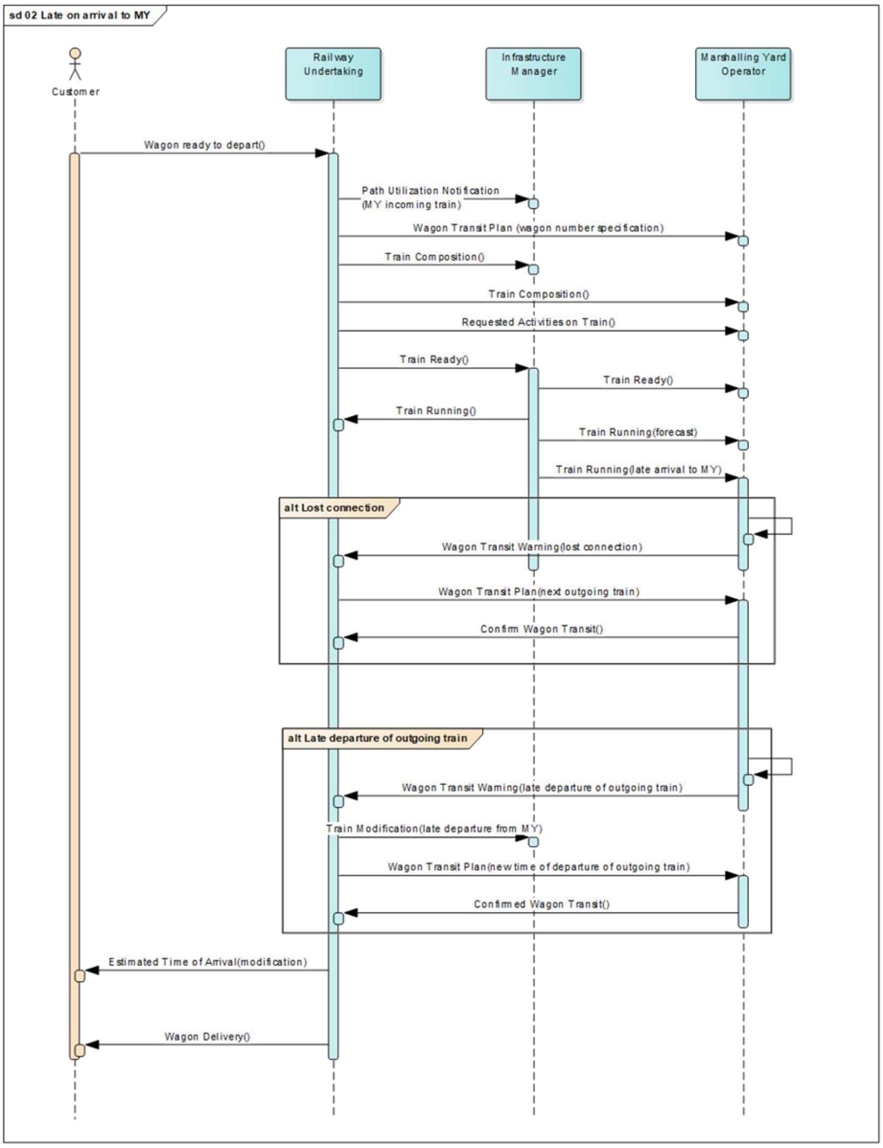


Figure 35: Third Scenario

Non-compliance with the wagon transfer schedule on the part of MY

The fourth scenario deals with a situation where there was a non-compliance with the wagon transfer between trains during the processing of the wagon. This situation can occur, for example, when wagons are misplaced on individual directional tracks or when the MY is full.

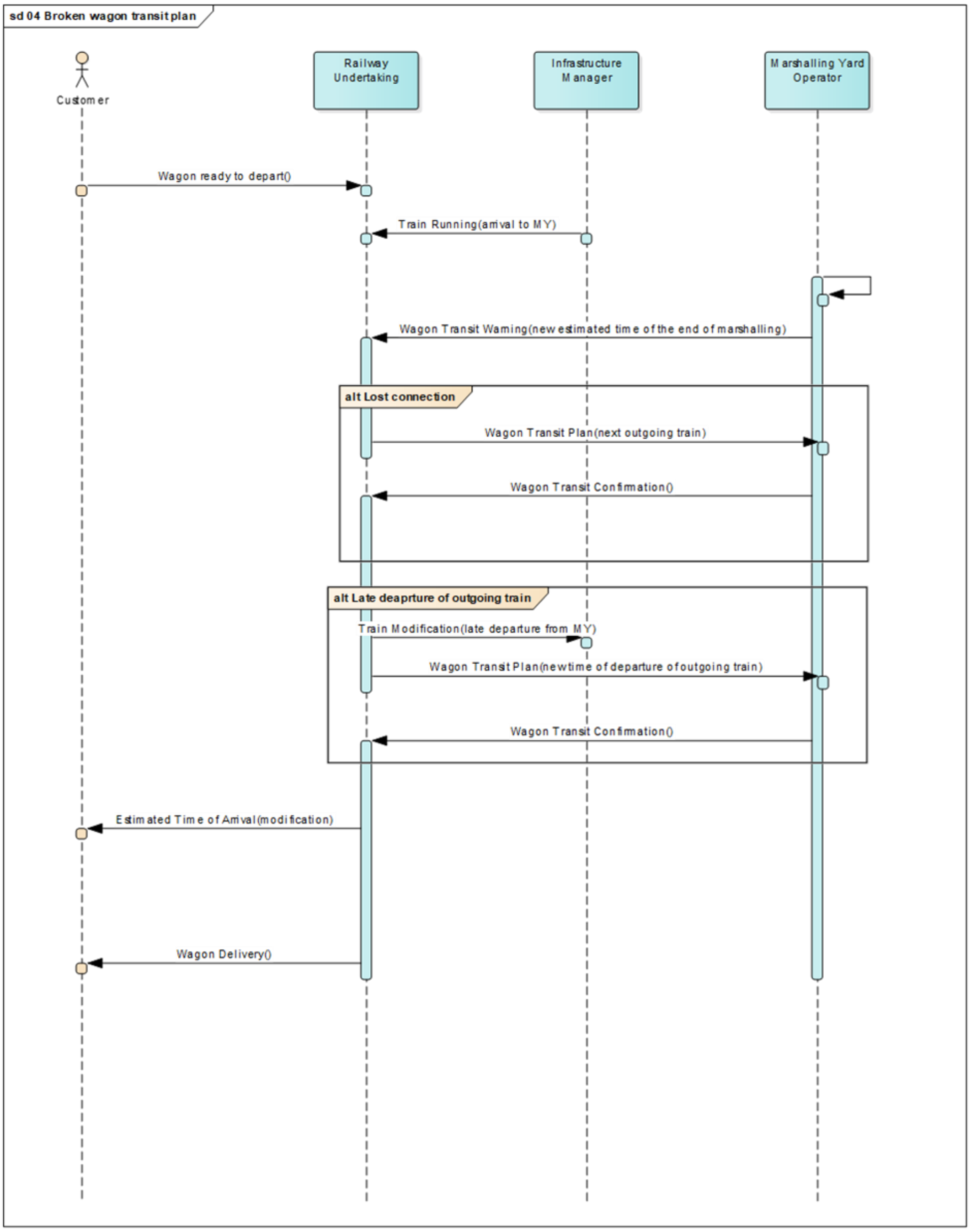


Figure 36: Fourth Scenario

Changing the wagon transfer during marshalling in the MY

The fifth scenario describes a situation where a change in the wagon transfer is requested by the RU (another departure train, change of ordering of the departure train, etc.).

6.8 Sources of data and information to optimize the work of the station and its surroundings

The basic sources of data and information for optimal or suboptimal management of terminal or marshalling yard processes, which may even be a classic marshalling station, are currently information systems (IS) on, not only, the Czech railway. These are usually the information systems of the RU or the infrastructure manager. In exceptional cases, such as aforementioned terminals and marshalling yards within terminals or directly linked to these terminals, the information systems of the relevant operator may be the data and information sources.

As already indicated, types of information systems, which can be distinguished according to the following divisions, take part in the continuous flow of information, which is essential for the functioning of some optimization tool for process optimization in stations or terminals.

Based on the IS operator:

- Railway undertaking's IS,
- Infrastructure manager's IS,
- Terminal or station IS.

Based on usage in time:

- IS for long-term planning (for the whole year),
- IS for medium-term planning (with view in days),
- IS for short-term planning and ad-hoc plan changes (tens of hours),
- IS for operational management (hours, minutes).

Based on the nature of the managed area:

- IS for managing traffic on the complete network,
- IS for managing traffic on a selected part of the network,
- IS for managing traffic at nodes and traffic points.

Based on the type of managed capacity source:

- IS for planning and managing wagon movement,
- IS for planning and managing movement of locomotives and trains,
- IS for planning and managing staff.

In this project, it is necessary to deal with the characteristics of the systems listed above with the exception of the IS for managing traffic on the complete network and IS for planning and managing staff. All other types of systems should be involved either directly (in real-time decision-making) or indirectly (in particular information based on the long-term plan) in the preparation of an optimization tool for support of the decision-making of dispatchers.

The following text pays attention mainly to the information and information systems that have a direct impact on traffic management and decision-making in real time. The reason for this is the assumption that operational information systems work with input information that is already optimized during the preparation of long-term and medium-term plans. In other words, if actual traffic were to take place with high accuracy according to long-term and medium-term plans, there would be no need to make major decisions on the organisation of operations in real time as the optimal solution had already been achieved in the said plans.

The first demonstrative example is constructed as follows:

- Customer: METRANS KOMBI
  - The service involves transporting containers between specific terminals and handling their distribution and collection before and after sea transport
- Route: Hamburg-Waltershof (DE terminal) – Ústí nad Labem (CZ) – Praha-Uhříněves / Česká Třebová (CZ terminals)
- RUs: ČDC DE (DE) and ČDC (CZ)
  - Other partners: Terminal Hamburg operator – cooperation with HACON/Thales
- Local staff keeper: ČD, Metrans
  - CZ terminal operator is Metrans
- The entire transport operation is managed by ČDC, with the formal handover/acceptance of licences taking place in Dresden-Friedrichstadt. Detailed data descriptions of the transport technology are available, allowing an accurate estimation of the ETI/ETA. However, specific data on the technology at the origin terminal in Hamburg-Waltershof is not currently available and the information provided is dependent on the readiness of the train to depart from the origin station.

The second demonstrative example is constructed as follows:

- Customer: Automotive Škoda Auto
  - Transport of cars from the Škoda Auto car factory (Mladá Boleslav, Solnice) to collecting in MY/terminal Nymburk (CZ).
- Route: Nymburk (CZ) – Děčín (CZ) – Emden (DE) and back, loaded trains from Nymburk to Emden and empty trains back
  - Nymburk is considered as a Škoda Auto terminal
- RUs: ČDC (CZ), DB Cargo DE (DE)
  - Handover/takeover between RUs in Bad Schandau (DE)

- Local staff keeper: ČD
    - CZ terminal operator is ČD Cargo (MY).
- Currently, there is a comprehensive data description of the transport technology available exclusively for the CZ section. In the direction from Nymburk to Emden, the Estimated Time of Interchange (ETI) can be calculated, although the Estimated Time of Arrival (ETA) remains unknown. Conversely, in the direction from Emden to Nymburk, crucial information concerning the ETI/ETA for the DE section is missing, making only rough estimations possible. Additionally, there is a lack of essential data information from DBC DE for comprehensive planning purposes.
- Within fixed time slots for available resources, the shift plan is predetermined to ensure non-stop or time-limited availability of resources. The aim is to achieve an evenly distributed workload throughout the shift, minimising peaks and troughs and ensuring efficient resource utilisation.
- Conversely, in the floating time slots scenario for available resources, the shift plan is dynamically adaptable based on the requirements arising from current transport schedules. In this case, the aim is to dynamically allocate shifts according to the train timetable, allowing flexibility and responsiveness to changing traffic demands.

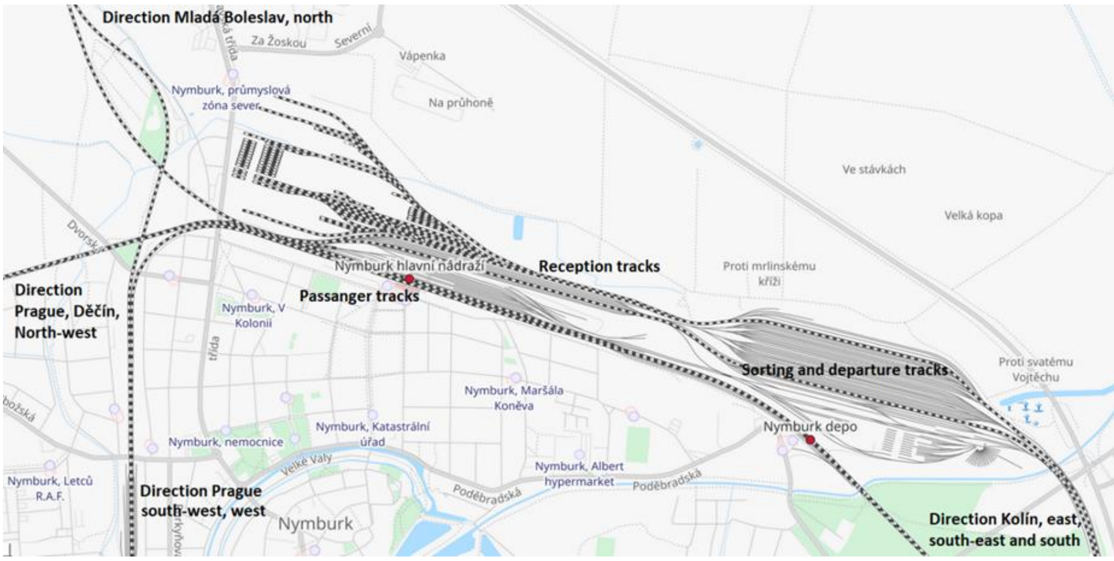


Figure 37: Scheme of the Nymburk terminal in the Czech Republic

6.4.5. Dynamic dispatching requirements for Yard Coordination System (YCS) (Malmö, Sweden)

This is the specification of the Use Case 5 as a result of Workpackage 27 dynamic dispatching and the associated developments, respectively the challenges to overcome.

In EU-RAIL FP1 Motional, Trafikverket and RISE are developing a demonstrator denoted yard coordination system. The basis of this system was developed in Shift2Rail, see

(Fr8Rail III, 2023) for more details. The system will be further enhanced in Motional WP4/5 and WP11/12 with, e.g., real-time connection to TMS and enhanced planning functionalities. The scope of YCS is to coordinate the planning of the track allocation for the arrival/departure yard of a larger marshalling yard. The development uses Malmö marshalling yard as case, but the concept can be generalized to many other yards. Figure 38 illustrates the layout and actors at the Malmö marshalling yard. For the arrival/departure yard, there are several different actors and organizations that are dependent on the yard and that should be coordinated, and YCS coordinated the track allocation need for the most significant actors: the line manager from the infrastructure manager (Trafikverket), the yard manager from the yard operator (Green Cargo), and the terminal manager from the terminal operator (Mertz).

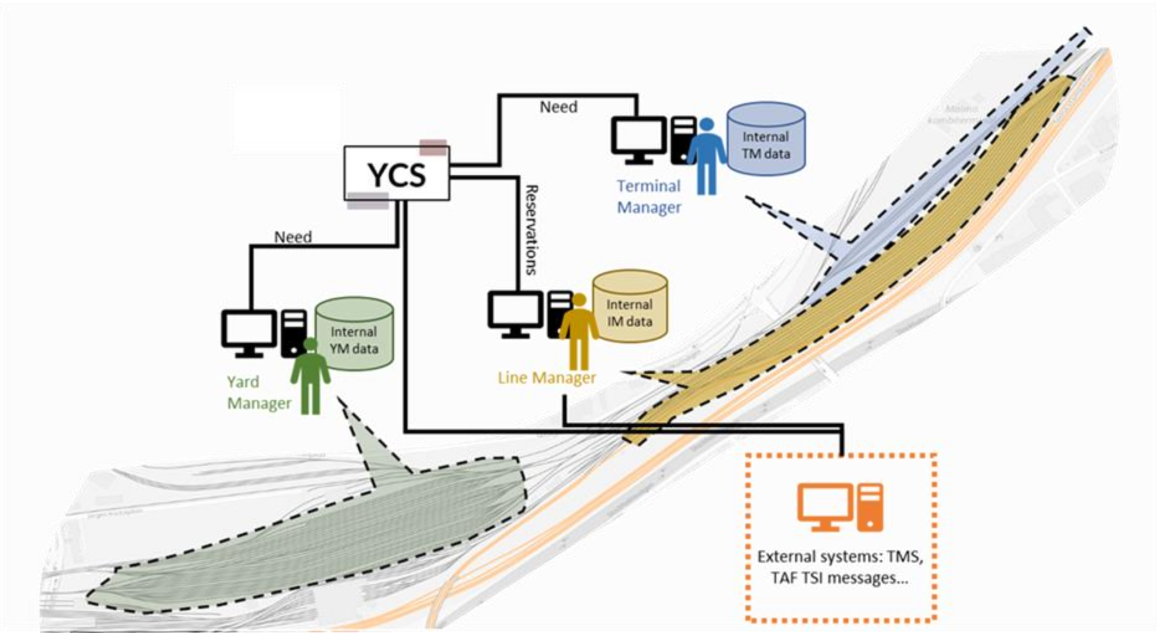


Figure 38: Layout and actors at Malmö marshalling yard.

Figure 39 illustrates the user interface of YCS for the Line Manager after Shift2Rail is finished. The interface visualizes all that is needed to make the track allocation, e.g., arrivals, departure, shunting operations, track reservations, track need, and train preparation activities. See (Fr8Rail III, 2023) for more details. The demonstration(s) regarding the development of YCS is a part of FP1 Motional.

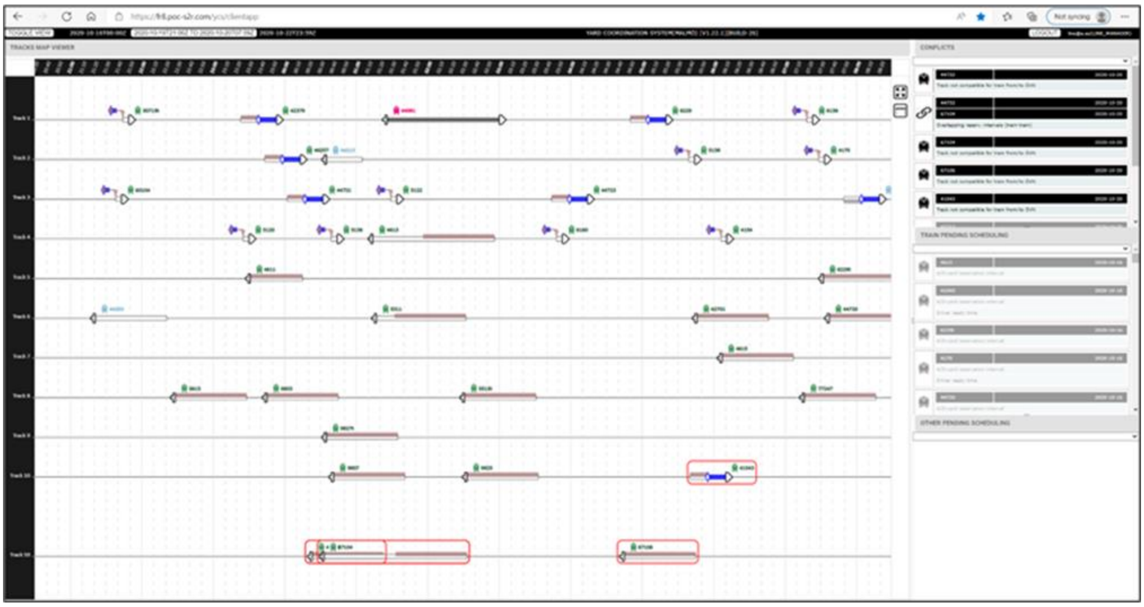


Figure 39: User interface of YCS

The dynamic activities at the yard have an implication on the planning of the arrival/departure yard. There are restrictions on simultaneous activities, e.g., a locomotive to/from the stables can prohibit simultaneuos shunting activities or moving wagons to the multimodal terminal. Thus, the dynamic dispatching decisions have an implication on the track utilization. In FP5 TRANS4M-R WP27, requirements related to dynamic dispatching aspects will be collected and will be delivered to FP1 Motional WP5. These requirements will be taken into consideration when developing the next generation of the YCS demonstrator, i.e., in enhancement that will be made during the next wave of EU-RAIL, from 2026 and forward.

6.5. Conclusion

A significant effort has been spent in the first months of TRANS4RM as a preparation to Work Package 27.

The partners involved in Work Package 27 have a strong market focus and are convinced, that the output of Work Package 27 will not be an academic description of how an optimum could look like, but a comprehensive summary of "best practices" reached with the 5 use cases. Therefor the Use Cases have been chosen in real environment, internationally spread and in a collaborative way. With stakeholders that are mainly searching for commercial benefits from those optimizations, be it more revenues, thanks to better loaded trains or more tasks that can be performed in the same time with the same amount of resources or lower costs, due to better utilization of existing infrastructure and a reduction of unproductive tasks.

Furthermore, the Use Cases will also show limitations, where optimums cannot be achieved yet. It is the aim of the work package 27 partners to list them and explain why they could not be overcome and why they are hindering further optimizations.

7 Intermodal Prediction

The main purpose of intermodal prediction systems is to provide timely and accurate predictions for arrival and departure times on relevant locations, milestones or processes. This information is provided to connected systems of different actors (terminal operators, shippers, railway undertakings, intermodal operators, infrastructure managers, logistic service providers etc.). By sharing this information with the transport chain, the overall predictability and transparency of multimodal transport increases, especially for rail transport.

Within TRANS4M-R, this high-level, global benefit will be translated into several dedicated use cases (Chapter 7.7). Intermodal Prediction therefore plays an important role for almost all aspects of Seamless Freight. Its applications will be featured in both showcases (Seamless Corridor and Seamless Multimodal).

To this extent, the following chapter describes the requirements, functionalities, processes, data sources as well as further specifications for intermodal prediction systems. Firstly, the general scope of the prediction systems is described (7.1). This includes a mapping of the relevant processes (7.2) as well as a dedicated list of milestones/timestamps for the terminal and yard processes (7.3). This list is primarily based on the original Rail-CDM approach developed in a study for the Rail Freight Corridor Rhine-Alpine financed by the European Commission. It was then further refined during the EDICT project and finally adapted in TRANS4M-R to include further yard processes and ensure a global interoperability with all aspects of Seamless Freight.

In a next step, relevant data types and data formats are described (7.4). These are necessary to obtain the data for the above-mentioned milestones/timestamps. For intermodal prediction systems, the terminal data format is EDIGES (7.4.2), a voluntary market standard adopted by several large players throughout Europe. For the main line information, TAF TSI is used throughout (7.4.1). This chapter will also highlight the parameters of each relevant message type that are to be used as input for any prediction models. Since some of these parameters are not mandatory information to be included by the data provider, the chapter also contains a brief, high-level what-if analysis for the lack of certain, potentially relevant, information.

Afterwards, the prediction systems themselves are described (7.5). For TRANS4M-R, both an ETA (estimated time of arrival) prediction system (7.5.1) as well as an ETD (estimated time of departure) prediction system (7.4.2) will be developed, featuring advanced machine-learning algorithms. For the evaluation of the prediction accuracy, quality KPIs are introduced (7.6).

Finally, the asset warehouse is described (7.6.1). Although not a prediction system in of itself, the asset warehouse is one of the main use cases of the intermodal prediction systems and will, once implemented, also increase reliability and predictability of rail transport.

7.1 Main processes and operational mapping

Intermodal rail transport, or better road-rail combined transport (CT), is a transport technique to facilitate the transport of intermodal loading units (containers, swap bodies, semi-trailers) by using rail on long distances and road on the first and last mile.

Today's CT business ecosystem is composed by interdependent elements that are significantly impacted by developments of: (1) physical assets (infrastructure, wagons, terminals, loading units, cargo), (2) stakeholders (infrastructure managers, railway undertakings, CT operators, terminal Managers, trucking companies, logistics companies, shippers), (3) authorities (policy-makers, customs authorities, regulators) and (4) information processing capabilities and data flows.

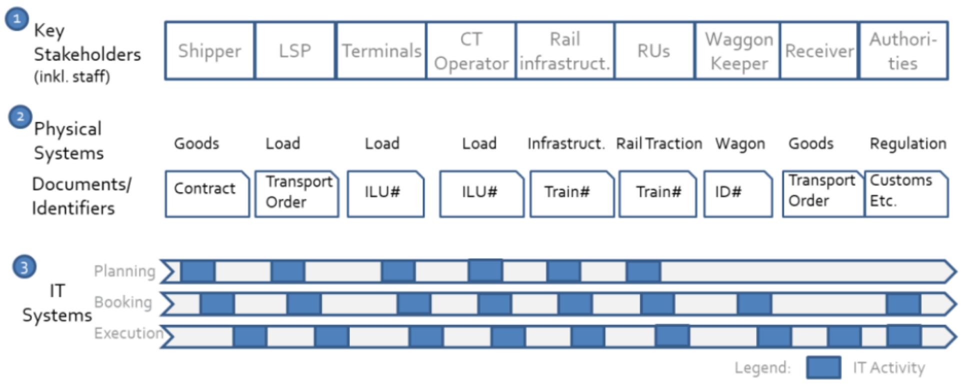


Figure 40: the key components of the CT ecosystem

Conducting a detailed process analysis in intermodal is a usual exercise of analysing all types of processes to identify opportunities to improve the way the various stakeholders operate. Using this type of analysis, stakeholders may evaluate their business processes and pinpoint what is and isn't working within their operations. In the next chapters, the project partners will identify the relevant processes and time stamps needed to improve the overall predictability in combined transport operations.

Combined transport uses the terms initial leg, transhipment, main leg and final leg, as shown in Figure 41. In some cases, packing (stuffing) and unpacking (stripping) are also added.

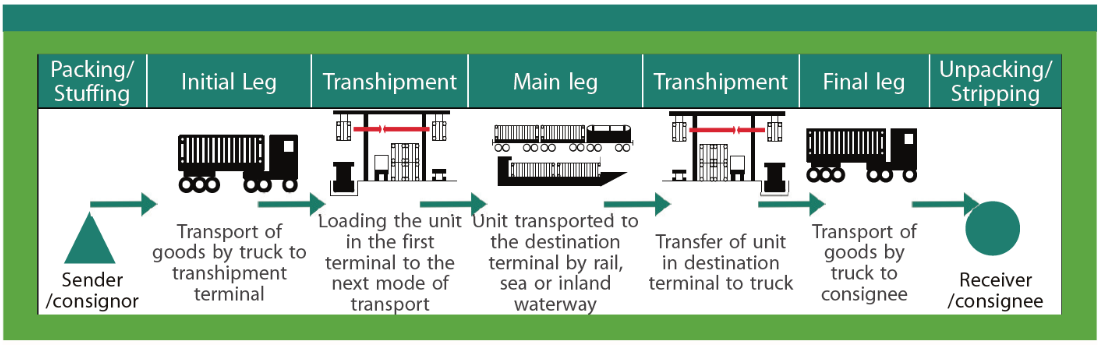


Figure 41: Main processes of a typical intermodal chain

- **Initial (road) leg (first mile)**: the initial leg describes the first part of the transportation of the loading unit(s) holding the cargo from one or more shippers to a transhipment facility (terminal). The term is applied mainly to road transportation but also to rail, air and water.
- **Transhipment**: the change of mode between vessels, inland waterway vessels, railways and trucks is called transhipment. Transhipment takes place in a transhipment node known as intermodal terminal, freight terminal. According to the type of equipment used, the transhipment process is referred to as "vertical" or "horizontal".
- **Main leg:** the main leg refers to the transportation of the intermodal loading units from the terminals to the nearest closest terminal of the consignee.
- **Final (road) leg (last mile)**: the final leg describes the transportation of the intermodal loading units from the receiving terminal to the consignee. Typically, the final leg is performed by truck connection.

In the context of the ELETA project[1], the project partners had to describe the above-mentioned main processes into four detailed use cases (see Figure 42 for graphical overview):

- Use case 01: departure terminal including initial road leg (first mile)
- Use case 02: main leg (rail) in normal conditions
- Use case 03: main leg (rail) in case of deviations
- Use case 04: arrival terminal including final road leg (last mile)

For each of the use cases, a process mapping was used to visually map out the workflows and processes (including the message types – EDIGES and/or TAF TSI – see next chapter

[1] ELETA is a co-financed project under Connecting Europe Facility (CEF), launched in September 2017, which aims to demonstrate the advantages of exchanging the Estimated Time of Arrival (ETA) data within the whole rail supply chain management.

E

for additional details). The purpose of process mapping is to communicate how a process works in a concise and straightforward way.

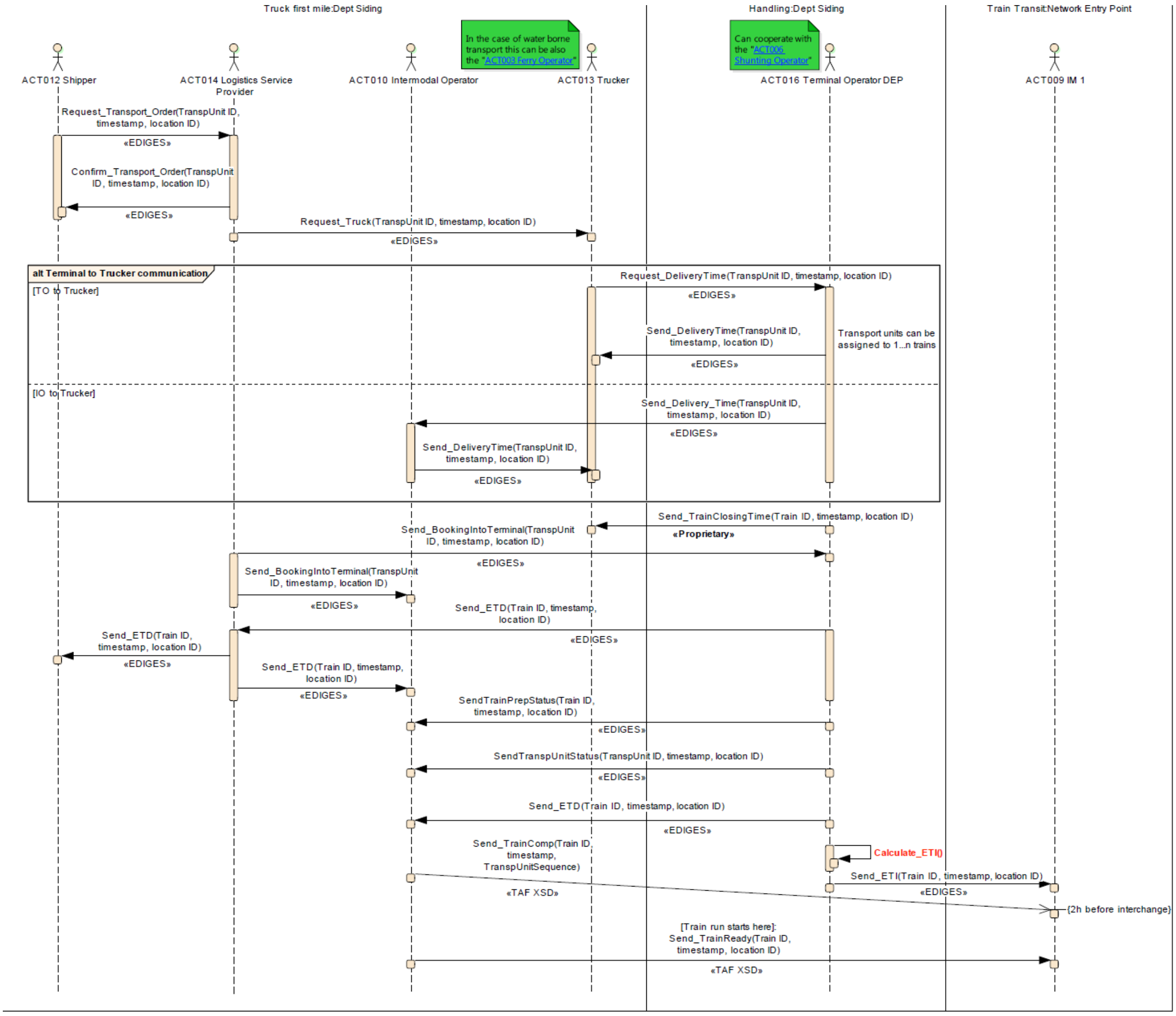


Figure 42: Use Case 01 - Process mapping at terminal departure (ELETA project)

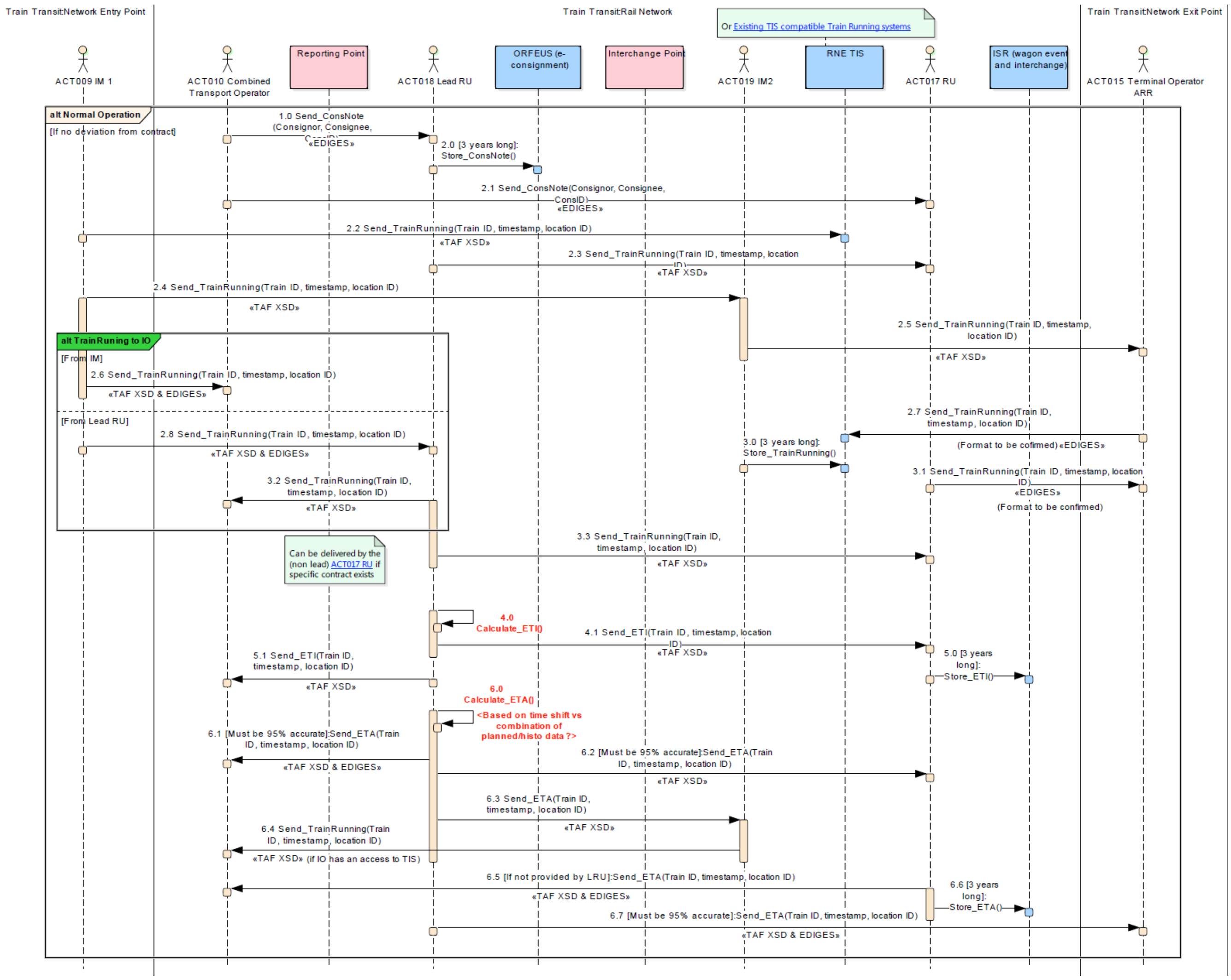


Figure 43 – Use Case 02 - Process mapping during main railway leg – normal conditions (ELETA project)

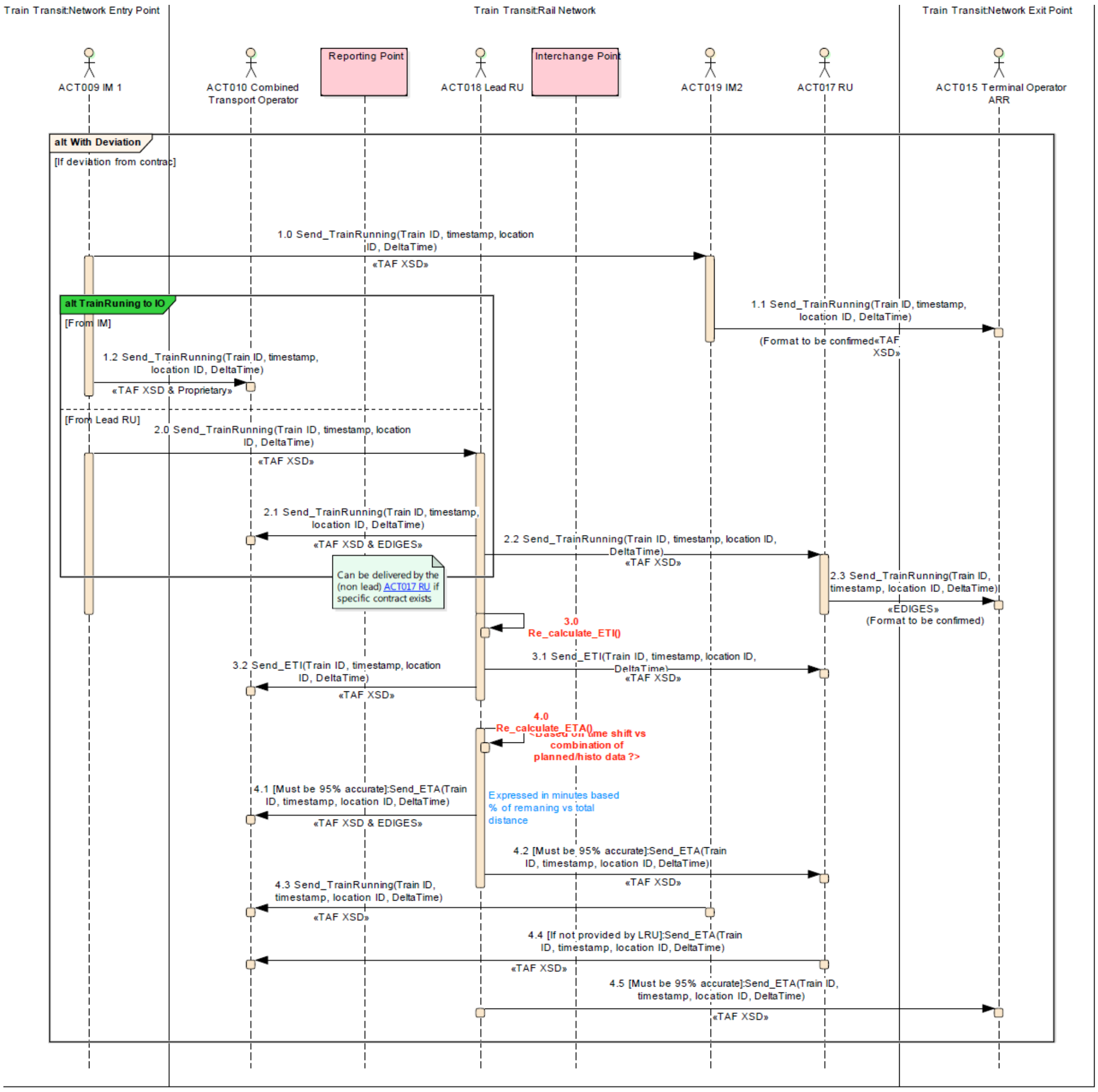


Figure 44: Use Case 03 - Process mapping during main railway leg – with deviations (ELETA project)

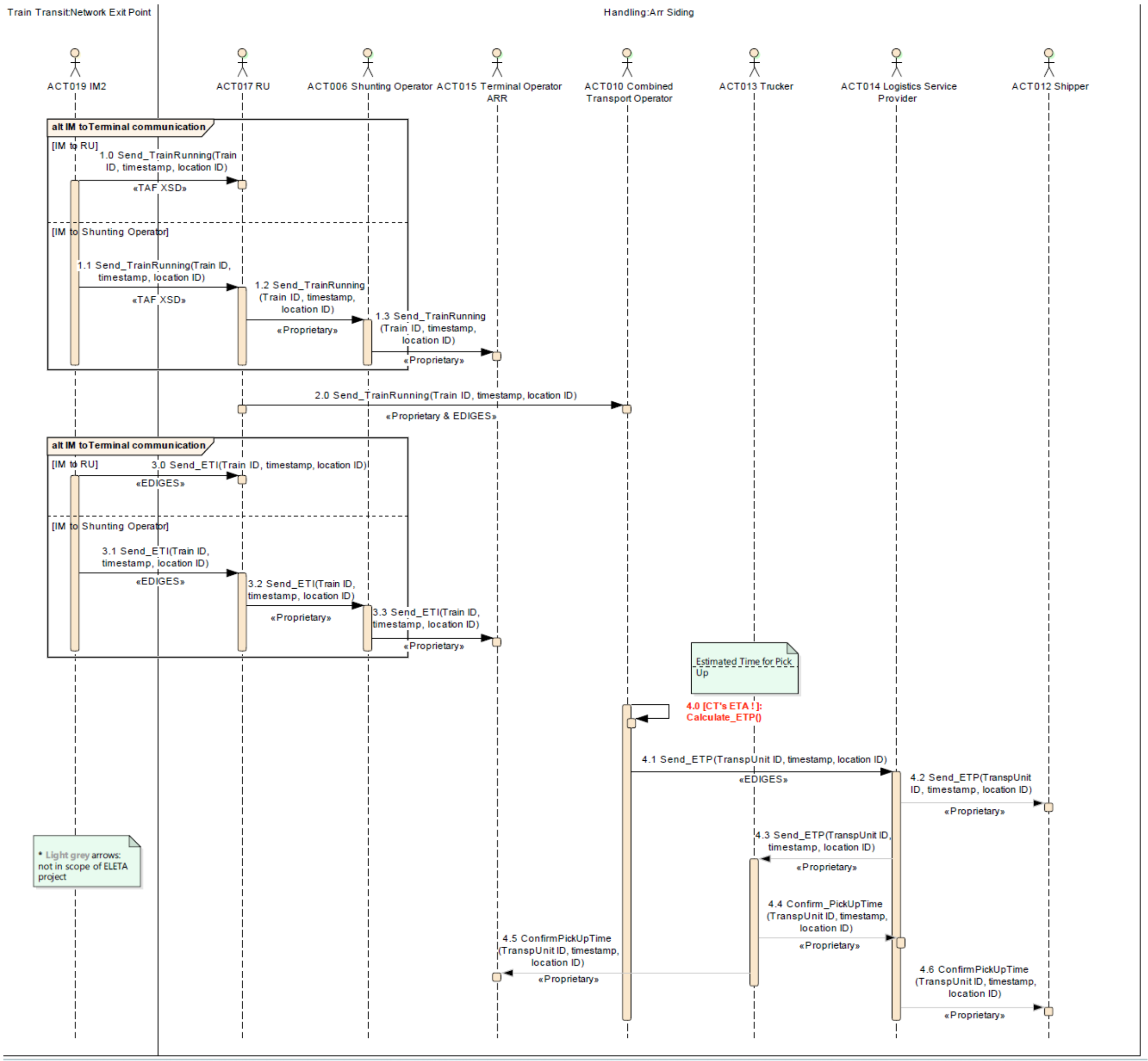


Figure 45 – Use Case 04 - Process mapping at terminal arrival (ELETA project)

7.2 List of Milestones and Timestamps for Seamless Freight

As the chapters for Seamless Planning and Dynamic Dispatching have shown, the planning and dispatching processes, especially for first- and last-mile rail transport, can be quite complex. There are a multitude of different actors and processes involved. To ensure the development of sustainable solutions, it is therefore essential to come up with a harmonized list of milestones. This list is the basis of measurement for the prediction systems that will be developed in accordance with the specifications for Seamless Freight. This list combines the results of (partially still ongoing) European and national R&I initiatives with the expertise of the TRANS4M-R partners.

The following definitions should be utilised within the project:

- **Milestone**: the status or geographic position of a train, wagon set or loading unit in the transport process
- **Timestamp**: the digital record of the time of occurrence of a particular milestone
- **Actual Time / Time stamp**: the time recorded once a specific milestone is reached
- **Estimated Time / Time stamp**: the time that a milestone is calculated to be reached
- **Planned Time / Time stamp**: the time that a milestone is scheduled to be reached according to a timetable

The basis for this harmonized list is the Rail-CDM (Railway Collaborative Decision Making) feasibility study. This study demonstrated that the Airport CDM is transferable from aviation to rail and that it could contribute to resolve key rail challenges.

Rail-CDM should provide enhanced predictability of railway processes, to provide stability of the operations and allow better resource utilisation. Predictability is therefore defined as a strategic objective to be achieved through Rail-CDM. This is supported by tracking milestones and setting target times in the handling process.

An initial list of key train events for rail freight transport was drawn up that could serve as potential milestones. The further elaboration of this list must be an integral part of subsequent development steps.

#	Milestones Descriptions (Key train events)	Related Timestamp to Milestone	Who Inputs	Timestamp Acronym	Aviation Equal	Planned	Estimated	Targeted	Actual
1	Train enters the main line at origin terminal	**Actual Enter Main line Time**	**IM**	**AEMT**	-	**PEMT**	EEMT		**AEMT**
2	Train enters the network of the final IM	Actual Enter Final IM Time	IM	AEFT	-	**PEFT**	**EEFT**		**AEFT**
3	Train leaves the mainline and enters the handover station	**Actual Leave Main line Time**	**IM**	**ALMT**	ALDT	**PLMT**	**ELMT**		**ALMT**
4	Train leaves the handover station and enters the connection line	Actual Leave Handoverstation Time	RU/SO	ALHT	-	PLHT		TLHT	ALHT
5	Train leaves the connection line and enters the transhipment track	**Actual Leave Connection line Time**	**TO**	**ALCT**	AIBT	**PLCT**		TLCT	ALCT
6	All potential checks are done and unloading starts (Bereitstellung)	**Actual Start Unloading Time**	**TO**	**ASUT**	ACGT	**PSUT**	ESUT	TSUT	ASUT
7	The unloading of the train ends	Actual End Unloading Time	TO	AEUT		PEUT			
8	*Start of shunting/decomposition if waggon sets are stored in a siding*	*Actual Start Decomposition Time*	*TO*	*ASDT*					
9	*End of shunting/decomposition if waggon sets are stored in a siding*	*Actual End Decomposition Time*	*TO*	*AEDT*					
10	*Start of shunting/composition if waggon sets were stored in a siding*	*Actual Start Composition Time*	*TO*	*ASCT*					
11	*End of shunting/composition if waggon sets were stored in a siding*	*Actual End Composition Time*	*TO*	*AECT*					
12	The inspection of the empty train is completed	Actual Empty Inspection Time	TO	AEIT					
13	The loading of the train starts	Actual Start Loading Time	TO	ASLT	ASBT	PSLT			
14	The loading of the trains ends (Ladeschluss)	**Actual End Loading Time**	**TO**	**AELT**		**PELT**	EELT	TELT	AELT
15	The brake test & train inspection starts	Actual Start Brake test Time	TO	ASBT		PSBT			ASBT
16	Timestamp when the target time for the "train ready for shunting to handover station" is issued	**Target Ready for Shunting Time**	**RU**	**TRST**	TOBT				
17	The brake test & train inspection ends / is completed without failure	Actual End Brake test Time	TO	AEBT		PEBT		TEBT	AEBT
18	Timestamp when the target time for the "approval of time to enter the main line" is issued	**Target Mainline Approval Time**	**IM**	**TMAT**	TSAT		EMAT	**TMAT**	
19	Timestamp when the target time for the "train ready to enter main line" is issued	**Target Ready for Main line Time**	**RU**	**TRMT**					
20	Train is declared ready for shunting (Terminal exit)	**Actual Ready for Shunting Time**	**TO/SO**	**ARST**	AEGT	PRST		TRST	ARST
21	Train leaves the transhipment tracks and enters the connection line	**Actual Start Shunting Time**	**TO/SO**	**ASST**	AOBT	PSST	ESST	TSST	ASST
22	Train leaves the connecting cine and enters the handover station	Actual Enter Handoverstation Time	SO	AEHT		PEHT		TEHT	AEHT
23	Train is declared ready for main line entry (Train Ready for Dep.)	**Actual Ready for Mainline Time**	**RU**	**ARMT**	ARDT	PRMT		**TRMT**	**ARMT**
24	The IM provides the actual main line approval (Green Light)	**Actual Main line Approval Time**	**IM**	**AMAT**	ASAT				
25	Train enters the main line (actual movement detection by sensor)	**Actual Enter Main line Time**	**IM**	**AEMT**	ATOT	**PEMT**			**AEMT**

Figure 46: List of milestones according to the Rail-CDM study

In the context of the Rail-CDM study, milestones are a breakdown of common actual rail operation events and focus on the prediction of train events that could impact capacity on corridors and international networks, including the destination terminals. Prediction updates are triggered through defined generic process for contingency and discrepancy checking, information and alert message sharing to other stakeholders and is allocated to specific stakeholders: Infrastructure Manager (IM), Railway Undertaking (RU), Shunting Operator (SO) or Terminal Operator (TO).

The status of the message to be exchanged at the respective milestone is defined as planned, estimated, targeted or actual where Planned Times are defined as originally planned times used for the initial (long term) planning and contractual agreements between the stakeholders/customers; Estimated Times are defined as estimate times based on real-time information about the current status, aimed to facilitate re-planning to secure capacity from Terminal Operator or Infrastructure Manager; Target Times are defined as dynamical updates of the intentions /plans for the subsequent process milestones based on actual status of train operational progress; Actual Times are defined as events that actually take place and shall not be mixed with Estimates or Targets.

In the context of the German project KV4.0 and of the European project ELETA, the milestones and the timestamps have been further developed and are cover all the main processes as described in chapter 7.1. Figure 47 provides an overview of all common agreed time stamps and Table 10 provides a first description of these time stamps under the perspective of calculating an ETA.

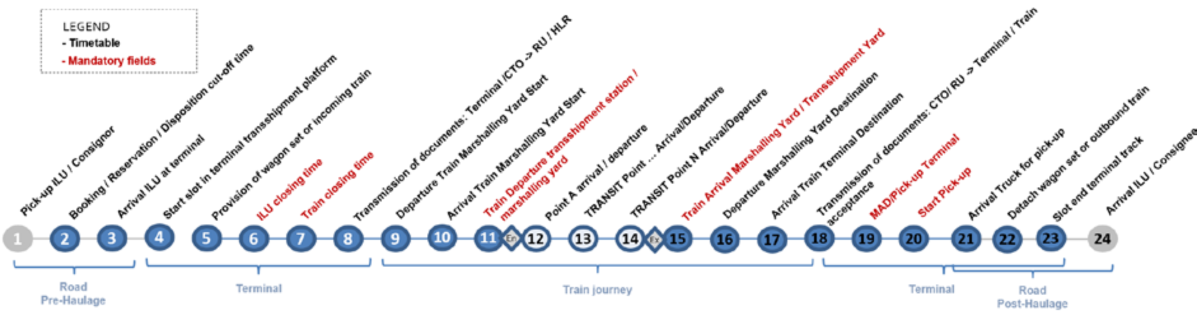


Figure 47: Overview of all common agreed time stamps

#	Time stamp name	Time stamp description
1	Pick-up ILU/Container	
2	Booking/Reservation/Disposition cut off time	
3	**Arrival ILU at terminal**	**ETA of Truck provided by LSP**
4	Start slot in terminal transhipment platform	
5	Provision of wagon set / incoming train	
6	ILU closing time	
7	Train closing time	
8	Transmission of documents: Terminal / CTO to RU /HLR	
9	Departure Train Marshalling Yard Start	
10	Arrival Train Marshalling Yard Start	
11	Train Departure Transshipment Station / Marshalling Yard	
En	**IM Entry Point (first)**	
12	Point A: Arrival / Departure	
13	**Transit Point … Arrival/departure**	**ETA from RU at a hand-over point** (e.g. hand-over of responsibility between RUs)
14	**Transit Point N: Arrival/departure**	
Ex	**IM Exit Point (final)**	**ETA $_{IM}$ simultaneously ETA option for Lead RU**
15	**Train Arrival Marshalling Yard / Transshipment Yard**	**ETA option for Lead RU at arrival in the Marshalling / Transhipment yard** (optionally line configuration dependent)
16	Departure Marshalling Yard Destination	

17	**Arrival Train Terminal Destination**	**ETA option for Lead RU at destination terminal (optionally line configuration dependent) key output of project**
18	Transmission of documents: CTO/ RU to Terminal / Train	
19	MAD / Pick-up	Mise à Disposition (MAD) or pick-up at terminal with the status "train is under the crane". Unloading is possible but not yet finished or cannot yet start (e.g. due train arrival during terminal closure time).
20	**Start pick-up**	ETA of CTO with the ILU available for onward carriage to inform LSP and indirectly trucker that goods can be picked-up. Not required for Pilot Phase 1. Can be an optional delivery for some CTOs.
21	**Arrival of truck for pick up**	ETA of truck for pick-up (ETA $_{TR}$) provided by LSP and sent to the CTO who forwards it to the TO

Table 10: Description of common agreed time stamps

In the context of the CEF funded project EDICT, it was requested to further harmonise the time stamps and milestones for the terminal operators for the following main reasons:

- Requests from the feasibility studies R-CDM and Q-ELETA
- Data on train status at terminals facilitate: (1) planning of operations (e.g. computation of ETAs/ETPs), analysis of punctuality and integration into the future Rail Collaborative Decision Making (R-CDM)
- Timestamps and delay reason codes are well defined for trains when running but not yet for terminal operations (at train preparation level)
- For terminal-related operations, various definitions/ versions of timestamps have been created, used by operators and proposed by consultants
- Harmonised timestamps on terminal operations are needed for data exchange by means of TAF-TSI train running message

As a first step, an inventory of already identified milestones and timestamps has been created based on (1) the detailed mapping process of some key terminal operators (see Figure 48), (2) the list of milestones of the R-CDM and Q-ELETA feasibility studies and (3) the milestones already exchange today with TAF TSI and EDIGES data format exchanges.

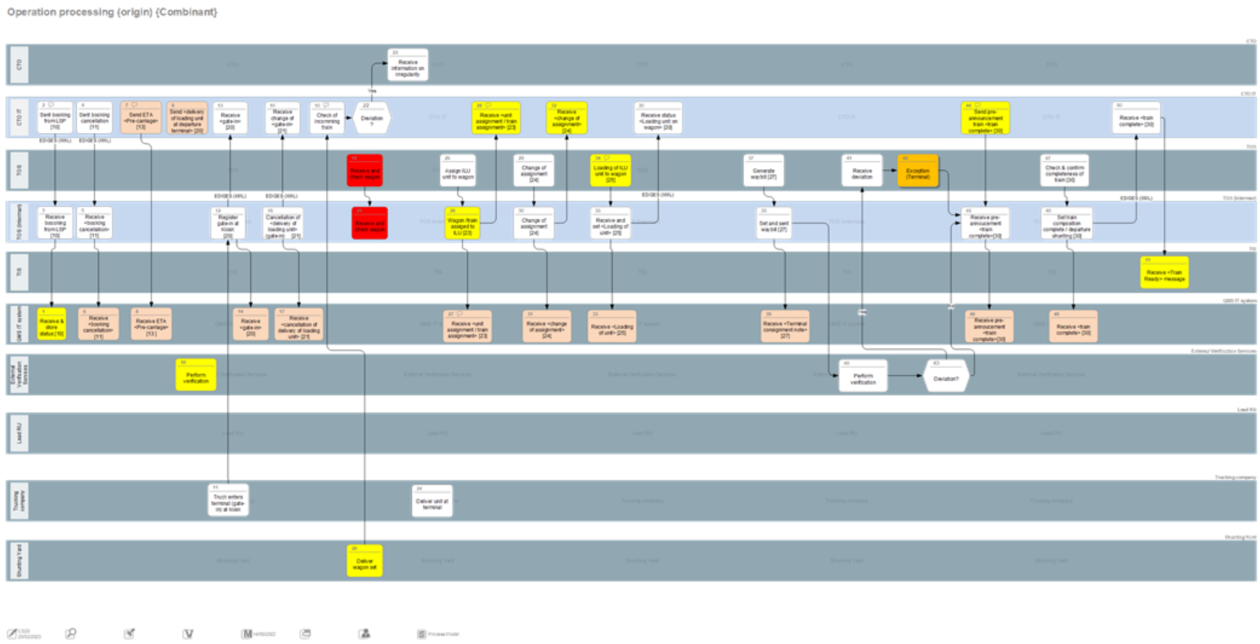


Figure 48: Detailed process mapping of a terminal (based on the EDICT project)

The evaluation and selection of the milestones for the terminals was carried out thanks to the organisation of specific workshops with all terminal partners of the EDICT project.

The purpose was to evaluate and select the appropriate milestones and time stamps for the terminals (two different lists were elaborated):

1. Validation of the definition of each single milestone
2. Validation of the time stamp of each single milestone (planned, actual, estimated)
3. Validation of the level of each milestone (train, ILU, wagon)
4. Validation of the EDIGES status code (e.g. 10 – booking)
5. Validation of the direction of the message (e.g. TO => CTO)
6. Validation of the relevance of the milestone (e.g. x = yes)
7. Validation of available milestone by the various project beneficiaries (yes = company can already manage this milestone in their respective TOs)

Milestone ID	Description of the situation at the milestone	Status	Level	Relevance	Qualifier	Status code EDIGES	Mandatory to send messages in Ediges?	Direction of the message
Departure								
D01	the time that the booking of a loading unit is made (including booking details + updates)	Actual	ILU	(x)	Optional	10 - Booking	Yes	LSP -> CTO CTO -> TO
D02	the time that a loading unit is cancelled	Actual	ILU	(x)	Optional	11 - Cancellation	Yes	LSP -> CTO CTO -> TO
D03	the estimated time that a Loading unit starts its journey towards the departure terminal (via truck)	Estimate	ILU	x	Future (mandatory)	13 - Pre-carriage (estimated)	Future	LSP -> CTO CTO -> TO
D04	the actual time that a Loading unit starts its journey towards the departure terminal (via truck)	Actual	ILU	x	Future (mandatory)	Pre-carriage actual?	Future	LSP -> CTO CTO -> TO
D05	the time of verification of physical status of the loading unit prior to the check-in	Actual	ILU	(x)	Optional	15 - Verification	No	TO -> CTO
D06	the time that a truck enters the terminal	Actual	ILU	x		20 - Gate In ITU	Yes	TO -> CTO
D07	the time the terminal reverses the truck entry (cancellation)	Actual	ILU	x		21 - Cancellation Gate-in ITU	Yes	TO -> CTO
D08	the time that a loading unit is unloaded from the truck	Actual	ILU	x				TO -> CTO
D09	the time that a loading unit is refused for unloading from the truck	Actual	ILU	x				TO -> CTO CTO -> LSP
D10	Planned departure of train terminal time slot (schedule)	Plan	Wagonset	val		No	No	TO <-> CTO

Figure 49 – Extract of the list of harmonised milestones and time stamps for terminals (based on the EDICT project)

The result of the validation is a long list of terminal milestones and timestamps:

- Each milestone has been defined and identified by a unique ID (for example D6 as the actual time that a truck enters the terminal)
- In total 35 milestones have been defined and selected: 24 milestones for departure and 11 milestones for arrival
- Nearly all milestones are covered by one status code in EDIGES – very few from R-CDM and TAF TSI

Based on this long list and based on the new TAF TSI requirements for terminals, the terminals are also motivated to exchange terminal-related information with other stakeholders:

- Principal motivation for terminals: to receive information on actual train positions and (estimated) train arrivals at their terminals (hence not only for train arrivals at the network exit point but also for trains arriving under the crane)
- Connectivity: Other systems (for example RNE TIS) must be able to receive information on terminal operations (actual time of trains reaching certain terminal milestones).
- Benefits: by sending information to such systems, terminals would also receive reliable train-related (forecast) information in the TAF TSI format.

The terminals are involved in the data flow not only as receiver but also as sender of important data elements.

Table 11 provides a detailed list of milestones that should be shared with the terminals:

- The milestones D22 and A08 shall be mandatory milestones and transmitted by RUs. For A08, the potential new running TAF TSI status code 16 (MAD) from the TAF TSI message in 4.2.4.3 could be used. If not possible within the EDICT project, the terminals should be responsible for providing this information.
- The agreed milestones must be mapped with the TAF TSI running status codes.
- Terminals receive data from TIS by means of the train running information message (compatible with EDIGES S34) and train running forecast message (compatible with EDIGES S36).
- Terminals need to be able to receive the train delay messages (Train Delay Cause Message 4.2.4.3)

Milestone ID	Description of the milestone	Direction of the message	Matching	
			Possible Data Formats	R-CDM
D21	the time that the train has been inspected by the RU, is under responsibility of the RU and is ready to start its journey	RU => TO/CTO	EDIGES S34	ARST-Actual Ready for Shunting Time
D22	the actual time-the train leaves the terminal and starts its journey	RU => TO/CTO	EDIGES S34 TAF TSI TRI	ASST-Actual Start Shunting Time
D23	the time that the train leaves the connecting line, enters the handover station and arrives at the (public) network entry point	RU => TO/CTO	EDIGES S34 TAF TSI TRI	ARMT-Actual Ready for Mainline Time
D24	the time that the train starts its journey on the public network	RU => TO/CTO	EDIGES S34 TAF TSI TRI	AEMT-Actual Enter Mainline Time
A01	the time that a train arrives at the network exit point (handover station)	RU => TO/CTO	EDIGES S34 TAF TSI TRI	ALMT-Actual Leave Mainline Time
A02	the time that a train departs from the network exit point (handover station) identified by its Primary Location Code (PLC) towards the terminal of destination identified by its Subsidiary Location Code (SLC)	RU => TO/CTO	EDIGES S34 TAF TSI TRI	ALHT-Actual Leave Handover Station Time
A04	the time that the train is estimated to arrive at the terminal	RU => TO/CTO	EDIGES S36 TAF TSI TRF	
A07	the time that a train enters the terminal of destination identified by its Subsidiary Location Code (SLC)	RU => TO/CTO	EDIGES S38 TAF TSI TRI	ALCT- Actual Leave Connection Line Time
A08	the time that the train or wagon set is available and ready for handling by the terminal operator *Note: this is the so-called MAD RU*	RU => TO	EDIGES S72 TAF TSI TRI	

Legend
TAF TSI TRI = TAF TSI message Train Running Information
TAF TSI TRF = TAF TSI message Train Running Forecast Information

Table 11: Milestones to be received by terminals (based on the EDICT project)

Table 12 provides a detailed list of milestones that should be sent by the terminals:

- Some of these milestones should or have already been inserted as mandatory requirements into the TAF TSI Regulation, which should be displayed in the RNE TIS interface.
- All milestones related to unit level are not part of the TAF TSI Regulation; only train level information should be exchanged in the TAF TSI context among stakeholders.
- The milestones D16 or D17 are considered as the mandatory milestones. For the EDICT project D17 will be used. For EDIGES users, it means to use the message S30. For TAF TSI, the Train Ready Message or the Train Running Information (with a specific status code) should be considered for the RNE TIS integration.
- The other milestones are relevant for improved communication with CTOs or LSPs.

Milestone ID	Description of the milestone	Direction of the message	TAF TSI Relevance & RNE TIS	EDIGES		Matching
				Message	Status (EDICT partners)	R-CDM
D06 D08	the time that a truck enters the terminal the time that a loading unit is unloaded from the truck)	TO => CTO		S20	50%-60%	
D13	the time when the ILU is loaded on the wagon	TO => CTO		S25	90%	
D16	the time that the wagon set must at the latest be handed over to the RU with documents given by the consignor (CTO or its representative/terminal) to the RU *Note: this is the so-called HLR*	TO => RU	X (TAF TSI Train Ready Message or TRI)	S70	20%	
D17	the train is ready to depart from the terminal *Note: this the actual HLR (responsibility handed over from TO to RU)*	TO => RU	X (TAF TSI Train Ready Message or TRI)	S30	60%	AELT Actual End Loading Time
A06	the estimated time that a Loading Unit can be picked up at the arrival terminal (ETP)	TO -> CTO CTO -> LSP		S37	40%	
A09	the time that loading units, which have arrived by train, are available for pick up by a Logistic Service Provider/road haulier	TO => CTO CTO => LSP		S40	70%	

Legend
TO = Terminal Operator | CTO = Combined Transport Operator | LSP = Logistics Service Provider | RU = Railway Undertaking
TRI = Train Running Information

Table 12: Milestones to be sent by terminals (based on the EDICT project)

In a final step, the milestones were cross-checked with day-to-day operations. As a result, a few milestones were added to complete the list. The comprehensive list of milestones for Seamless Freight can be found in Appendix 14.3.

7.3 List of systems and formats that will/might be connected

This chapter describes the two main data formats that will be used for train-related information, TAF TSI for the main line (7.5.1) and EDIGES for the first- and last-mile processes. The chapter highlights the relevant message types and describes their main parameters which are needed to adequately use this message. Since not all of these message types are optional, and since neither EDIGES nor TAF TSI have a full coverage (although the latter will be made mandatory), the consequences of any missing parameters will also have to be considered. The main data source for the TAF TSI messages is RNE TIS. For EDIGES, the KV4.0 platform fulfils a similar purpose. Both these sources have been already accessed regarding initial test data. However, the intermodal prediction systems must also be able to integrate data directly from the sources (RUs/IMs for TAF TSI and TOs/CTOs/RUs for EDIGES).

7.3.1 TAF TSI

The Technical Specification for Interoperability related to Telematic Applications for the Freight Subsystem of the Rail System in the European Union (TAF TSI), aim to set a framework for the efficient interchange of information between all the possible service providers involved in the freight transportation chain. The underlying concept of the TAF TSI specifications is that all service providers must work together through efficient exchange of communications, cooperation, and open access in order to provide a seamless freight transportation service.

The TAF TSI, defines the IM as the provider for the allocation and reporting of paths, and the controlling and monitoring of trains. The RU is the provider for operating trains and managing fleets. The TAF TSI also defines the Lead Railway Undertaking (LRU) as the provider that takes into account the costumer's request, defines the transport service and coordinates with additional RUs that might be involved in the transport chain.

The TAF TSI specifications define the information exchange between service providers - mainly between RUs and IMs - needed to perform the freight transportation service. The information flow needed for a freight transportation service considered in the specifications include the consignment orders made by the client to the LRU, the train path definition between IMs and RUs (Path Request), the train preparation (i.e., to communicate the train composition or when the train is ready) the train running information, eventual service interruption information, the ETA, and the wagon movements, among others.

The implementation of the TAF TSI specifications across the railway sector in Europe is measured periodically by the European Rail Joint Sector Group (JSG), based on an optional survey that is sent out to companies in the freight sector across Europe. The last implementation report was issued in 2022, and it included the responses from 325 companies, out of 786 invitations, in 26 countries. The report is useful to understand the compliance of the specifications in general and the usage of each message type in particular.

Each company sends specific information depending on specific business by the message types (I.e. path request is sent by the RU and Path Detail is sent by the IM). The exchange of the messages is made by a defined peer-to-peer application or "Common Interface", which can be implemented by the company on internal servers or using the RNE Common Interface. Such information must contain unique identifiers needed to retrieve the unique ID for all objects over their complete lifecycle. The lifecycle starts with the planning phase until the phase of accounting. These so-called Object Identifiers are:

a. Train (including Reference TRID with Reference Calendar)
b. Route
c. Path
d. Path Request
e. Case Reference
f. Capacity Model
g. Capacity Needs Announcements
h. Catalogue Path

As the Common Interface is a commonly used way of transmitting TAF TSI data, the RNE TIS service will be used as the main data provider for train-related TAF TSI information. However, since the setup of such an interface is, especially for some smaller actors, too costly, the intermodal prediction system must also be able to receive TAF TSI information outside of the RNE TIS service.

7.3.2 Message types, their parameters and an estimation of their compliance in Europe:

The main TAF TSI message types that are of relevance for an intermodal prediction system are:

- Path Detail Messages (PDM),
- Path Section Notification Messages (PSN),
- Train Running Information Messages (TRI),
- Train Running Forecast Messages (TRF),
- Train Running Interruption Messages (TRIM),
- Train Composition Messages (TCM) and
- Wagon Performance Messages (WPM).

7.3.3 Path Detail Messages (PDM)

Path Detail Messages are sent from the IM to the RU and are used to confirm details on the train path requested by the RU. There are three types of requests: path study, path request and path modification. All request types contain common information on the operator's contact information and on the identification of the train. The relevant section is reflected in the Planned Journey Location in the Path Information parameters. This Planned Journey Location exists for each operational point on the planned route and contains information on the location (name, code), on the planned time (booked time), on the train (loco type, weight, length, maximum speed, ...), and on the operational train number that is required to clearly identify the train and to connect the plan data taken from this message to the real-time data taken from other messages.

For the intermodal prediction system, the PDMs are the main reference information on which basis the plan data for a train run is built. Without this information, the system will not know the planned route of the train and therefore cannot access the corresponding training data. It will also be more difficult to gauge the delay; without the scheduled times, this is only possible by referencing historical data. Any changes in the ad-hoc schedule then will not be reflected, leading to potentially inaccurate or only partially available predictions.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Type of Request (Path study, request, or modification)	Mandatory
Location (Country, Code)	Mandatory, name not mandatory
Booked Time (time planned according to current disposition)	Not mandatory
Train (technical) data	Not mandatory
Operational train number	Not mandatory

Table 13: Important Parameters in PDMs

The fact that the information especially on the identifiers, the booked time, and the train number are not mandatory, is in stark contrast to the importance of these parameters as described above. These messages must be complete to be used to build a timetable with the planned data for each train run. Nevertheless, for the observed test data, all relevant parameters were delivered. During the development phase, when more data will be used, it will have to be seen if this is also the case for the rest of the network.

The compliance/level of fulfilment for IMs and RUs (based on a voluntary ERA survey, see below) paints a similar picture for all message types. The big players have a near 100% completion, whereas smaller players struggle to meet the compliance criteria. Although this does not affect the foreseen use case environments (chapter 7.7), where all relevant TAF TSI message types can be delivered, it does become an issue when trying to integrate these smaller players into the intermodal prediction system.

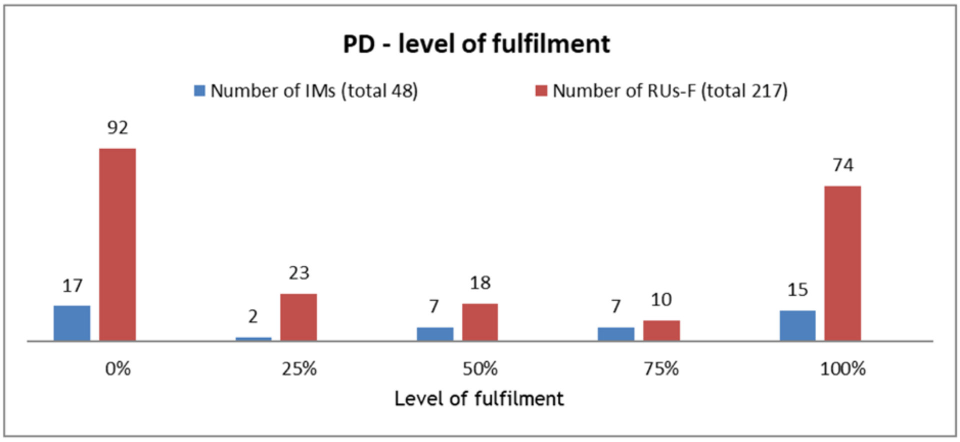


Figure 50: Level of fulfilment of PDMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf *p.26*

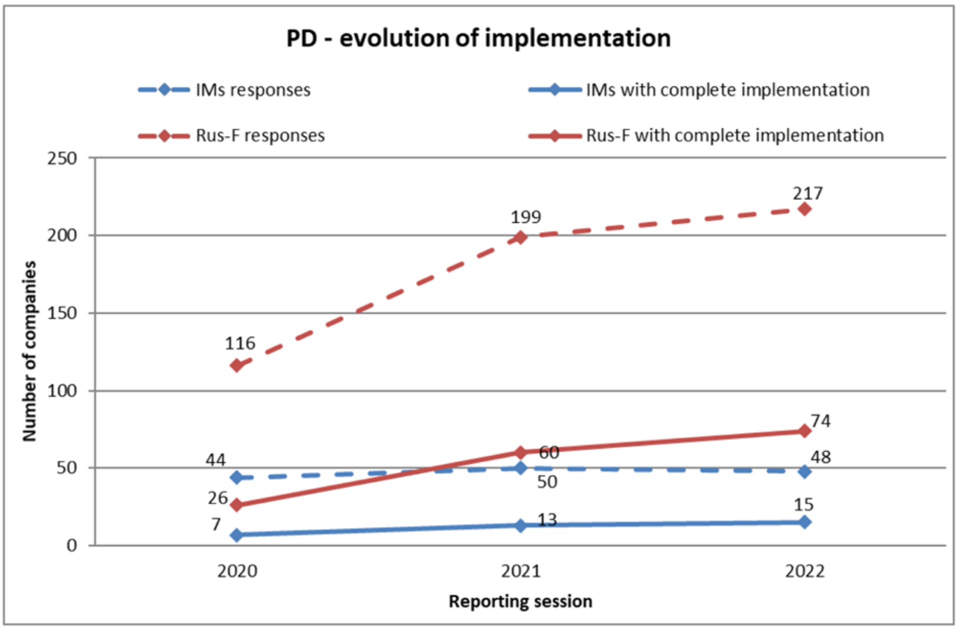


Figure 51: Evolution of implementation of PDMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf *p.27*

7.3.4 Path Section Notifications (PSN)

Path Section Notification Messages are used for notification about the usage of path sections during the planning and operational phase for coordination and data synchronization purposes between RUs and IMs. In practise it is used for cancellations of train paths. This might either be true for the entire train or only for parts of its route. For each affected location or section of locations, a path section notification is sent. They contain information on the affected train (operator information and train identification). The section is described by its start and end station. The train number used at this section can be provided but is not mandatory. Finally, information on an interruption (reason, time) can be provided but they are also not mandatory.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Affected section (start and end station)	Mandatory, time and location name not mandatory
Operational train number	Not mandatory
Interruption information (description, date and time, reason)	Not mandatory

Table 14: Important parameters in PSNs

All of the above-listed parameters must be sent for the PSN to be interpreted correctly by the prediction system, except for the interruption information. The primary benefit of the latter parameter is for the purposes of training the algorithm as well as providing additional information for the current status of a train. For example, a network-wide effect such as frozen tracks would then be transferred to other trains on the same route or part of the network which might potentially be affected.

7.3.5 Train Running Information (TRI)

Train Running Information (TRI) messages are sent while the train is running every time the train arrives at, departs from, or runs through an agreed reporting point (location). They are also sent if the agreed initial running time is attained, if the delay exceeds an agreed threshold, or if a train running information message is requested via another message, the "Enquiry Trains At Reporting Location" message. They always refer to one single train and its reporting point or location. As was true for the other message types, train running information messages contain information to clearly identify this train by its operational train number. The Train Location Report informs about the current location and the time of arrival, departure, or run through. Compared with the plan data, this enables the calculation of the current delay, which is also part of the train running information message. The current plan data is shown as the BookedLocationDateTime parameter. This references to the most recently updated train schedule. In contrast, the ReferencedLocationDateTime parameter shows the intial/commercial time. The delay is provided both against the BookedLocationDateTime as well as against the ReferencedLocationDateTime.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Operational train number	Not mandatory
Location (country, code)	Mandatory, name not mandatory
Actual time	Mandatory
Status	Mandatory
Plan time (Booked/Referenced), delay	Not mandatory

Table 15: Important parameters in TRIs

Without the train running information, no ETA can be calculated – at least not on a TAF TSI basis. If for a relevant section, TRIs are only partially available or often unreliable, alternative data gathering methods for the current train position have to be considered, such as GPS data.

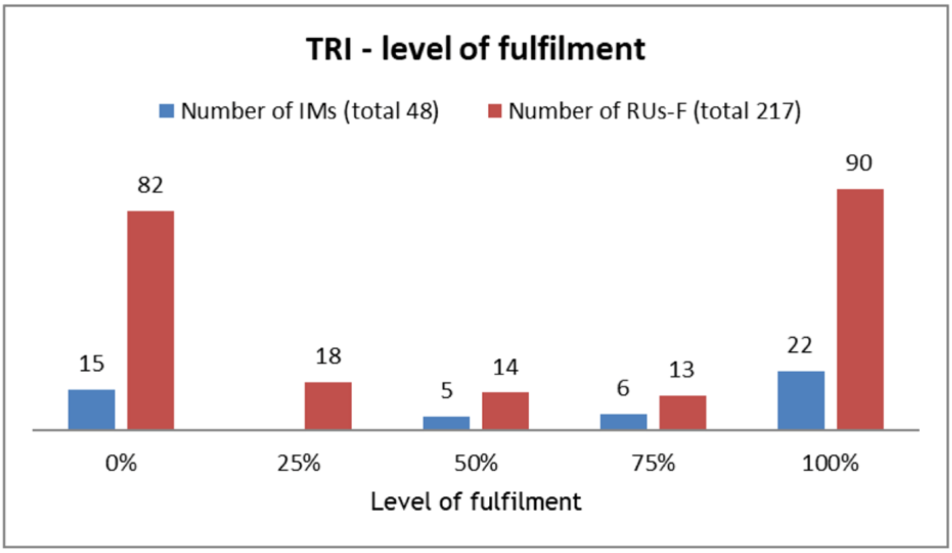


Figure 52: Level of fulfilment of TRIs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.30

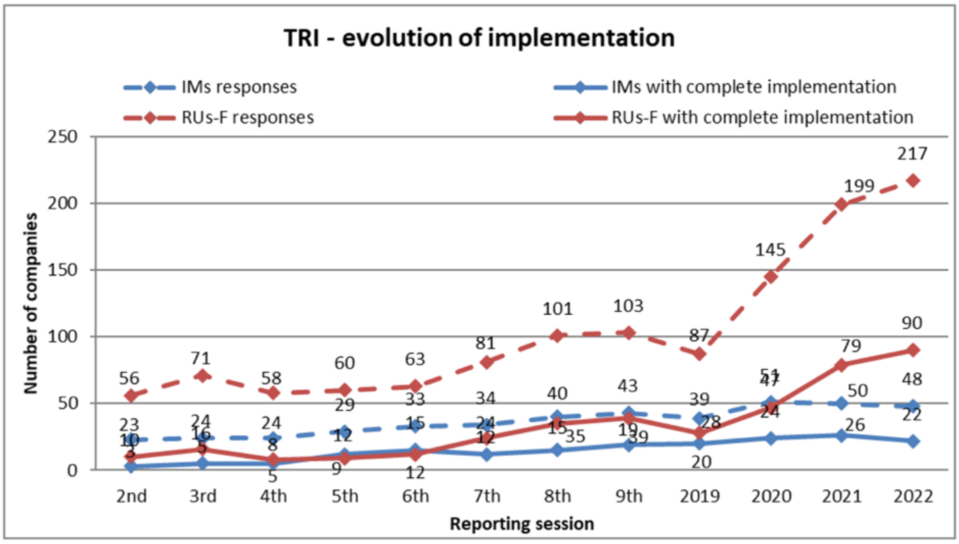


Figure 53: Evolution of implementation of TRIs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.30

7.3.6 Train Running Forecasts (TRF)

Train Running Forecast (TRF) messages are issued from the IM to the neighbouring IM upon departure from or movement past agreed points or prior to reaching the first reporting point if, owing to a delay, the train has not reached the bilaterally agreed initial running time. They are also issued from the IM to the RU when, at the next stopping or handling station, out-of-schedule running is anticipated that exceeds the threshold agreed with the RU responsible for the train. These messages are also issued in any cases for handover points, interchange points, for the destination point and for each other reporting point predefined by contract. The message contains information on the identification of the train (company, date, train number, …) and on the affected location (ISO-code, country code, time, status).

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Operational train number	Mandatory
Location (country, code)	Mandatory, name not mandatory
Actual time	Mandatory
Status (run through, arrival, or departure)	Mandatory
Plan time (Booked/Referenced), delay	Not mandatory

Table 16: Important parameters in TRFs

While a train running forecast is primarily used to gain additional information on delays of a train run, comparing the average accuracy from the TRFs issued by the IMs with the prediction accuracy of the different prediction models also yields additional benefits for the quality analysis. The intermodal prediction system, especially the ETA prediction system, must be able to deliver its forecasts in the Train Running Forecast message type to be TAF TSI compliant.

As already identified above, the fact that the identifying parameters are not mandatory could pose an additional challenge of linking all relevant message types to a train run, especially when linking the EDIGES data to the TAF TSI data. The operational train number is not equal to a unique train ID and might change during a train run (for example when changing the network) and therefore cannot be trusted as the single source of truth for train identification.

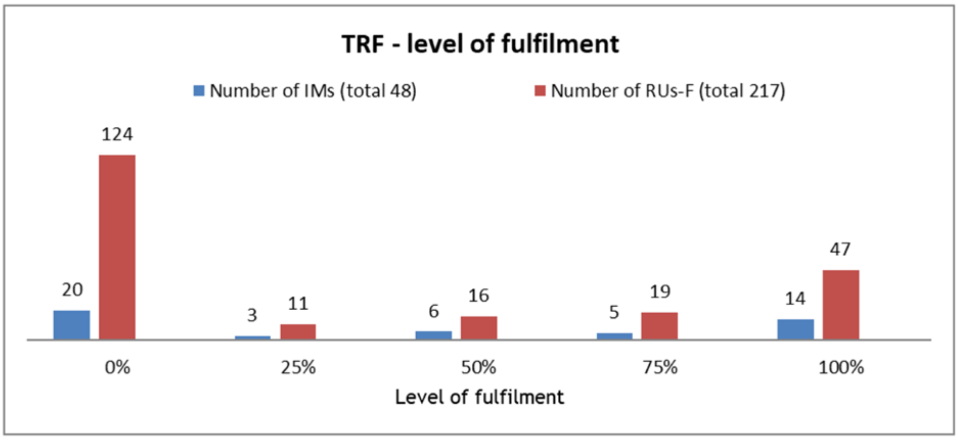


Figure 54: Level of fulfilment of TRFs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.31

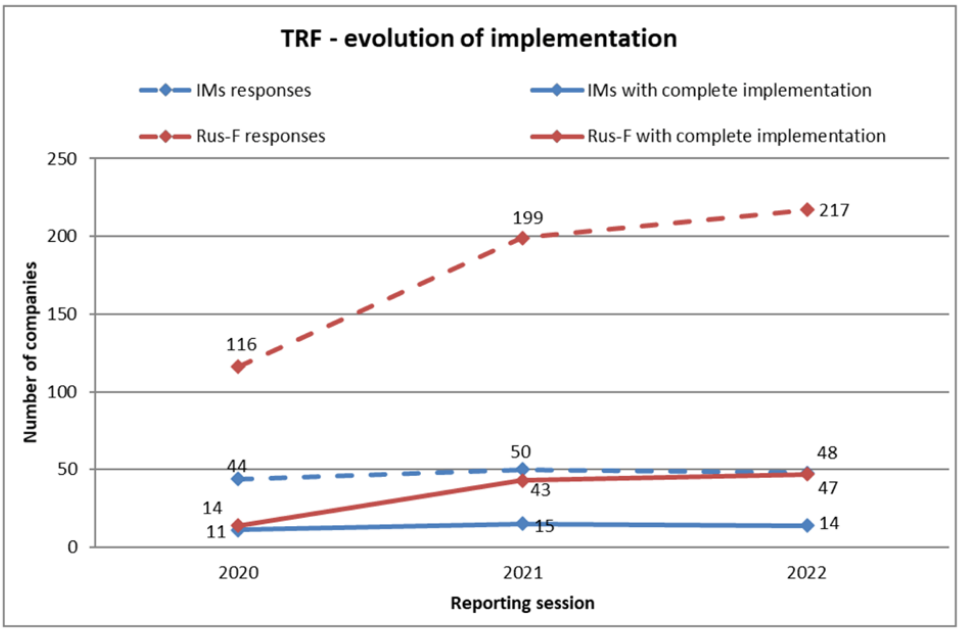


Figure 55: Evolution of implementation of TRFs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.31

7.3.7 Train Running Interruption (TRI)

Train Running Interruption (TRI) messages are sent for all trains that are in live operation and directly interrupted by a disruption or an incident. The message contains the operational train number for identification, the location and time of the disruption, the reason, the earliest end time, and the latest end time. Apart from the location and the time of the disruption, the information is not mandatory. Without these parameters, it could be impossible to identify the affected train and to estimate the effect on the further delay.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Operational train number	Mandatory
Location (country, code)	Mandatory, name not mandatory
Interruption time	Mandatory
Interruption reason, description, and duration	Not mandatory

Table 17: Important Parameters in TRIs

Since the prediction systems are still in the early stages of testing, the exact benefits of a TRI for the prediction accuracy cannot be quantified. It depends primarily on the degree of information provided, especially on the reason for interruption and the estimated length of interruption, as well as on the response time between the occurrence of the interruption in live operation and the transmission of the message to the prediction system. If all parameters are provided, but the message arrives only after a significant delay, it can still be used to further train the prediction models. In the future, when a TRI arrives (in time), missing information could then potentially be mitigated by this training data.

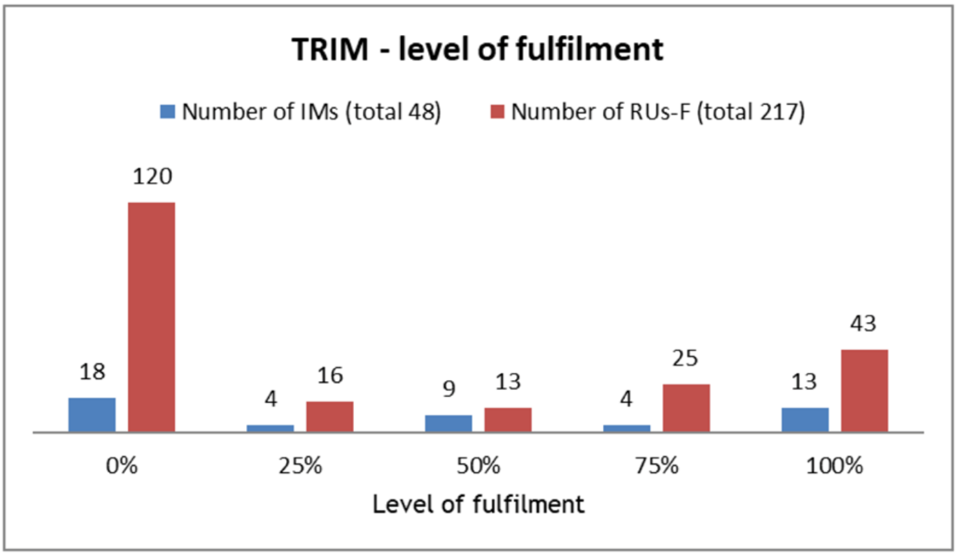


Figure 56: Level of fulfilment of TRIMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.31

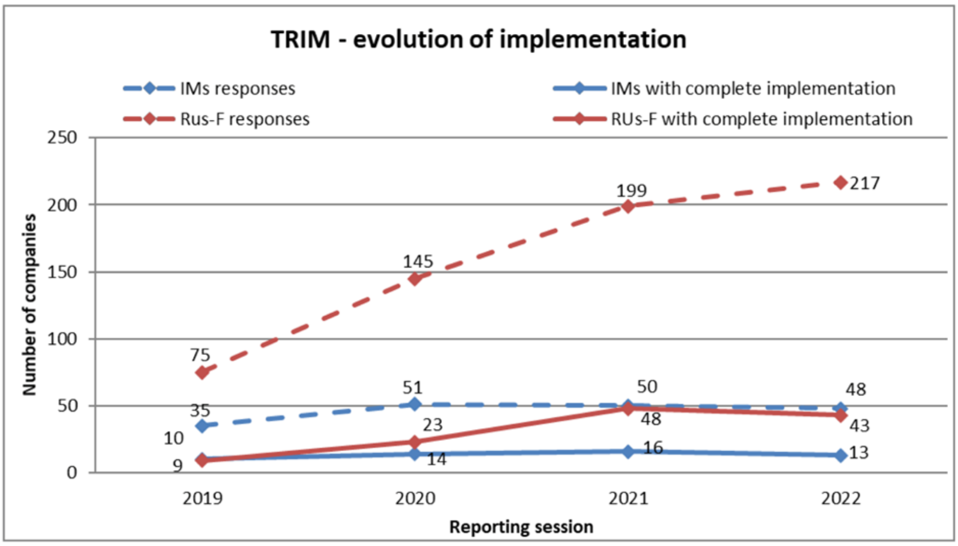


Figure 57: Evolution of implementation of TRIMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.31

7.3.8 Train Delay Cause (TDC)

Train Delay Cause (TDC) messages describe for each delay the respective reason using a harmonized reason code list. Operational -information or the train number can be used to identify the train, but these parameters are not mandatory. The delay is described with the location, time, cause, and delay minutes. These parameters are mandatory.

For the description of delay causes, codes as defined in UIC leaflet 450-2 are used. The IM must first decide which of the codes is applicable based on national rules. All delays should be reported with a train delay cause message regardless of whether they occurred at a reporting point or between two points. In the latter case, the next reference point will be given as location of the delay. Each train delay cause message can contain only one delay cause. This means that multiple messages must be sent if the train delay is to be attributed to more than one reason code. These messages will then report only those delay minutes caused by the given code. They should be sent immediately when the delay code is known. In case of a later correction of the reason, a message with the corrected delay cause and status alteration must be sent. If the delay minutes must be changed, the original messages must be deleted and new messages must be sent.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Operational train number	Mandatory
Location (country, code)	Mandatory, name not mandatory
Status (run through, arrival, or departure)	Mandatory
Delay reason, delay time, delay minutes	Mandatory, time of reason coding not mandatory

Table 18: Important Parameters in TDCs

Information contained in the train delay cause message is of immense use both for the live train run as well as for training the prediction models. For live operation, the current delay calculation can be refined by this message, provided it arrives in-time. For example, reason codes indicating technical issues on the train might lead to further delays during the train run, whereas an operational stop due to a dispatching decision (e.g. train is overtaken by a delayed passenger train) do not necessarily cause any further delays (apart from the knock-on effect of delays).

During the early testing stages, we analysed the delay cause messages provided for several delayed trains on routes from Germany to the Netherlands and vice versa. For delays that occurred on the German section, delay cause messages are provided for every delay. They are created at the earliest when the train has left the delay location. Thus, the delay minutes are available at this time, but train running interruption messages would be needed to estimate the duration of a delay while the train is still waiting. Another observed issue is that the delay cause messages are often provided relatively late, usually 15 to 30 minutes after the train has left the location of the delay. This limits the usability of the information provided for live operation of the train, but nevertheless provides great benefit for training the prediction models in this regard. For the Dutch sections, no train delay cause messages were provided. Of course, these tests and their sample size will be expanded during the early stages of development in 2024.

7.3.9 Train Composition Messages (TCM)

Train Composition Messages (TCM) contain the train number to identify the described train. Necessarily, the section described has to be defined by its first and last operational point. Within the Train running tech data, information on the train type, length, and weight is mandatory whereas information on the maximum speed is only optional. Further details on the locomotive and the wagons can be provided but they aren't mandatory. Messages of this type are provided by the RU during the preparation phase to inform the IM about the train. If the train composition is changed during the train run, the responsible RU has to send an updated Train Composition Message to all partners involved.

Parameter	Mandatory
Identifiers (Company, Timetable Year, Start date, etc.)	Not mandatory
Operational train number	Mandatory
Section (origin, destination)	Mandatory, station names not mandatory
Train type, weight, length	Mandatory
Further technical details (maximum speed, locomotive type, wagon types, loading)	Not mandatory

Table 19: Important parameters in TCMs

This message type is mainly used for linking any information on loading unit level to the train-related information. To this extent, information on the wagon types must be provided in sufficient level of detail to allow this mapping of loading unit ID to train ID (either a unique train ID or the operational train number), potentially also using wagon type/wagon ID as an in-between step.

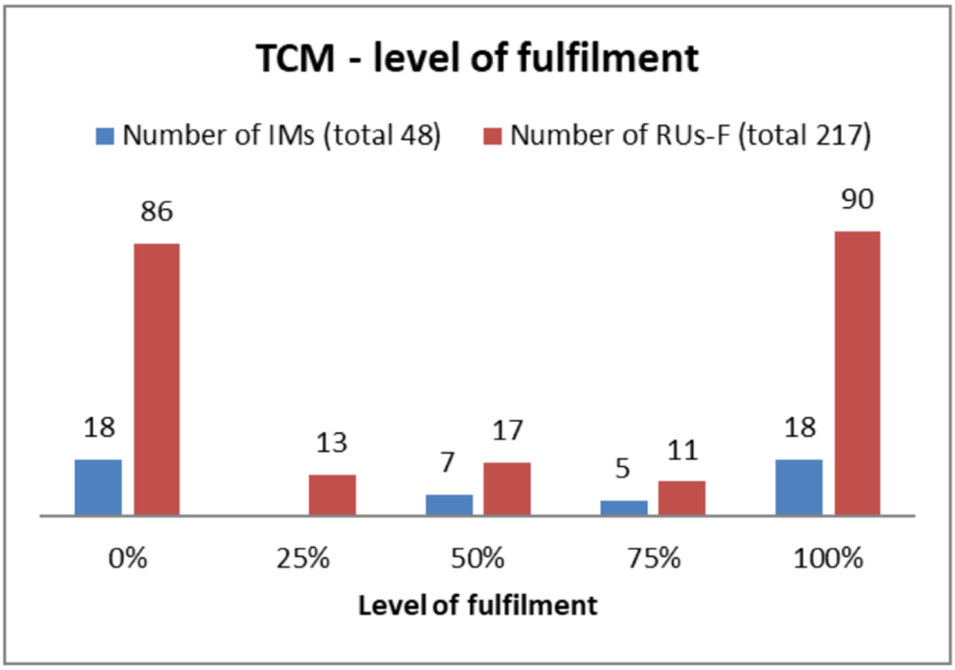


Figure 58: Level of fulfilment of TCMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.33

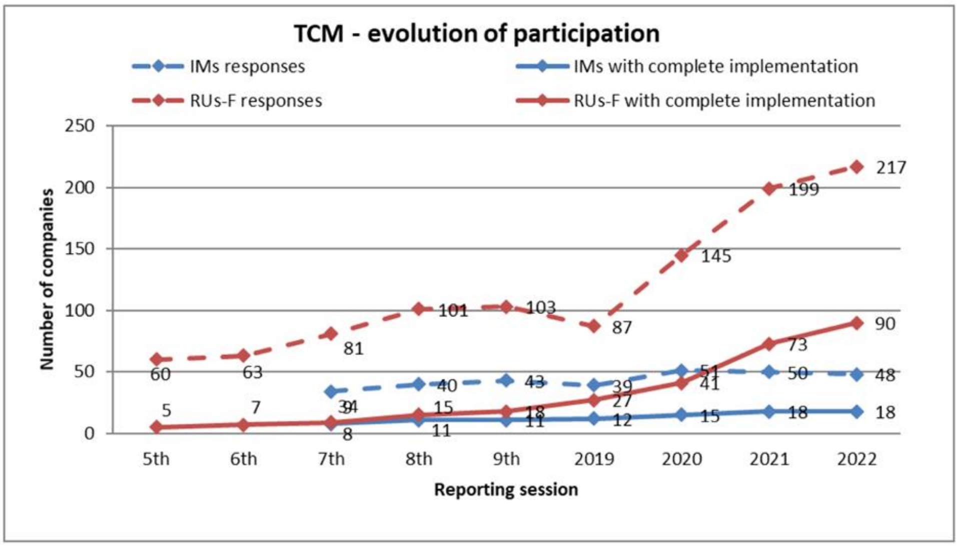


Figure 59: Evolution of implementation of TCMs

Source: https://www.era.europa.eu/system/files/2023-06/Agency_s%202022%20Report%20ERA-REP-114-IMPL-2022%20on%20TAF%20TSI%20Implementation%20-%20DI.pdf p.33

7.3.10 Wagon Performance Message (WPM)

Wagon Performance Messages (WPM) are delivered from the RU to the wagon keeper on request. They must contain the wagon-number for identification. The mandatory parameters describe start and end time of wagon usage, the covered distance, and the weight. Optional parameters add the start and end location. For this message type, the benefits for the prediction systems are not yet fully clear. However, they might be important to further support with the linking of loading-units to a train identifier (see train composition messages).

Parameter	Mandatory
Wagon number	Mandatory
Operational train number	Mandatory
Performed section (start and end location)	Not mandatory
Country	Not mandatory
Performed kilometers, performed weight	Not mandatory

Table 20: Important parameters in WPMs

7.3.11 EDIGES

Another important source for data about intermodal traffic are the messages sent in the context of KV4.0 data hub using the EDIGES standard. This KV4.0 data hub is provided by DX Intermodal GmbH which is a joint venture of companies involved in the intermodal supply chain. The EDIGES standard is specifically developed to exchange relevant information between CT stakeholders (CTOs, RUs, terminals, LSPs…) to ensure reliable intermodal transport. Some elements of the messages such as stations, terminals and country codes are based on the TAF TSI reference files and on UIRR master data (customer codes, gateway codes…) which enables an easy connection between these message types. However, as stated above, the prediction systems must also be able to use EDIGES data provided directly to the system (and not via the KV4.0 platform).

Within the EDIGES format, there are many status message codes that might be useful for intermodal prediction (ELETA & EDICT projects) and also for a quality management system (EDICT outputs):

Status code	Name	Description	Relevance	
			Intermodal Prediction (ELETA)	**Quality Management System (EDICT)**
10	Booking	This message is used to send booking of the transport information. It includes the order details, train details, goods information… Status 10 is used for new booking or for updating existing booking.	x *(without booking impossible to follow and monitor the transport)*	
11	Booking Cancel	Status 11 is used to cancel the		

		original booking (status 10).		
13	Shipment Pre-carriage	Status 13 is used for collecting information about the arrival of the truck at departure terminal.	x	x
18	Shipment Lead time	Status 18 is used to manage information about (average) waiting time at the terminal.		
20	Gate-In ITU	At the entrance of the loading unit at the terminal, on the base of an existing booking, and eventually after the check-in of the loading unit, booking data were modified and completed with the effective data as results from the documents of the driver who consigns the loading unit at the terminal.		x
21	Gate-In ITU Cancel	The cancellation message of the delivery of the loading unit is indicated as status 21.		
23	Wagon in train Composition	Based on loading units and wagons present at the terminal, the train composition is prepared by defining the wagon list. It is important to respect the correct sending-sequence of the different status as regards the wagon in the train and the loading units on the wagon: - Inclusion of the wagon in the train: --> send status 23. - Changing of the position of the wagon: --> send status 23 again. - Changing of the wagon or exclusion of the wagon from the train: --> send status 24. - Loading a loading unit on the wagon: --> send status 25. - Changing of the position of the loading		X (25 & 27)
24	Wagon out			
25	Train loading			
26	Train unloading			
27	Printing consignment note			

		unit on the wagon or unloading of the loading unit from the train: send status 26. In the event of changing the wagon in case the wagon is already loaded: - first status 26 has to be sent for each loading unit - then status 24 for wagon-cancellation and - afterwards status 23 for the inclusion of the wagon in the train.		
30	Train departure	At train departure from terminal, status 30 indicates train contents in terms of wagons, loading units, goods, other information and departure timing. The status 30 is valid either for train and for loading unit.	x	x
31	Train departure cancel	The cancellation message of train/loading units departure is indicated as status 31.		
32	EDI Consignment note	After train closure in departure terminal, status 32 reports consignment note information including the train list (related wagons and loading units).		
33	EDI Consignment note cancel	Cancellation message is indicated as status 33.		
34	Train transit control	Messages status 34 manage information about transit control related to a train. It includes information about the transit of a train at a certain station / geo-referenced point. Transit time regards a whole train. A cancellation message for status 34 is not foreseen. In case of incorrect status 34 messages, another message will be sent replacing the previous one.	X (equivalent to TAF TSI TRI)	x
35	Transport	The message code 35 is used in		

	information update	case of modification of transport information after the train is departed from the terminal.		
36	Train ETA	Messages status 36 manage information about train ETA at final terminal. Generally is sent from RU to Intermodal Operator or directly to destination terminal when there is a train delay. A cancellation message is not foreseen for status 36. In case of incorrect status 36 messages, another message will be sent replacing the previous one.	x	(x)
37	Unit ETP	Message status 37 identifies a new Estimated Time of Pick-up of every loading unit at destination terminal. Update of loading unit ETP is based on update information of a train arrival (ETA).	x	
38	Train arrival	Status 38 indicates that the train has arrived under crane, the documents have been handed over, the wagons and loading units have been compared and the train is therefore ready for unloading.	x	x
39	Train arrival cancel	Status 39 is used for the cancellation of a status 38 message.		
40	ITU Ready for pickup	Status 40 indicates for each loading unit of the incoming train that the loading unit is ready for pick-up by road or ready for re-expedition with another mode of transport or ready to be loaded on the next train in the gateway chain.	x	
41	ITU Ready for pickup cancel	Status 41 indicates the cancellation of a status 40 message.		
43	Shipment On-Carriage	Status code 13 is used to manage information about the arrival of the truck at	x	

		destination terminal.		
50	Gate-out ITU	Status 50 indicates the pick-up of a loading unit by road or by another mode of transport at the destination terminal. It depends on the terminal's processes if status 50 can be sent at the production of the pick-up documents or at the exit from terminal (gate-out message).	x	x
51	Gate-out ITU cancel	Status 51 indicates the cancellation of a status 50 message.		
60	Terminal Item Position	Position of the wagon or unit inside the terminal (geo-coordinates).		
70	Train HLR	Heure limite de remise. When the train at departure is handed over from the terminal operator to the RU.	x	(x)
71	Train HLR cancel	Status 71 indicates the cancellation of a status 70 message.		
72	MAD RU	Heure de mise à disposition. When the train at arrival is handed over from the RU to the terminal operator.	x	(x)
73	MAD RU cancel	Status 73 indicates the cancellation of a status 72 message.		
74	Transfer liability status	Transfer of liability from the RU to the terminal		
75	Transfer liability status cancel	Status 78 indicates the cancellation of a status 74 message.		
80	Terminal Slot	Status 80 is used to manage information about slot available for train arrival/departure.		
82	Terminal Info	Status code 82 is used to manage information about the terminal status and disruptions in the terminal.		x
99	Additional event	Status code 99 is used to inform about generic events		

		related for example to terminal or ports.		
CT	Commercial Timetable	This message contains information about commercial timetable.	x	x
OT	Operational Timetable	This message contains information about the operational timetable.	x	x
RS	Response	This is the status code for the response message to status code 10 (booking)		
TM	TerminalMaster Data	This message contains master data of the terminal including its position, its contacts and its opening hours.		
TD	TrainDisruption	This message documents disruption of planned train operation.	x	x
PT	PublicTimetable	This message contains a subset of the commercial timetable for public distribution.		
ND	NetworkDisruption	This message documents disruption of planned network operation.	x	x

Table 21: EDIGES status codes – relevance for intermodal prediction and quality management system

7.4 Prediction models

The following chapter describes the two different kinds of prediction systems that are relevant for (multimodal) rail transport. One system delivers a prediction of arrival times (ETA, see chapter 7.5.1), while the other delivers a prediction of departure times (ETD, see chapter 7.5.2).

7.4.1 ETA prediction system

This section describes the high-level setup of the ETA prediction system, highlighting main functions and requirements. At its core, it receives information from terminals, yards and the main line systems (chapter 7.3.1.1). It integrates this information (chapter 7.3.1.2) into its environment and feeds it to different ETA models, which in turn compute an ETA (chapter 7.3.1.3). The system then sends this ETA back to all relevant and connected systems (chapter 7.3.1.4).

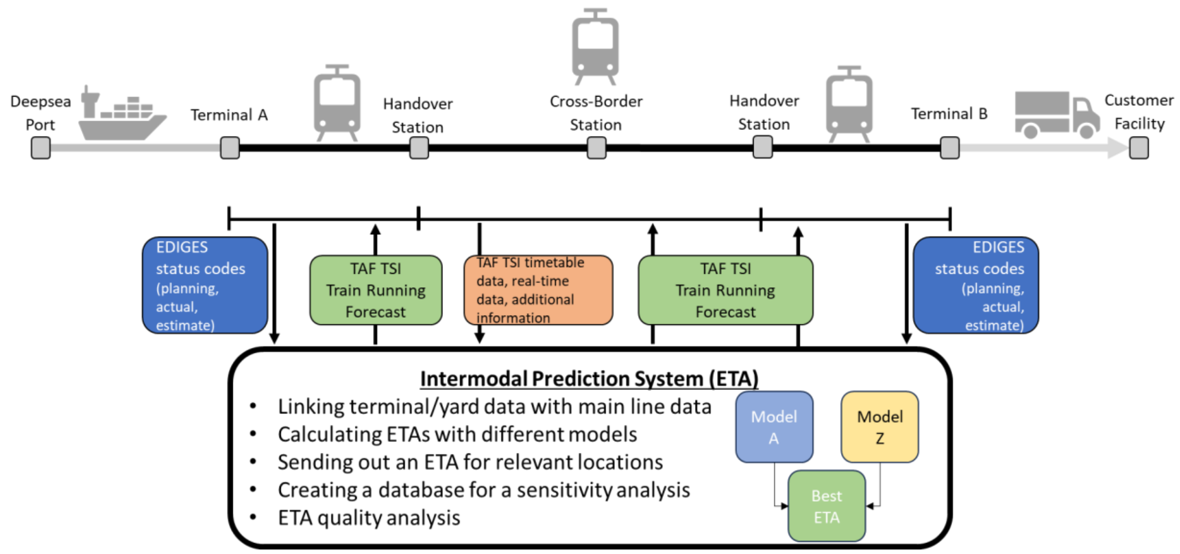


Figure 60: Overview on the Intermodal Prediction System (ETA) and its data sources during the intermodal transport chain

Source: Hacon

7.4.1.1 Information sent to the ETA prediction system

In general, the received information can be divided in two categories: train-related information and network-related information. For the basic functions of the ETA prediction system, only train-related information is required. However, to allow a more advanced and, subsequently, more accurate forecasting, also network-related information is needed.

Train-related information must be received from all relevant actors in a multimodal transport chain in the scope of origin terminal to destination terminal. The stakeholder groups that mainly provide this data are terminal operators (terminal data), yard operators (yard data), combined transport operators (timetable information, cancellations), railway undertakings (train composition, train position, timetable information) and infrastructure managers (train position via TMS). During this specification phase, Hacon has already received sample data for Kombiverkehr trains via the RNE TIS system (both live data and historical data).

The terminal data will be received in the EDIGES format. Each relevant timestamp (see chapter 7.3) is covered by an EDIGES status code. Some status codes cover more than one timestamp. In this case, the information within the message itself must be used to distinguish between the two timestamps. Another challenge is that the availability of information strongly varies depending on the terminal. This means that the ETA prediction system must be set up in a way that allows in theory to compute information for all timestamps. At the same time, it must still be able to calculate an accurate ETA with limited information. Of course, if information is only available scarcely, the prediction models will have less data to work with and thus, consequently, provide a less accurate ETA.

Another challenge is the partial lack of planning/timetable information. Although each terminal performs an operational planning, this does not necessarily translate into a full availability of planned times for each status code. This means that, when receiving a real-time information on a terminal timestamp, it is sometimes not possible to calculate the delay (=comparing planned with actual information). In such a case, the system has to rely on historical data. With enough information available, it can contextualize the current time and compute a delay estimation. If neither information on the scheduled time nor sufficient historical data is available, a real-time status code can only be used for a display and communication of the current train/loading unit position. It will only have a marginal benefit for the ETA prediction of this train/loading unit.

For the main line, the prediction system must receive timetable information, real-time information and additional information in the TAF TSI format. Each train run has a set of pre-defined locations, similar to train stations for a passenger service. The main difference is that for freight, the locations are usually not operational stops (exceptions occur especially for border stations). They can be defined as message points that serve as main reference for most train-related data.

The timetable information relates to the planned arrival of a train for each location. Although it is usually received at least two days in advance of the actual train operations, short/ad-hoc updates of this information may also occur. For live operation, a Train Running Information message must be received. Any other message type, for example Delay Cause Messages, further enhance the ETA accuracy for the current train. However, it has also been observed that in some cases, these additional messages are being sent with a significant delay (>30 minutes). In that case, while the messages will most likely not influence the ETA of the current train, they may still support the learning of the different models. Chapter 7.2.1 contains more detailed information on the TAF TSI message types and their parameters.

In addition to the train-related information mentioned above, the system should also receive network information. The term “network information” in this case encompasses all data that does not directly relate or is limited to the train run for which an ETA is being computed. This information includes, but is not limited to, infrastructure data (for example temporary capacity restrictions), weather data and train-related data for other trains in the same parts of the network.

For infrastructure data, information on construction works, line closures and other types of capacity restrictions should be received. Depending on the information available, an additional mapping exercise must be performed to link this data to the train-related information (see chapter 7.3.1.3). The same holds true for weather data. In this case, it has to be analysed during the WP28 activities if there is a statistical correlation between weather data parameters such as temperature, humidity and wind strength and train delays outside of extreme cases like tracks freezing over in winter, heavy storms leading to cancellations and so forth. In such cases, the path cancellations would however be already included in the TAF TSI messages (for example, path section messages or train interruption messages). Finally, the effects of train data for trains on neighbouring or the same parts of the network will also be analysed during the WP28 activities. Of course, such an analysis heavily relies on the availability of data.

7.4.1.2 Integration of received information

To allow for a throughgoing terminal-to-terminal ETA, it is essential to combine the train-related information from terminal, yard and main line to one train run. This train run must be described with a unique ID, as the operational train numbers (OTNs) might change during the course of the train journey, especially if it is an international train. To this extent, such a unique train ID must be either provided with the information itself (as it is partially already possible with data coming from Train Information System TIS from RNE) or be created by the system. In the latter case, the system must have all individual OTNs available. In addition, information must be provided that can be used as basis for linking these OTNs.

Parameters for linking the OTNs can be, but is not limited to, the date and time of operation, the first and last location (especially if the location names and IDs are identical throughout the data sources), train composition list and information about the operator. Additionally, for the information to be displayed on loading-unit level, the train composition list or any other information linking the loading unit IDs to a train ID (preferably the OTN or the unique train ID) must be provided. In such a case, any information that is provided on a train level, such as the TAF TSI messages, can then be transferred on a loading unit level. This is of particular importance when forwarding relevant ETA information to shippers and freight forwarders, such as the estimated time for pick-up.

7.4.1.3 ETA calculation (machine-learning models)

The ETA calculation is done on the basis of a “best value approach”. There will be several ETA models that have different underlying algorithms of computing incoming real-time and timetable data with the available historical/training data. As a consequence, different models will perform better depending on the situation. Some models might be better suited for regular transport operations, while others react better/quicker to unforeseen events.

Based on a continuous quality analysis, the system will decide based on the available data for a current train which model is going to be used. This further increases the overall accuracy and reliability of the ETA predictions. Chapter 7.4 describes in more details how the quality will be assessed and monitored.

7.4.1.4 Sending the ETA to other systems

Within the TRANS4M-R project, there are several use cases that require ETA values as input. The ETA prediction system therefore has to be set up in a way that allows for a configurable and flexible way of transmitting the forecasted values. In general, the ETA values can be transmitted with either the push or the pull principle. The push method means that, whenever there is an update, the latest ETA values for all chosen locations and timestamps will be sent to the connected system. With the pull method, the recipient sends an ETA request to the system, which then returns the requested ETA prediction for the selected train and location(s). During the development phase, both of these methods will be implemented. In addition, a configuration option will be installed, allowing data recipients to specify the trains, locations and update frequency of an ETA.

7.4.2 Terminal departure prediction model (based on yard departure prediction model)

One of the use cases to create seamless intermodal freight operations is predicting freight train departures (Estimated Time of Departure – ETD) from their origins, which can be yards or intermodal terminals. The state of the yards and Intermodal terminals and their departure status impact the running of the freight trains along the network and the arrivals to the destination. Delays from the origin may cascade onto the running along the line, and thus can be considered as a predictor for further ETAs.

In this project, relying on the knowledge obtained from previous Shift2Rail projects (fr8hub and FR8RAILIII) in yard departure prediction, a previously developed yard departure prediction model will be adapted to the intermodal context. The aim is to extend the model and make it applicable for other similar European intermodal terminals. The advanced level of the model will comprise a yard departure prediction and intermodal departure prediction connected to a network model. The approach is data driven; historical data from terminal operations will be used to train and test the machine learning the model. The model can also get ETAs and information regarding the arriving trains as explained in chapter 7.3.1.4 Sending the ETA to other systems, as extra predictors. The core algorithms for modelling will be tree-based algorithms comprising decision tree and ensemble versions, such as random forest and gradient boosted trees. The potential demonstrators are Malmö and Alnabru intermodal terminals or other similar terminals present in the project (see Chapter 6.3 Dynamic interaction).

7.4.2.1 Scope

The intermodal terminal departure prediction is focused on predicting the departure deviation for the departing trains which provides the ETDs. The departing trucks or any destination last-mile transportation is excluded from this model. The aim is to develop a generalized model in the context of European intermodal practices that could be with slight or none modification applied in different similar intermodal terminals. The model attempts to keep the sensitivity of the data for RUs and IMs by capturing major departure influential parameters into account implicitly and explicitly.

Additionally, the application of such prediction model is to represent a tool that assists the intermodal operators to have a control on departure reliability applying a data-driven approach which to some extent is equivalent of the experience of the intermodal terminal operators or may substitute or complement it in the future. The main application the model output will be available and usable for both IMs and RUs as a standalone departure prediction tool. The second application of this yard/terminal departure prediction model can be providing accurate departure predictions to robust short term path planning and timetable adjustment, which is explained in chapter 5.3.2.1 Identifying requirements for establishing reliable planned time of arrivals from yard/terminal departure predictions. The third application can be using ETDs as a prerequisite for accurate estimation of train arrival times – ETAs in a future application.

7.4.2.2 Method

Predictive analytics, in which historical data is used for predicting the future, is one of the applications of machine learning modelling. Among the machine learning algorithms, tree-based algorithms are suitable for the current problem of the intermodal departure prediction for the following characteristics: interpretability, feature importance, non-linearity, being robust to outlier, adequate performance, and few hyperparameters.

A departure prediction model should be interpretable, meaning that it will be easy for the users to understand how the departures are predicted. In this case, it's the terminal operators who will use the model output. Decision trees have a hierarchical structure comprising nodes and branches, where each node represents a question on a predictor of the target value (departure prediction value). The tree gets branched at each node based on a series of these questions. Therefore, for an intermodal dispatcher, it would be easy to understand how each departure deviation is made and what actually caused a train to delay as the tree will be visible. Besides, feature importance will be calculated by the gain factor and SHAP (SHapley Additive exPlanations) values in the model. The former sorts the predictors according to the impact on overall prediction performance of the model and the latter is a way to explain every prediction in terms of the significance of each predictor.

Intermodal operations are complex, comprising non-linear relationships between different factors on departure delays. These complex and non-linear relationships can be captured by the tree-based models. Freight trains may have large departure deviations (large delays may occur), creating outliers in the data and difficult to predict. Large delays sometimes are even more important to be predicted due to the impact they might have on other trains on the network. The ensemble versions of decision trees have shown adequate performance, especially, in the case of freight trains, which will also be tested in this project. Finally, tree-based algorithms require less tuning of hyper parameters. However, applying decision tree for extremely complex problems may lead to less adequate performance and overfitting should always assessed to before deploying the model for larger application. The model performance comparing the predicted values and the actual values from the real-world data will be evaluated by these metrics: mean absolute error (MAE), mean squared error (MSE), root mean squared error (RMSE), and mean signed difference (MSD).

7.4.2.3 Data requirements

Data for intermodal rail freight operations is required. This data shall cover information on train features, wagon features, train/wagon/terminal schedules, stations, and operations. Selection of the predictors is based on previous research on yard departure prediction from two previous Shift2Rail projects: fr8hub and FR8RAILIII (FR8RAIL III., 2022 ; Minbashi et al., 2023). In addition, some predictors are selected from the results of ANTOINE (ANticipatory Train Optimization with Intelligent maNagEment) project carried out at University of Luxembourg on intermodal factors that impact ETAs (Pineda-Jaramillo and Viti., 2023); the impact of these predictors will be explored in this project on intermodal departures. A period of one year of operational data may be sufficient for training and testing the models.

The following features could be extracted as potential predictors for the model training. Some of these predictors might be already available from the current operational data, some could be calculated or extracted from merging different data sources, others could be suggested to be collected and stored, since these predictors in the long run will depict the intermodal terminal operations in a comprehensive picture, which is in line with the overall scope of the project.

The first part of the required data is related to rolling stock in three levels of train, wagon, and locomotive. A comprehensive collection of all the predictors can be a base for a correlation matrix to exclude predictors if there is high correlation.

Train, Wagon, Locomotive Predictors	**Influence**
Train number	Influential
Maximum planned/ operated weight	Influential (at least one is required)
Maximum planned / operated length	Influential (at least one is required)
Number of wagons	Influential
Average wagon weight	Influential

Origin terminal	Influential
Destination terminal	Influential
Maximum TEU (Twenty-foot equivalent unit)	Influential
TEU count	Influential
Wagons order in a train	Potential
Wagon type	Potential
Wagon model	Potential
Wagon maximum speed	Potential
Locomotive model	Potential
Locomotive maximum speed	Potential

Table 22: List of predictors related to train, wagon and locomotive for ETD

The second set of predictors is related to the schedules at three levels of trains, wagons, and terminals. Different terminals may have different levels of elaborations in the schedules.

Schedule predictors	**Influence**
Train scheduled departure hour	Influential
Train scheduled departure month	Influential
Train scheduled departure weekday	Influential
Minimum wagon waiting/dwell time	Influential
Mean wagon waiting/dwell time	Influential
Median wagon waiting/dwell time	Influential
Maximum wagon waiting/dwell time	Influential
Scheduled technical stops (location, time, ...)	Potential
Scheduled station to change the driver	Potential
Scheduled station for passing/crossing	Potential
Total distance of the trip	Potential
Distance between stations for technical stops, change of driver, or pass/cross	Potential
Cargo type per wagon	Potential

Table 23: List of schedule predictors for ETD

The third set of predictors is related to the operational data and actual operations of the terminal and the network in the vicinity of the terminal.

Operational predictors	**Influence**
Actual train departure time/status/deviation	Influential (at least one is required)
Actual train arrival time/status/deviation	Influential (at least one is required)
Train idle/waiting durations	Potential

Average transhipment utilization rate	Potential
Average inspection time per wagon	Potential
Average handling/loading and unloading utilization rate	Potential
Locomotive availability status (delayed or on-time)	Potential
Locomotive delay	Potential
Driver availability status (delayed or on-time)	Potential
Weight per length of the departing train	Potential
Weight per wagon/average wagon weight	Influential (at least one is required)
Information on network disruptions or disturbances in the vicinity of the terminal	Influential (at least one is required)
Train idle/waiting times at the terminal (transhipment idle time, inspection idle time, departure idle time)	Potential
Actual wagon departure time/status/deviation	Influential (at least one is required)
Actual wagon arrival time/status/deviation	Influential (at least one is required)
Actual ITU departure time/status/deviation	Influential (at least one is required)
Actual ITU arrival time/status/deviation	Influential (at least one is required)

Table 24: List of operational predictors for ETD

7.5 Quality management

To ensure that the intermodal prediction services deliver a meaningful contribution to all connected actors, a continuous quality management is key. Data scientists and railway experts will regularly assess the accuracy of the different models (see section 7.3.1.3 for more information on the models themselves). For this evaluation, the ETA qualifiers from the TAF TSI handbook will be applied and extended with a dedicated handover point qualifier. Finally, the KPI calculations will be expanded to allow the integration of terminal- and yard-relevant accuracy evaluation.

7.5.1 Median ETA qualifier (METAQ)

The METAQ is calculated in a three-step approach. Firstly, the absolute error is measured by comparing the real arrival time with the forecasted arrival time. This is done for each location where an ETA update was generated by the models. In a second step, the absolute difference is then divided by the remaining actual travel time. This yields the relative error. Finally, the accuracy can be determined by subtracting the relevant error from 1. This accuracy builds the basis for the ETA qualifier (ETAQ).

To prevent extreme outliers from having a disproportionate influence on this KPI, the median is then finally calculated (and not the average) from all the ETAQs of all relevant trains and locations. The result is the METAQ KPI.

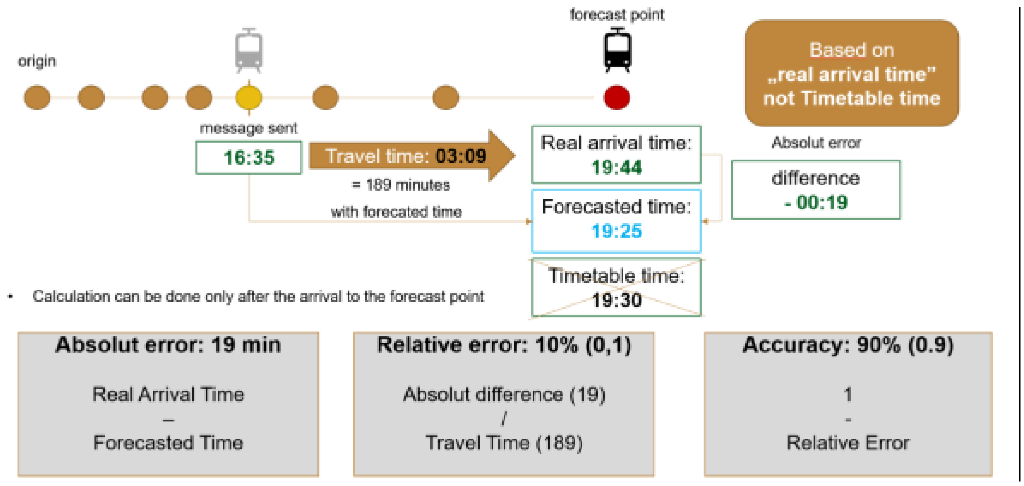


Figure 61: Error calculation process

Source: TAF TSI sector handbook

Any forecasts that are done less than 30 minutes prior to the train arrival (or, in a terminal-to-terminal prediction, prior to the gate-in message for the destination terminal) are excluded from this METAQ evaluation. Otherwise, even small inaccuracies would have a much larger impact due to the calculation method of the relative error.

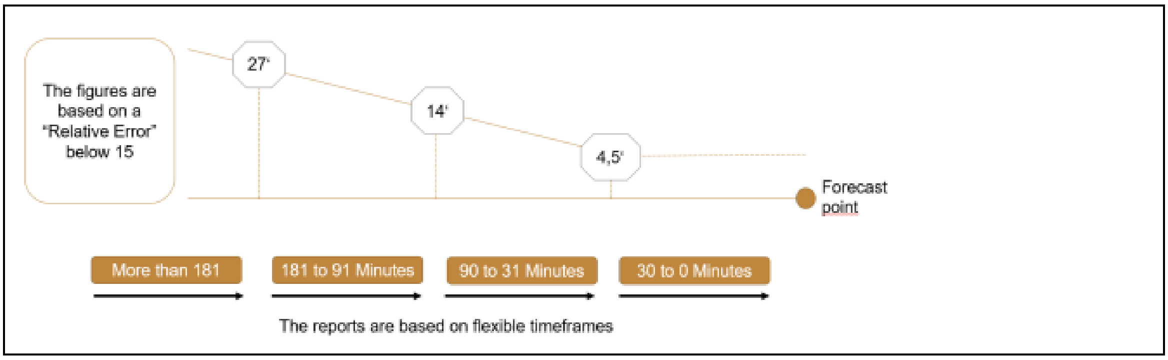


Figure 62*: METAQ evaluation for the inaccuracies of ETA calculated by the model*

Source: TAF TSI handbook

According to IM experts, the target value for the METAQ should be >85%, meaning that the median relative error should be less than 15%.

Handover point qualifier (HPQ)

The HPQ will be calculated in the same way as the METAQ described above. The main difference is the differentiation in locations and the corresponding adaptation of quality targets. In freight transport, any handover point (terminals --> (yard -->) main line, cross-border stations etc.) can represent a significant change in delay patterns. To this extent, the HPQ only takes into account the first location of a new IM/yard/terminal network.

The quality goals of the METAQ will be adapted accordingly. For the last relevant location (most likely the destination terminal; if no data is available, then the first location of the destination IM network), the target quality is >90%. For the first location in the second-to-last network (L-1), the target quality is >85%. In general, for each relevant location, the target quality is 90%-(5% * x), with x being the number of subsequent relevant locations.

Combined transport operator qualifier (CTOQ)

A specific requirement from the combined transport operators according to the TAF TSI handbook is the ETA accuracy 240 minutes before the train arrival at the terminal. In this case, this refers to the last location for which a Train Running Information message was received. There must be a 95% probability of the ETA having no less than 1 hour deviation from the actual arrival time.

Extending the TAF TSI ETA qualifiers to the first- and last-mile network

To allow for a seamless quality analysis, we propose to extend the ETA qualifiers as they are described in the TAF TSI handbook also to yards and terminals. To this extent, any relevant process, timestamp or milestone (see section 7.3), shall be treated as a "location" and thus be subject to the same way of measurement as the main line locations. As part of the development activities within WP28, the influence of this measurement will also be tested. Separate analyses and KPI measurements will be taken for a) the main-line locations as they are defined in the TAF TSI handbook, b) only the terminal and yard locations and c) all locations combined. This also supports in identifying critical processes and parameters for the evolution of delay patterns and the accompanying challenges for providing an accurate ETA.

7.6 Applications and use case environment for the prediction systems

This chapter describes the main applications within TRANS4M-R for the intermodal prediction systems that will also serve as basis for the showcases with WP33 and WP34. In addition to the applications described in this chapter, especially the ETA values can be used as input for several other developments, systems and functions for Seamless Freight.

7.6.1 Asset warehouse

The functionality of the warehouse should include the ability to process data with other information systems, which will enable the creation of an interoperable system. An important aspect is the mutual communication between the information systems and the warehouse with regard to the temporal and spatial availability of resources and with regard to the ETA of a specific train, which are calculated using prediction algorithms. The system should include standard information and additional data that lead to more accurate Estimates of Arrival (ETA).

It is important to regularly verify the compliance of the plan with reality based on the specified parameters in specified moments. These parameters can be determined by RUs or either customer. It is essential to commit the resources before the expected train transfer time. If resources for a specific train cannot be found and assigned through the warehouse, a problem will occur and the ETA will be recalculated – there is a link with terminal operation systems.

A properly established time frame for incident resolution is a critical aspect in logistics. In case an incident / event on the intermodal service takes place e.g. in Germany and a large period of time is remaining to point of interchange, the situation remains e.g. in the Czech Republic unresolved until the event reaches the relevant time or space. In this way, it is necessary to define two important times.

The first the moment when it makes sense to start actively solving the situation, based on real needs. The second one is the moment by which incident must be solved. The time parameters are variable and customizable according to the specific country or conditions. The trigger of process can be time-based, or it can be tied back to a certain event that will affect the flow of transport. It can also be set individually for individual shipments or railway lines, thus ensuring flexibility and accuracy in solving logistic challenges.

When searching for resources, appropriate options are sought in a specific/current time and space. This analysis is carried out on a case-by-case basis, taking into account the link to WP29. In addition, for trains which are due to pass through a specific point, advance notices H30 and H40, are also taken into account.

Alternative resources will be transported to the location defined by efficient and accurate calculations. Calculation of the ETA for the Czech section is possible if the foreign partner is unable to provide local data because it does not have local data available. Inputs are external and times are derivable. For the Czech section will be possible to calculate ETI and ETA using the prediction algorithm developed in WP28. Precise ETA on individual route sections will be achieved for the efficiency of the entire logistics process.

The entire route or only a part of it is generally analysed and compared to planned timetable. Information regarding each point/location where a train or shipment could be is considered. Based on the ETA, it is always necessary to have an overview – reference times and points in comparison to deviations in time or in route are taken into account. The combination of prediction algorithms ensures higher accuracy compared to the current calculation approach.

Every infrastructure manager has different approach to solve train delays. Extreme options are considered in the range from -3 hours to +20 hours, while in reality they can reach up to +12 hours. Austrian IM tolerates deviations within a time frame of approximately one hour, while in Germany the approach to this issue is set very strictly also. Available time enables flexible manoeuvring of resources and routes without major difficulties, which ensures efficient logistics operations.

Approaches that can be applied to solve the delays:

- new path request (new times, path or times and path) with new assignment of resources,
- an alternative path listed in path catalogue is used,
- scheduled train is cancelled at all and moved to next day, service is performed according to the valid regular timetable for the day.

The properties of the resource are taken into account. If the resource does not meet the requirements in the specified time, the system identifies this problem. The next steps are performed by the system:

System notifies the problem and automatically searches for alternative sources in time and space, taking into account the path, license, technical parameters and resource capabilities as follows:

- searching for suitable sources in own resources,
- searching for suitable sources in resources of other RUs.

Searching includes calculation of reachability of resources.

If the system does not find a suitable alternative source, system notifies the problem to dispatcher and manual solution takes place as follows:

- searching for suitable sources in own resources,
- searching for suitable sources in resources of other RUs.

The following Figure 63 shows an example of the use of Asset Warehouse.

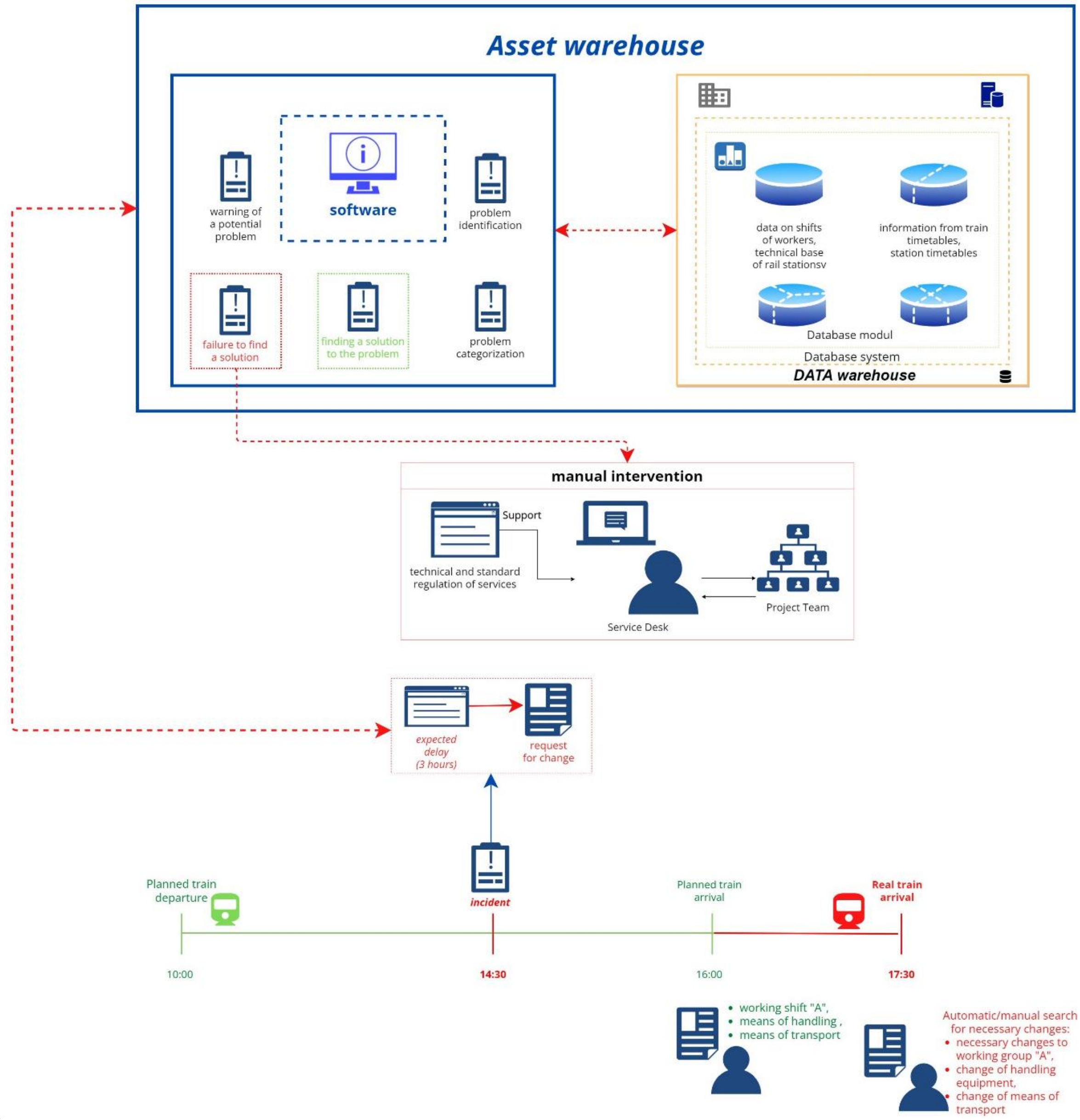


Figure 63: The schema of the Asset Warehouse environment.

The availability of resources is also monitored from the point of view of spatial availability, in order to ensure the smooth running of processes regardless of where they are performed.

The interface is a key element in the communication between Asset Warehouse and other information systems of railway companies. The first point dealing with the interface is a precise description of the data that is transmitted. Subsequently, it is important to analyse the information systems of individual railway companies. This description is key to understanding their structure and composition. The evaluation of the compatibility between these systems is another important step, as it enables the seamless exchange of data between Assets Warehouse and other information systems. This interaction may include real-time data flow, advance schedule information, and the frequency of these data exchanges. To ensure effective communication, it is essential to standardize the way data is processed from different information systems. The communication will be based on TAF TSI standard thus ensures uniform access to information and simplifies the processes of data exchange and interpretation.

Demonstration of process flow is possible on timeline, e.g. a certain train is waiting at the port terminal, where all the requirements are met and even on the next section on the travel are all resources ready to use according to timetable. The timetable contains all the necessary information. However, unexpected problems may occur. Suddenly, the entire transport plan starts to move and the consequence is that the availability of resources on the other sections will not be available (spatial availability) or time availability of resources does not correspond to reality.

In case there is a discrepancy between the planned and real time availability of the resource, the system first identifies the problem. It tries to automatically find alternative resources, not only within time and space, but also with regard to the route/path, with knowledge of train schedules and technical parameters. However, if the system does not find a suitable alternative source, it switches to manual intervention.

At this stage, the system marks a problem and the user's manual work begins. The user tries to find a solution first in his own resources and in than in the resources of other RUs (all resources are visible in Assets Warehouse). Deviations from the original plan can be seen on the graphical timeline. These shifts within the available time windows can be flexible, either forward or backward, taking into account start of shifts of train drivers and their possibilities of use and disposability of other personnel and locomotives. If necessary, we consider cancelling the planned transport, shifting the transport times or introducing a completely new timetable. At the same time, since the properties of the paths behave similarly, they are solved within FP1, work in this WP focuses on using the paths that are available to us. Assets Warehouse uses available paths as a basis for assignment of resources to particular train. It is also possible to consider resale of paths to other RUs.

Definition of general functions of an asset warehouse. Definition of general interfaces of asset warehouse for intermodal prediction purposes.

- Establish common functions and interfaces to receive data on bookable capacities and services from providers, publish them for booking, provide data for ETI/ETA correction, notify suppliers, and ensure precise correction of booked services for dynamic dispatching and ETA correction outputs regarding availability of resources that we want to use for rescheduling of transport (change of ETI/ETA). Data about progress of a transport and impacts (weather, strikes, infra or resource failures, deviations). Data from and to prediction algorithms are necessary.

- Identify and specify all input parameters into Asset warehouse and RUs information systems (PRIS, DISCOR, DISC-M, ELITE) for prediction of changes impact on MY/last mile and planned resources (locomotives, drivers, staff). Development of functions of a common asset warehouse is integral.
- The indispensability lies in the assignment of trains to transport in the period just before or already during the transport. At the moment when the train is already running on specific section of the previous RU, in following section the resources of the next RU are just being assigned to the train according to its actual composition (including destination). It is necessary to obtain and process info about deviation (change of time or route) from predictive algorithm.
- Verification and re-assignment of planned resources will be performed by Asset warehouse. The objective is to provide end to end decision support tool for efficient utilization of locomotives, drivers and other resources.

Specification of the functions and modules that will be developed in WP28 ("asset management warehouse blueprint"). Highlight the relevance of this topic for the intermodal prediction activities.

- It is necessary to provide data for ETI/ETA correction after the booking process and precision and corrections of booked services regarding the outputs of dynamic dispatching and ETA correction.
- Due to the long distance of the train, there are many reasons that can change the ETI/ETA and also the needs of the real sources. RUs must be able to reassign sources (locomotive, driver, staff in station). At the moment when the train is already running e.g. in DE, in CZ resources are only assigned to the train according to its real composition (including destination).
- It is essential to provide or to have available the timetable of the trains concerned, input accurate ETI/ETA from the forecasting IS (possible rerouting/sharing of the TAF TSI message) and also ensure availability and status of resources and their characteristics/parameters.
- The objective is to link train coverage requirements in an updated/refined state to specific available resources and identify missing resources/uncovered train performance.
- Time availability of resources - when deciding whether a resource is applicable for a specific case/transport, it is necessary to take into account the time availability of each resource. In case of occurrence of a resource on a train, this means that any time shift of the path does not necessarily mean a change of resource if the shift does not exceed the time availability. Only in the event of a shift in time out of availability, will a search for a new/other suitable source.

Short description of relevant systems used by CDC:

PRIS - System for operational dispatching in marshalling yards. It ensures monitoring of marshalling yard processes including staff activities, is a source of data on real operational events with the wagon and consignment, train composition, monitors the operational status of wagons and enables data exchange with other carriers. It also includes an operational database of all wagons that ČDC needs to register for its operations. Tracking of registration and technical data throughout their life cycle.

DISCOR – Information system for dispatching and for operational management support. System provides automated up-to-date information on operational situation (train position, objects on trains, irregularities), complex monitoring during train's live cycle in relationship to business cases shipped by the train. The application allows operational assignment and modification of locomotives and drivers on trains.

DISC-M – Application used to plan train utilization, includes all transport types (single wagons, complete trains), such as loaded or empty wagon movement. Key functions are – planning of wagon journey according to current plan, capacity reservation for wagons in trains, definition of wagon handover in MY, monitoring and evaluating wagon transport plan and responses to the irregularities.

ELITE - Application used to prepare a short-term plan (operational plan) based on the long-term plan and its deviations/changes. From this point of view, it is a continuous adjustment of the trains for the day and their eventual enrichment with a link to business cases and information about the shipment. In short, this application combines the operational and commercial parts of the plan. It is mainly about the preparation of the future transport solution, the solution of individual partial transport and its connection to the capacity of the route and other resources (locomotive, driver, staff).

7.6.2 Evaluation of potential benefits from high-precision ETA at the Verona Quadrante Europa Terminal

The use case aims to measure the potential benefits of the reception of a high-precision ETA based on the terminal departure prediction model, by monitoring a rail freight service from terminal to terminal, including all of the processes and locations in between. Such potential benefits are expected from an optimization of activities and processes triggered by the promptly reception of the ETA that will allow a dynamic re-planning of the activities at the Verona Quadrante Europa Terminal in Italy.

Description of the terminal

Verona Quadrante Europa is terminal located in the city of Verona, in the Veneto Region in Italy. It covers an area of approximately 180,000 squared meters, with 15 tracks with lengths according to Table 25:

Track	Length [m]
1	600
2	600
3	665
4	652
5	652
6	690
7	690
8	650
9	650
10	650
11	700
12	700
13	700
14	700
15	700

Table 25: Overview on the tracks of the Verona Quadrante Terminal

The terminal is divided into three 'modules':

1. The first module, on the RFI managed area is composed of two track bundles: the first contains tracks 1 and 2 which are served by rubber-tyred cranes, and the second contains tracks 3, 4 and 5 that are served by gantry cranes.
2. The second module, also on the RFI managed area, consists of two track bundles: the first contains tracks 6 and 7 which are served by wheeled cranes, and the second contains tracks 8, 9 and 10 that are served by gantry cranes.
3. The third module is on the *Quadrante Europa Terminal Gate* area, and consists of a single bundle of tracks that contains tracks 11 to 15 which are served by gantry cranes.

The area occupied by the tracks, bridge cranes, gantry cranes and the space reserved for handling wheeled cranes (including truck lanes) is approximately 80,000 m2.

The remaining 100,000 m^2 area is dedicated to the storage of intermodal units. The storage area belongs partly to RFI, partly to *Quadrante Europa Terminal Gate* and partly to *Quadrante Servizi*.

Description of the processes and activities

1. Intermodal Transport Unit (ITU) drop-off

For the drop-off of an ITU to the terminal by road, the customer (MTO), through the IT systems, makes a reservation, i.e. the assignment of the ITU to a scheduled rail transport relation leaving the terminal.

The Verona Terminal is equipped with a dedicated truck accumulation area located before the gates. In this area the Pre Check-in operations are carried out which consist of:

- Verify the existence of a booking, by entering the identification code of the ITU in the management IT system using a provided tablet, and checking that the data on the ITU corresponds with the data on the booking.
- Safety checks, which may affect the loading and unloading of the ITU on the train or truck:
  - Cracks or deformations of the corner blocks and clamp grips that are visible to the naked eye;
  - Incorrect labelling of ITUs carrying RID goods aor hazardous waste;
  - Load imbalance (visible to the naked eye)
  - Material spills or drips particularly for ITUs containing RID goods and hazardous waste.
- Quality controls that do not affect loading and unloading of the ITU:
  - All irregularities detectable to the naked eye by checking the ITU from both sides and from the rear (closing of the sides, doors and sliding sheet locking harpoons, integrity of the tarpaulins and walls, correct positioning of the customs cable and of the sheet holding hooks).
  - Checking the seal ID number of the ITU, when easily findable without exposing the operator to any risk, and entering the number into the management IT system using a provided tablet.
  - Loaded ITUs must have a seal; in cases where there is no seal, for full ITUs, the pre-check-in Operator will give a seal to the driver in charge (who will apply it to the ITU when possible and without exposing themselves to any risk) by taking it from the seal stock provided at the terminal and also entering the number in the management IT system through the provided tablet.

Once the Pre-Check-in checks have been completed with a positive outcome, the truck is directed to the access gate where the Check-in Operator reviews the transport documents (CMR, DDT) and any other required documents, and completes the booking by entering:

- the driver's name

- the plate number of the tractor;
- the weight stated on the documents or declared by the driver;
- A confirmation of the labels relating to RID goods and hazardous waste;
- for ITUs containing waste, the number of the FIR or Annex 7 and confirmation of the EWC code.

After checking that the introduced data is correct, the driver digitally signs the delivery document and collects a copy. The delivery document authorises the access of the ITU to the terminal, on which the ITU's positioning sectors (dwell area or track of the corresponding train) is included, as well as the rules of conduct, the bar code for exiting the terminal and eventual damages found at the entrance during the pre-check-in phase are indicated. Once the acceptance operation has been completed, the delivery status of the ITU becomes visible on the tablets of the involved crane operators, via the management IT system application. For semi-trailers that do not have to be loaded directly onto the train, the driver independently proceeds to park in the dwell area indicated in the delivery document.

2. ITU Pick-up

To pick up an ITU from the terminal, the customer makes a pick-up reservation via the IT systems, i.e. picking up an ITU from the terminal via road transport. Upon arrival of the tractor at the terminal, the Gate Operator receives from the driver the code of the ITU to be collected. Upon entering the data in the management IT system, and displaying the booking, the system requests the entry of the unique pin code. If the above data is not found, the collection of the ITU is rejected.

The driver, after checking that the data entered in the service monitor is correct, digitally signs the re-delivery document and collects a copy. The hand-over document authorises the tractor to enter the terminal, and on it are indicated the sectors where the ITU is located (dwell areas or track of the corresponding train), the rules of conduct, the bar code for exiting the terminal and any eventual pre-existing damage on the ITU. Once the acceptance operation has been completed, the status of the ITU pick-up is visible on the tablets of the involved crane operators, when applicable, via the management system IT application. In the case of semi-trailers in the dwell areas, the driver independently hooks-up the lorry and proceeds to exit the terminal. For all ITUs exiting the terminal, a check is made on the delivery documentation presented by the driver to ascertain the congruence between the plate number of the outgoing tractor and the ITU loaded on it.

At the exit barrier of the terminal, there is an operator assigned to exit controls (PC-OUT). For each lorry with an accompanying ITU, the PC-OUT must check that the driver is in possession of the pick-up documentation issued by the operations room or the exit authorisation document (stamped, initialled, and dated, a copy of which he will collect). In the absence of such documentation, the operator is not authorised to open the exit barrier and must contact the operations room to report the anomaly.

3. Loading of trains for departure

The MTO sends the load list, i.e. the list of ITUs to be loaded on a specific train, by e-mail or via a shared IT system. The Hall Operator associates in the management IT system the load list provided by the MTO with the list of wagons that compose the departing train according to the indications received from the MTO. The load list is communicated to the crane operator via the management IT system application through a vehicle tablet, where the crane operator confirms the loading operations they performed.

Once the loading operations of all the ITUs scheduled for the departing train have been completed, the operator in the operations room performs the checking and control operations of the material loaded on departure. This final check is done before handing over the train to the RU in order to be certain that the loading operations have been carried out correctly. The checks are performed via tablet, or by ticking the wagon/UTI matching check list printed from the management IT system, and consist of the following activities:

- Check the correspondence between the wagon number and the code of the UTI;
- Check that the attachment and anchorage of the corner blocks with the ankle twists are perfectly seated in the appropriate seats, for the part that is not visible to the crane operator;
- Check the correct insertion of the SR pin into the wagon fifth wheel coupling, only when it was not possible for the ground operator to check it;
- Check the correct positioning of the legs of the semi-trailer in relation to the wagon loading surface;
- Check the positioning of the ITU on the wagon with respect to the weight and loading pattern of the wagon;
- For tanker ITUs, check for leaks paying particular attention to ITUs containing RID goods or hazardous waste;
- For semi-trailers, check that the air suspension has been emptied;
- In terminals where the loading regulations provide for securing swap bodies or containers against tipping or falling due to the wind, it is necessary to apply fixing springs in the appropriate slot in the ankles.

By placing a “flag” for each ITU shown in the check list, on paper or in the tablet, the operator from the operations room indicates that the checks described above have been carried out. Any anomalies found must be punctually reported on the space provided in the paper check list or tablet (train note), indicating the wagon number and the anomaly found. The operator shall ask the crane operator to regularise any anomalies found due to loading errors (out of twist or turntable) and must in any case note them on the paper check list or tablet.

4. Unloading Incoming train

Once the train has been placed in the terminal by the railway shunter, the Hall Operator proceeds to check the wagons and ITUs using the tablet or by comparing the correspondence of the data in the printed checklist obtained from the computer system with the data on the wagons and ITUs. These checks refer to the documentation and status of the vehicle (both for communication with the rail carrier and for the customer or client).

- Security checks:
    - State of the ITU on parts of the ITU affected by the unloading activity, (upper corner blocks, clamp grip), visible to the naked eye;
    - Check for ITUs containing dangerous goods or hazardous waste the correspondence of the UN code shown on the check list with the plating and labelling on the ITUs, and check for possible spills or leaks.
- Quality controls:
    - Check the seal ID number, if indicated in the consignment note and easily detectable without any exposure of the Operator to any risk
    - In cases where the seal, indicated in the consignment note, is found to be missing, the Hall Operator shall raise a petition to the MTO;
    - Visual check for any damage detectable to the naked eye (e.g. cuts, dents, bulges, etc.);
    - Removal of UTI fixing springs if present.

By placing a flag for each wagon in the wagon/UTI matching check list printed from the management system or directly in the tablet, the Hall Operator indicates that the checks described above have been carried out. The Hall Operator, once the checklist has been completed with a regular result, authorises the unloading of the train, indicating to the Crane Operators the unloading operations required for the wagons and the eventual storage on the ground required for the arriving ITUs, all through the IT system on the vehicle tablet.

The Crane Operator confirms the unloading operation through the vehicle tablet as well and can associate in the IT system the data of the ITUs and assign storage areas in the event that there has been no specific indication from the operations room, and therefore they have identified on their own initiative the area they consider suitable. In the event that the ITU is collected directly from the train, the driver shall present at the collection point indicated in the delivery document, positioning themselves in the defined location for the ITU to be collected. For the unloading of ITUs with the use of a gantry crane or overhead crane, it will be the Operator on the ground on the indication of the Crane Driver on board the crane, who will indicate the correct stopping position to the Driver for the unloading operation.

5. Train-to-train handling (gateway)

Gateway operations consist of the transfer of ITUs from one train to another. These operations can be carried out either directly by moving the ITUs from one convoy to another or through short technical stops in the allowed stopping areas. The operation is managed through the management system on the basis of customer bookings and required loading plans.

Possible causes of delays

As described above in the description of processes and activities, in each of the steps described there are several checks that the operators perform for each individual ITU. At any of these steps a problem may emerge that can prevent the loading of the specific ITU onto a train, which can cause:

- Delay in the completion of loading which can prevent the train from departing on time,
- Rejection of the wagons from the technical inspection
- Cancellation of the train

In addition to the causes resulting from terminal activities, the delay in train departures may also be attributable to shunting activities, due to the station's unwillingness to receive the train (because it is cluttered or otherwise), or to the shunting equipment or personnel being unavailable for contingency reasons.

Possible advantages of the reception of the ETA at the terminal

Having a high-precision ETA transmitted directly to the terminal, for arriving trains, would make it possible to notify the MTOs and consequently the drivers who have to collect the ITU in real time by means of SMS or push notifications through a specific APP (Terminali Italia is already thinking of developing a 'drivers APP'). To monitor the effectiveness of these communications, the check the time taken by drivers (from check in to check out, but also all intermediate steps) could be checked and compared with the times of drivers who did not receive the communication. It would also provide 'priority' access lanes for those who show up close to the arrival of the train.

Another possible benefit is the rescheduling of shunting slots, under operational management by the shunting manager, who, knowing the actual ETAs, can reprioritise and perform shunting more efficiently. This efficiency can be measured through the number of shunting operations performed (currently 10% of shunting operations are not performed due to lack of time) and through the possible increase in quality offered (on-time shunting/total shunting).

During the testing activities and the preparation of the demonstration as part of the development phase, we will be able to determine the benefits more accurately. Depending on this evaluation, methods on how to quantify/measure these benefits will be developed. Some initial suggestions can be found below, although they may be subject to modification depending on the results of the tests.

Possible KPIs to measure the benefits at the terminal

1. Common through time from check in to check out at the terminal: The through time is currently measured for the trucks that enter the terminal and could be an indicator to estimate the impact of the ETA transmission to the terminal, as through times could potentially be reduced when truck drivers are informed of the actual time that they need to check in in order to pick up/drop off.
2. Average dwell time for trains at the Verona Quadrante Europa Terminal: The dwell time can currently be estimated by pairing the train services arriving and leaving the terminal. It can be an indicator to estimate the optimization of the shunting operations at the terminal that the high-precision ETA could bring, as available tracks could be used more efficiently knowing the exact time that planned operations will need to be performed.

Requirements for data transmission:

The use case will be based on the transmission of data regarding the planning of train runs and operations of a freight transport service at the yard/terminal, and data containing messages regarding the main milestones related to the freight transport service, including the terminal/yard, train run and possibly intermodal trip segments. These messages will be transmitted to the Hacon ETA Management Platform, where an algorithm designed by Hacon will calculate the ETA based on the planned activities (at the terminal and main line) and the actual messages that arrive in real time regarding the state of the train at the different stages of the train/service. The Hacon ETA Management Platform will in turn send the data regarding the ETA of the train to the terminal of arrival in order to test the potential benefits at the terminal side. The required steps for data transmission include:

- Train planning/timetable from the RNE common platform or directly from the IM to the Hacon ETA Management Platform.
- The planning of the activities at the terminal/yard from the terminal management system to the Hacon ETA Management Platform.
- The messages related to the real time information of the train from the RNE common platform to the Hacon ETA Management Platform.

- The messages related to the real time information of the terminal activities from the terminal management system to the Hacon ETA Management Platform.
- The ETA messages from the Hacon ETA Management Platform to the terminal.

Data standards:

- TAF TSI for the main line
- EDIGES for the terminal messages
- TAF TSI compliant messages for the ETA calculated by the platform

Data owners/providers:

- IMs own the data regarding the timetable/planning of train runs.
- RUs and IMS own the specific TAF TSI messages that they send for the different steps of the train run.
- RNE also owns data regarding the TAF TSI messages that arrive at the RNE common platform
- The terminal owns the data regarding the planning of operations and the EDIGES messages related to the activities at the yard/terminal
- Hacon owns the data related to the ETA algorithms and messages regarding the calculated ETA

Data consumers:

- Hacon utilizes the data regarding planning and real time activities for both main line and terminal operations
- The terminal utilizes the data regarding the calculated ETA to test the potential benefits in the use case/demonstrator.

7.7 Prediction systems as input for Terminal Operating Systems (Germany)

This chapter describes on a high-level an additionally planned application for the prediction systems for several terminals in Germany to support the quantification of benefits of prediction systems via KPIs.

An intermodal terminal needs to optimize its processes in order to be profitable. Optimized processes mean in essence the least amount possible of Container movements. Another essential part for the profitability of intermodal Transport in general and therefor the further growth of this sector is to accelerate processes especially for trucks (Truck-in/Truck-out).

An accurate time of arrival and a correct loading list are essential corner stones to allow for truck companies to plan their journeys in the most efficient way.

Additionally, the terminal can reorder its planned activities on a given day, based on new priorities.

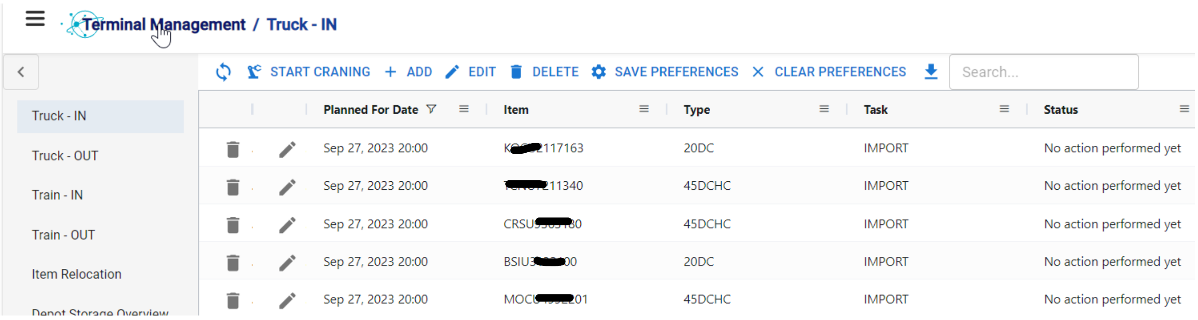


Figure 64: Terminal Management system with an overview on planned truck arrivals

In opposite the terminal can deliver valuable inputs himself to increase punctuality of the railway network. But also to deliver information on short term or mid-term planned free capacity either in the terminal or on trains. This is an important input to calculate e.g. alternative routing and as well an important input to work package 31 to show potential available capacity.

To measure the impacts of the optimization resulting out of an accurate and in time intermodal prediction we intend to rely on three main KPIs.

1) Dwell time of container in a terminal
   The time a container is in the terminal from arrival via Rail or Road to departure via Rail or Road. In normal economic situations it is the objective of a terminal to reduce this time in order to maximize capacity. Only in exceptional cases or major disruptions of the worldwide supply chain, the terminals can have a commercial interest to not optimize this turn around time in order to earn at least storage fees.
2) Dwell time of Trucks
   The time it takes for a Truck to enter the terminal and leave the terminal again. This is linked to various processes and procedures that cannot be accelerated by intermodal prediction but by dynamic dispatching (work package 27) but at least the waiting time inside the terminal should be reduced with accurate intermodal prediction.
3) Amount of unproductive craning tasks
   The better the intermodal prediction the more accurate a planning of next craning tasks can be done, so that this unproductive movements can be reduced.

8 Standardised European Railway Checkpoints

Standardised European Railway Checkpoints are wayside monitoring systems designed for detection and condition monitoring of trains passing through operational points located strategically along the railway network. For freight trains, which is the focus of the Checkpoints developed in TRANS4M-R, the concept is adapted in order to enhance supply chain efficiency, operations, maintenance and inspection. The concept is a further development of the previous work carried out in Shift2Rail and the concept of "Intelligent Video Gates" (IVG). Thus, the IVG can be viewed as one type of railway checkpoint.

In this chapter the term Inteligent Video Gate (IVG) is primarily used to refer to the previous concept developed in Shift2Rail and the term "Standardised European Railway Checkpoints", short "Checkpoints", is used for the elaboration of the concept within FP5 - TRANS4M-R.

In FP5 - TRANS4M-R, the emphasis of the concept is on freight trains and improving freight operations in terms of data sharing within supply chains as well as maintenance and inspection of rolling stick, whereas FP3 focuses on gates installed at main lines and also including passenger trains. Moreover, close alignment is sought for the development in both Flagship Projects and in line with the work carried out in the System Pillar of EU Rail, where standardisation and harmonisation are addressed.

The main objective of the concept of "Standardised European Railway Checkpoints" is a further development of the previous work in Shift2Rail and the concept of "Intelligent Video Gates" (IVG). The intelligent video gate (IVG) consists of a gate system installed at relevant railway nodes and equipped with cameras and RFID readers for automatic identification of wagons and intermodal loading units. The IVG is to be located at, or nearby, railway facilities where it can lead to significant improvements for processes within the supply chain, related to time, planning, work safety, maintenance and claims.

The concept of IVG is now further developed within TRANS4M-R in order to explore further functionalities of the concept, including also another operational stop: border crossings (apart from terminals and yards). Moreover, standardisation of technologies and data management are further addressed in order to propose a harmonised European implementation of the concept.

As illustrated by Figure 65, the work with the concept is divided in three parts: 1) Specifications, which is addressed in WP25/T25.4 and reported in this deliverable, 2) Development, which is carried out within WP29 and 3) Demonstration, which is carried out both in WP29 and jointly in a showcase with other WPs of Seamless within WP33 Showcase corridor.

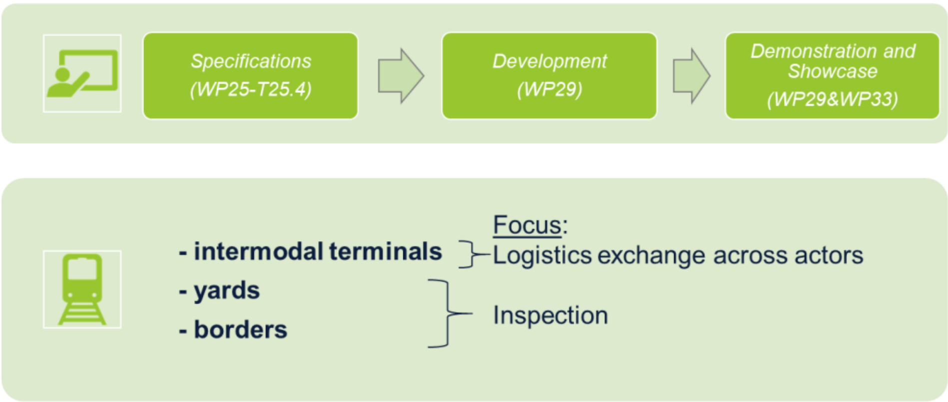


Figure 65: Working structure and focal areas for "Standardised European Checkpoints"

The structure of chapter 8 corresponds to the tasks and objectives stated in the DoA of T25.4;

- 8.1 Background description,
- 8.2 Process analysis for the considered operational stops (yards, terminals and borders),
- 8.3 Functional and non-functional requirements,
- 8.4 Technical specification for the detection and identification technologies,
- 8.5 Data sharing and interoperable IT systems and
- 8.6 Harmonised procedures and regulations.

8.1 Background description

8.1.1 Previous Shift2Rail projects

In order to give a common starting point for the continued development of the IVG concept within the concept of European railway checkpoints, this chapter presents a description of the gates that were developed in the previous projects in terms of functional requirements, technical specifications and installation plan as well as other descriptions of similar gates and concepts belonging to the project partners.

Within the two Shift2Rail projects *FR8HUB, WP4 Intelligent Video Gate* and *FR8RAIL III, WP3 Intelligent Video Gate* the concept of an Intelligent Video Gate was developed, installed and demonstrated. Further details of the development of the Intelligent Video Gates are to be found in the deliverables from FR8HUB D4.1 and D4.2 (Kordnejad et al. 2018 and 2019) and from FR8RAIL III D3.1, D3.2, and D3.3 (Kordnejad et al., 2020, 2021 and 2022).

8.1.1.1 FR8HUB WP4 Intelligent Video Gate (IVG)

The concept of IVG was first addressed within Shift2Rail in FR8HUB WP4 Intelligent Video Gate of IP5, 2017-2019. Within that framework, two deliverables were produced; D4.1 (Kordnejad et al., 2018) and D4.2 (Kordnejad et al., 2019). As a technical system, the IVG consists of structural components (gate components for keeping/housing devices, electrical supply, etc.), technical components (image recording, illumination, RFID reader, user interfaces) as well as logical components (image processing, RFID processing, memory, visual data evaluation, etc.).

8.1.1.2 FR8RAIL III WP3 Intelligent Video Gate (IVG)/Demogate

Within the WP3 in FR8RAIL III, three deliverables have been produced containing requirements definition and IVG preliminary installation report D3.1 (Kordnejad et al., 2020), description and preparations for a demonstrator of the IVG D3.2 (Kordnejad et al., 2021), and demonstration and evaluation D3.3 (Kordnejad et al., 2022).

The aim of D3.1 “Requirements Definition and IVG Preliminary Installation Report” was to define requirements for installations of Intelligent Video Gates together with a preliminary installation report for a single-track installation at a terminal or yard.

The aim of D3.2 “Description of demonstrator - Intelligent Video Gate” was to describe and prepare for a demonstrator of the IVG. The aim was achieved through the installation of intelligent video gates at two pilot sites, Gothenburg, Sweden and Nuremberg, Germany, see Figure 66 and Figure 67. The gate in Sweden was installed 10 minutes from the port of Gothenburg and the one in Germany was installed at the marshalling yard of Nuremberg just by the hump.

The final deliverable of this WP, D3.3, was a demonstrator of the installed gates, including an evaluation of identified use cases.

Figure 66: Physical installation in Gothenburg, Sweden

Figure 67: Physical installation in Nuremberg, Germany

8.1.1.3 IVG at intermodal terminals

Establishing IVGs in intermodal terminals can have several positive effects. From the perspective of the terminal operator, the IVG concept would imply an improvement in operational efficiency, mainly due to:

1. Faster arrival process. Handling deviation and identification of wagons and cargo carriers with higher degree of automation during arrival processes, e.g. check-in (document handling) / damage claims / handling of dangerous goods.

2. Faster departure process. Higher degree of automation at departure e.g. departure control, improved safety and handling of dangerous goods.
3. Improved and faster operational management when sequence of wagons and intermodal loading units (ILU) (and any deviations from pre-arranged sequence) are known in advance, which enables optimized transshipment plans and a more seamless interface toward road transporters.

Improved services at terminals imply an improved and more attractive range of services. In the long-term perspective this should lead to a higher degree of customer satisfaction and contribute to the modal shift ambitions of the European green deal and sustainable transport goals.

Figure 68 illustrates the main information that can be automatically and digitally retrieved from the IVG and the main operational benefits that this could lead to. When studying the benefits and added value that image processing and RFID will imply, they appear to be a good complement to each other. The image processing can read codes and placards of dangerous goods without extra equipment on the wagon or ILU, unlike other technologies, where RFID requires that the units are pre-installed with tags. The camera can also be used for other purposes than purely detecting and identifying devices, such as damage inspection and departure control. RFID technology can identify vehicles at detector stations that are not part of IVGs and that are owned by infrastructure managers, operators and shippers. In particular, RFID adds increased reliability to the IVG concept as the technology provides a reliable complement to the camera, which does not achieve the same level of reading capability, especially in unfavourable operational situations such as dirty devices and in difficult winter conditions.

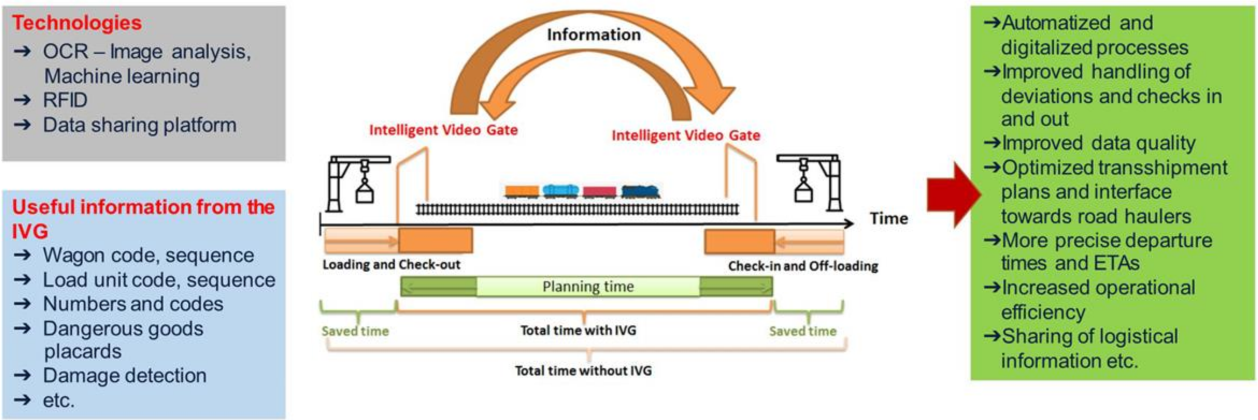


Figure 68: The main identified benefits of the IVG concept. Information (blue box) that can be identified and benefits (green box) that it can lead to (Kordnejad et al., 2020)

8.1.1.4 IVG at Marshalling Yards

Marshalling yards are train formation sites for single wagons or wagon groups in railway freight traffic. The transportation of single wagons or wagon groups is performed in mixed trains. These operations differ significantly from block trains. After their arrival, the individual wagons or wagon groups are disassembled, shunted and finally reassembled into new mixed trains leaving for different destinations (DB Cargo, 2020).

Once a train arrives at the marshalling yard “arrival zone” (see Figure 69 for an overview of the yard in Nuremberg in Bavaria, Germany), a shunting locomotive pushes the entire train slowly over a hump. An employee separates the wagons from each other by releasing the coupling. From this moment, the separated wagons or wagon groups move on a track without human action and only by gravity (DB Cargo, 2020).

After passing the IVG on this track, the wagons enter the classification tracks, where the wagons are reassembled in a different order. The track switch is triggered by the automatic shunting system of the yard (DB Cargo 2020). According to their weight, the wagons accelerate differently. That is why automatic brakes are located in the tracks which regulate the wagons speed.

Figure 69: Different parts of a marshalling yard in Nuremberg, Bavaria, Germany. (Kordnejad et al. 2020)

8.1.1.5 Evaluated use cases

As part of the tasks of suggesting paths for data exploitation and the final evaluation of the IVG concept, a set of use cases were identified and evaluated within FR8RAIL III D3.3 (Kordnejad et al., 2022). See Table 26 for short descriptions of these use cases.

Use case	Description
Information to customers	An **information system gives customers** of railway undertakings and terminal operators the possibility to access **timestamped information about ILUs, wagons and trains** gathered by IVGs, along with **estimated deviations** from their planned time of arrival.
Planning	IVGs located at sending terminals or along railway lines can provide useful information for **the transshipment planning** at intermodal terminals.

Damages	Detection of damages, initially graffiti.
Dangerous goods	Information collected by IVGs can help infrastructure managers with more **accurate status of dangerous goods**.
Dangerous goods and TMS	Use of IVGs to improve and **optimize the scheduling** of transits with dangerous goods for reducing **the exposure risk**.
Use cases for the IVG at yards	IVGs are currently used to speed up and digitalize the reporting process of the **maintenance** ordering unit. Through identification of the damages on the high-resolution images, risks for the employees' health and the amount of unnecessary paperwork can be reduced.

Table 26: Identified and evaluated use cases for the IVG concept within FR8RAIL III D3.3 (Kordnejad et al., 2022)

8.1.1.6 Important informational aspects

ILUs have standardized codes (see Figure 70), which an IVG equipped with OCR analysis can find. There are several examples of that in use at ports.

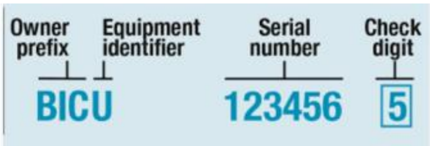


Figure 70: Standardized ILU code

Inland ILUs do not necessarily have standardized codes, see example in Figure 71.

Figure 71: Example of code on inland intermodal loading unit

The format of inland ILUs is not standardized either. For example, sea containers are stackable while most inland ILUs, for example semi-trailers, are not.

Information about dangerous goods can be found on *placards* and *orange-coloured plates* on wagons and ILUs. Both these types of signs are described in *Regulations concerning the International Carriage of Dangerous Goods by Rail (RID)* (OTIF, 2023a).

An orange-coloured plate, see Figure 72 displays a hazard identification number indicating the type of hazard (upper part of the plate) and a UN number indicating the substance or group of substances (lower part).

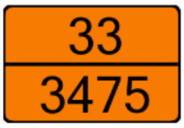


Figure 72: Orange-colored plate

Placards provide important information about the hazard classes (for example, *flammable liquids* or *oxidizing substances*) of the dangerous goods, see example in Figure 73. They might be harder to interpret using software than orange-coloured plates.

Figure 73: Example of placards

8.1.1.7 Note on efficiency from the customer side

It is important to recognize that it is the transportation duration that the customer wants to be as short as possible, from the arrival at the first terminal to the pickup at the last terminal. That (in principle) is a proxy for the customer's willingness to pay.

From a transportation mode competition view, the transportation duration is to be compared with, for example, the duration of a similar road transport (same origin and destination). Every hour that can be removed from the terminal handling and railway transportation duration increases railway attractiveness to the customer, see Figure 74.

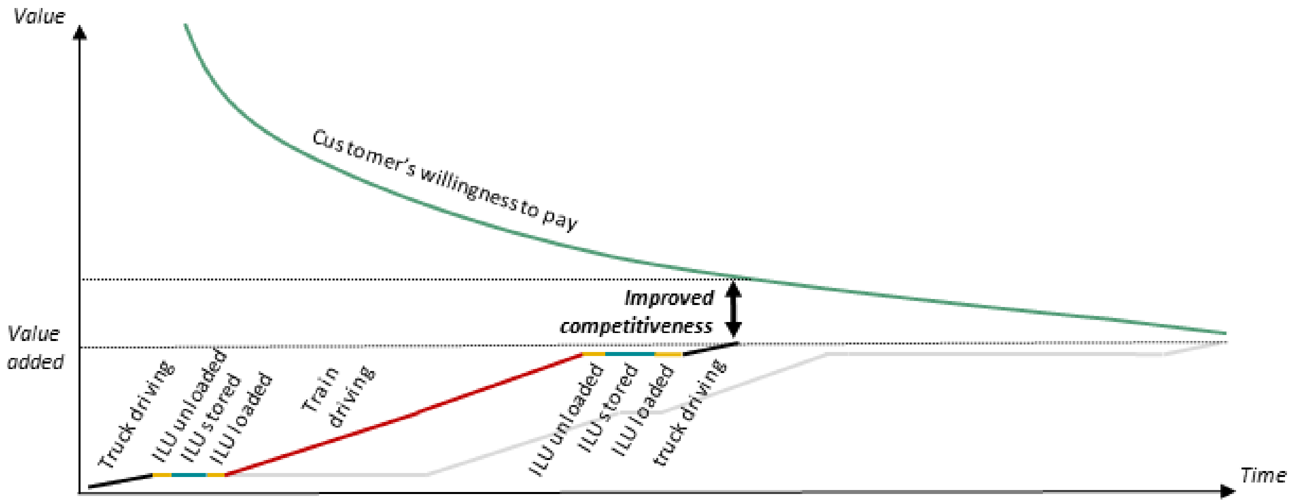


Figure 74: Customer's willingness to pay for transportation

Here, the IVG is a tool to improve competitiveness for the railway industry by reducing the dwell times of ILUs, thereby improving the opportunities for a larger modal share for intermodal transports. As a bonus, reduced dwell times will improve utilization of the rolling stock, since the time each ILU is standing on a wagon is decreased.

This is in line with Lean methodology: waste is removed (from the customer's perspective) by removing durations of the transport where the ILU is standing still (and thus not adding value to the service that the customer is paying for).

8.1.1.8 Further functionalities investigated

Within FR8RAIL III WP3 synergies were investigated with FR8RAIL II WP5 Freight Automation Deliverable 5.1 (2020), in particular regarding track side inspection through IVGs and the ***train preparation process including the brake test process***. The synergies are elaborated in FR8RAIL II D5.1. Here, a short summary is made regarding the main outcome. The train preparation phase including the brake test includes a number of visual inspection assignments, which could in theory be carried out by the IVG. However, innovative solutions are required for handling alarm detection on departing trains on non-dedicated lines with mixed traffic, further elaborated in D5.1. The visual inspection for external control of the rolling stock could for this purpose concern the following:

- First and last wagon number, complete train, brakes off
- Cables, hoses, pipes
- Running gear
- Pantograph
- Brake blocks (where visible)

- Position of various air taps of the brake system

If a microphone is attached to the IVG system, also acoustic control could be carried out, in order to detect air leakages.

8.1.2 Technical Specifications

As a technical system, the IVG consists of structural components (gate components for keeping/ housing devices, electrical supply, etc.), technical components (image recording, illumination, RFID-reader, user interfaces) as well as logical components, the latter is further elaborated in the subsequent sections (image processing, RFID-processing, memory, visual data evaluation, etc.).

8.1.2.1 Selection of components

The main technical components composing the Intelligent Video Gate are:

- Cameras
- Illuminators
- RFID readers
- Wheel sensors

For each of these components a detailed description is provided in D4.1 (Kordnejad et al., 2018), together with its main technical characteristics, necessary for component evaluation during the selection process.

8.1.2.2 Installation of IVG

The IVG system described in this section is installed on the entrance/exit tracks of the terminal or yard. Ideally, all rail movements in the terminal run over one track or a double track. This can however not be achieved in all terminals (for example terminals with several routes into the terminal) and several IVG systems could be needed. Generic construction requirements for IVGs at intermodal terminals were presented in D4.2 (Kordnejad et al., 2019).

The installation of the IVG needs about 20 meters for the measurement zone along the track. The installation also requires sensors, preferably wheel sensors, to trigger the IVG for a start-up procedure of cameras and illuminators. The required distance between the sensors and the gate depends on the actual train speed at the site. The wayside IVG components, such as cameras and illuminators, should be placed on a wayside pole approximately three meters from the rail, mainly due to electromagnetic compatibility (EMC) regulations as well as optical characteristics and local regulations in each country. For the physical site installation, it is important for the pole to be stable and robust to avoid that mechanical vibrations produced by the running trains are transferred to cameras, something which could lead to blurred images.

Regarding the construction requirements, different scenarios of local conditions need to be considered. The draft illustrated in Figure 75 General minimum distances in construction works corresponds to general minimum distances in construction works near/at railways including gauge guidelines, electromagnetic impact guidelines etc. in order to avoid heavy tests for approval and interference with other infrastructures or rolling stock. Trains in this site transit at approximately 40–50 km/h.

One single camera can get a high-definition picture of the entire side of a wagon. The image definition is enough to detect intermodal loading unit code as well as the EVN (European vehicle number, sometimes referred to as UIC code) of the wagon. The EVN will also be detected by the RFID reader, if the wagon is equipped with an RFID tag. Illuminators are installed in order to have clear wagon photos also during night.

If damage detection is required, a dedicated camera for the bogie side check or a 3D system could be good alternatives. As described in D4.1 (Kordnejad et al., 2018) this function should be carried out using laser scanners (or calibrated cameras for 3D pictures).

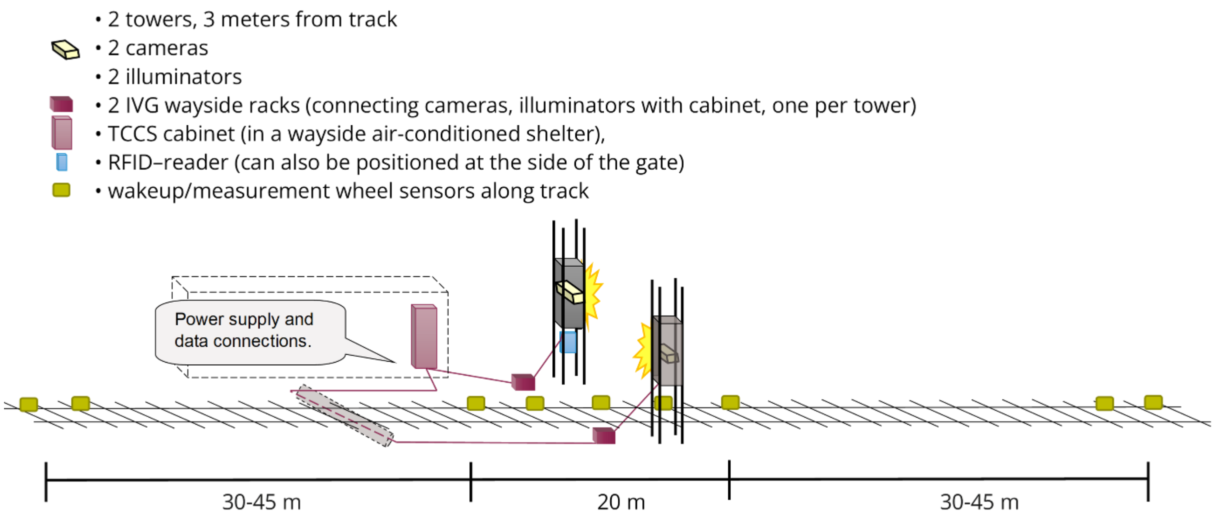


Figure 75: General minimum distances in construction works (Kordnejad et al., 2019, modified)

Full data collection on both sides of the train leads to more precise results and higher reliability of data. If one side of the train is of such poor condition (e.g. graffiti, dirt, exposure problems, etc.) that almost none of the numbers could be identified, this lack of information would lead to higher manual effort later, after the train has arrived.

If shunting is done through the gate, i.e. wagons pass several times in random pace, the solution might not work properly. This also applies when the train goes very slowly, stops or restarts. Minimum speed should be above 10 km/h. In case of uneven speed, it will be handled by the system as long as the train remains above 10 km/h or preferably above 15 km/h. At the DB gates at yards, other types of sensors are used, adapted for lower speeds. The vibration sensitivity of the cameras is different depending on the train velocity when passing through the gate. At low velocity (less than 25 km/h) the ground forces are lower than in higher velocity and the need for a safe pool installation shall be adjust to the speed at the site.

The RFID-tag reading will work at any speed of the train, low or high. The following basic construction requirements assume bidirectional vehicle movements on the track(s) and should give an overview of the most expectable variants for implementation.

8.1.2.3 Basic construction requirements

The following basic requirements should apply in the installation site in order to allow correct IVG setup and functionality:

1. 60–80 meters of rail for installation purposes
2. Train speed above 15 km/h
3. 4–5 meters of free lateral space for the installation of wayside poles holding cameras, illuminators, RFID and other equipment
4. Power supply for wayside equipment
5. Free space and power supply for the cabinet in a nearby conditioned shelter. Cabinet dimensions 600x800 mm base and 2100 mm high. Possibility to open doors on both sides of cabinet. Each door is 600 mm wide (mounted on the narrower sides of the cabinet).
6. Ducts for passing electric and optical fibres from the wayside installation zone to the cabinet inside the shelter.

8.1.2.4 Data sharing

A data-sharing system called *Deplide* is used for distributing the data from the gate in Gothenburg. The system, which has the event streaming platform *Apache Kafka* as one of its core components, has been developed at RISE and is used in several logistics projects. Deplide receives and distributes data over channels called *topics*. The system also provides reliable storage of the received data and may process the data in different ways. The location and role of Deplide in the overall data flow are presented in Figure 76 Data flow chart for the IVG installed in Gothenburg during FR8RAIL III.

For each train registered by the IVG, a Deplide topic receives the output of the image processing system as a message in XML format. A specially developed software component, a so-called *stream processor*, transforms the message into one message per wagon in the train. These wagon messages, which are published on another Deplide topic, mainly follow a general format called *Railway Coordination Messaging Format* (RCMF), which is also used in other railway-related RISE projects. However, the messages also contain some data that are not part of basic RCMF. Examples of such data are RFID readings and ILU information.

Apart from the data from the IVG, Deplide manages many data flows between various stakeholders in the logistics chain all the way from data capture sensors to operators and shippers. Deplide cooperates with the Spanish logistics platform SIMPLE and other stakeholders' platforms or inhouse systems. This experience will be utilised in future developments. There are various initiatives within EU that deal with data sharing, for example FEDeRATED (2023) and Alice (2023).

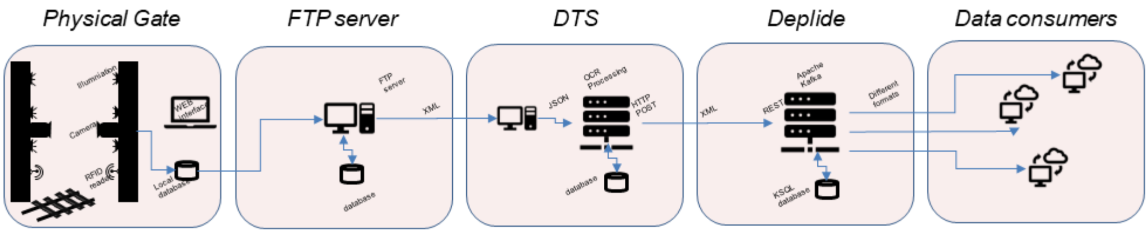


Figure 76: Data flow chart for the IVG installed in Gothenburg during FR8RAIL III

8.1.2.5 Recommendations for further improvements

Even though the basic functionalities of the type of intelligent video gate installed in Gothenburg work well, there is room for improvements of the information extraction from the images produced by the gate. The most important areas for improvement are described below.

The accuracy of the readings of EVNs and ILU codes needs to be improved. The performance of the system must be nearly as high as human performance (so that there is no need to double-check the output), but according to the evaluation included in deliverable D3.3 of the FR8RAIL III project (Kordnejad et al., 2022), the system can correctly read only 78.30 % of the EVNs and 85.39 % of the ILU codes that a human evaluator can read from the images. In addition to this, there might be EVNs and ILU codes on the wagons and ILUs that are not (fully) visible to the evaluator. Some of the latter cases might be solved through the addition of cameras in different angles and positions or through improvements of the image quality, while others are, for example, caused by the codes being damaged and thus unreadable regardless of image quality. Apart from these problems, it sometimes happens that the system misinterprets other characters that are visible in the images as codes.

The system sometimes reports wagons without EVNs. One reason for this is that two physical wagons may form an articulated wagon or a multiple wagon. This means that they are permanently attached to each other and thus administratively considered to be one wagon with one EVN. In such cases, the EVN may be written on only one of the wagons in each pair. The image processing system will then report two wagons, one of which has no EVN. This is a correct interpretation considering what is visible in the image (so improvements of the image processing will probably not help), but an incorrect one from an administrative perspective. One way of solving this problem is to post-process the readings by looking up in a database whether or not each EVN registered by the gate belongs to an articulated wagon or a multiple wagon. This would work because different EVN series are used for wagons of different types. Physical wagons that are part of the same administrative wagon can then be grouped together.

It is common that semi-trailers and swap bodies do not have ILU codes, but that they have other codes decided by their owners. These codes are currently not detected by the system, but the addition of this functionality is desirable, even though the number of code types may be too large for this to be possible. Also, it sometimes happens that ILUs are not detected at all (that is, that the system does not report the existence of an ILU which is actually present on a wagon).

The accuracy of the readings of placards and orange-coloured plates (indicating dangerous goods) also needs to be improved. According to deliverable D3.3 of the FR8RAIL III project (Kordnejad et al., 2022), only 84.00 % of these signs are currently correctly detected. Note, however, that while orange-coloured plates are considered correctly detected if they completely agree with what a human can see in the image, placards only have to be *found* by the system to be considered correctly detected. The reason for the lower evaluation requirements for placards is that since the camera produces black and white images, it is not possible to reliably distinguish between different placards for which the colour affects the interpretation. To make it possible for both the gate and human validators to distinguish between different placards, the current camera must be replaced by a colour camera.

The system does not decode the readings of RFID tags on wagons and is thus not able to use them to check the EVNs that have been extracted from the images or to fill in missing EVNs. Adding this functionality would be very useful. Finally, probable train numbers provided by the infrastructure manager should preferably be added to the readings from the gate (since this information is very important but impossible to obtain from images of the trains).

In order to improve the system performance based on previous experiences the following lines of action shall be followed:

- Clear definition of the possible use cases to be covered, identifying all the possible situations in an operational environment: all types, position, quantity of codes and signs to be detected; type, size, number, position of loads; size, type, arrangement of wagons.

- Generate a data set as big as possible, including images with all the possible situations described above, to be used to train and evaluate an image processing model.
- Define a set of technical specifications for the system (see chapter 8.4.1).
- Define a benchmark to evaluate system performance (see chapter 8.4.1).

8.1.3 Other gates and similar concepts

This section presents other gates and similar concepts that the involved IMs of the project have implemented until now, their components, functions, number of gates, how they are located at the yards, ownership and service and plans of future functions, components and usage.

8.1.3.1 Gates at yards – DB, Germany

DB have 13 Intelligent Video gates at 8 marshalling yards in Germany (as of 2023-03-09), see Figure 77 Location of DB's Intelligent Video Gates. All gates are located at the hump of the marshalling yards. In average around 1000 wagons pass each IVG per day. The main part of the detected wagons are wagons of the single wagonload traffic as well as damaged wagons which are going to the workshops at the marshalling yards.

Figure 77: Location of DB's Intelligent Video Gates

While DB Netz as the owner of the infrastructure is responsible for the set up and installation of the IVG, DB Cargo is in lead of the operation and the different respective business processes. Furthermore, suppliers and modifications to the system must be certified by DB Netz according to the standards of the German railway authorities. Changes and new setups in shunting yards need to follow the requirements of DB and the EBA (Eisenbahn Bundesamt – German Ministry of Railway Transport) to guarantee safety and security (Kordnejad et al., 2020).

When the IVG is approved and installed behind or before the shunting hump, the wagons are passing the IVG with a maximum speed of up to 40 kilometres per hour. The average operating speed at this point of the yard is about 15 kilometres per hour. While passing the IVG, the wagon is scanned by a combination of laser sensors and cameras mounted on the gate. While passing this gate the speed of the wagon is measured. This information is used by the image editing software in order to generate pictures in the needed quality (using line scan cameras) (Kordnejad et al., 2020).

The plans are to focus on the optimization of the use of the data from the existing IVGs, through machine learning and data analysis, rather than building new gates. To better detect wagon damages different technologies like microphones or other camera types and different camera perspectives are under investigation.

Gates – ProRail, the Netherlands

ProRail has three IVGs in use: at Schiphol Airport and at Hogebrug for passenger trains and one in Moerdijk, near the Port of Rotterdam, for freight trains.

ProRail is using the IVGs for wagon number/wagon load recognition and administration, maintenance and damage detection of the brake-blocks of trains and of the pantographs with image recognition. ProRail has planned to install six IVGs at Botlek and Waalhaven in the Port of Rotterdam in 2023 for number recognition (wagon numbers and cargo information) and the roll out of eight IVGs in 2024 for inspection of the pantographs and wheel sets of passenger trains together with NS. Together with NS, ProRail has developed a vision on Wayside Train Monitoring Systems (WTMS) in which ProRail foresees to test and develop systems for wheel profile measurements as well. In this vision, ProRail will be the owner of all the WTMS systems and distribute the data to the different rail operators. This is still work in progress in which ProRail also makes steps in data sharing (see Figure 78 Possible architecture for a Datahub that can be used for "realtime" datasharing of Wayside Train monitoring Systems).

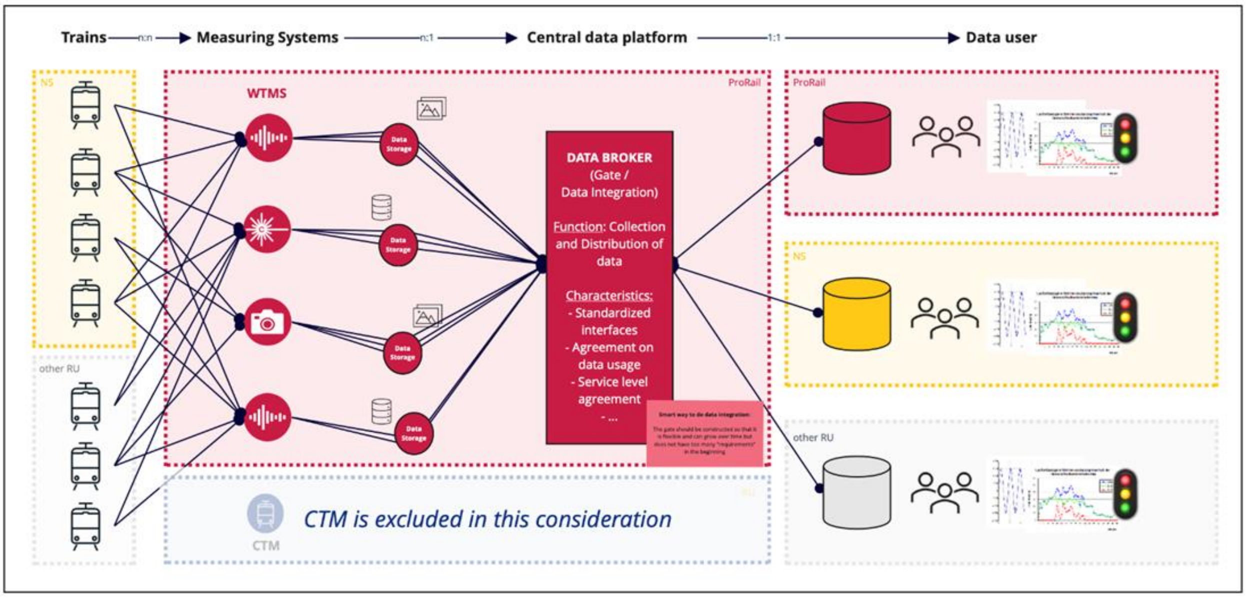


Figure 78: Possible architecture for a Datahub that can be used for "realtime" datasharing of Wayside Train monitoring Systems

Gates – ÖBB, Austria

In Austria, ÖBB Infrastruktur AG has installed 47 checkpoints with cameras and 173 checkpoints with sensors. The map in Figure 79 Location of cameras, Austria. Green = existing, Blue = planned shows the checkpoints (in green the existing and in blue the planned). At the checkpoints with cameras, at the moment only the load is checked. Therefore, the checkpoints are not real Intelligent Video Gates because the images are not checked with any AI software. ÖBB-INFRA owns and serves the checkpoint and ÖBB-RCA as railway undertaker receives the data.

The used cameras are Basler BIP2-1300C-DN with additional infrared flasher. The used sensors are wheel power sensors (axle load, wheel defects, load ratios), hot axle box detector sensors (axle bearing temperature, disc brake temperature, parking brake temperature) and dragging equipment detection sensors.

Starting 2023, the first proof of concepts was made for the automatic processing of images with AI software.

Figure 79: Location of cameras, Austria. Green = existing, Blue = planned.

8.2 Process analyses for digitalisation and automation at borders or other operational stop points

Now that the background of the Checkpoints has been described within the context of different countries, the different processes at the considered operational stop points (borders, terminals and yards) will be zoomed in and elaborated. Several bottlenecks are identified and the context of international agreements, such as *Agreement on freight Train Transfer Inspection* (ATTI), is taken into account.

In the final part of this section, multiple use cases are identified and several opportunities are named where Checkpoints can contribute towards seamless rail freight traffic. These use cases vary from identification of the train composition to different damage detection technologies. In a later stage of this Flagship, a prioritization will be made among these different use cases.

Checks required before a train departure are stated in Table 27. The procedures are the same for all of the three considered operational stops (borders, terminals and yards).

1.	Check the train number, the loco number(s) and the wagon numbers.
2.	Check the sequence of the wagons and the ILUs.
3.	Concerning GCU Appendix 9 we must check the running gear, suspension, brake, wagon underframe and bogie frame, buffing & draw gear, wagon body, loads and ILUs, condition of the brake hoses, fixing points of the ILUs in the wagon.
4.	Potentially broken, rusty, bent and hanging parts are being checked.
5.	Readability of all writings, signs, pictograms, revision dates is also checked.
6.	A full brake test (if the last brake test is older than 24 hours).

Table 27: Checks needed before a train can leave a terminal, yard or border station

The technical wagon inspection is described in detail in the GCU (2023). The APPENDIX 9 to the General Contract of Use for Wagons describes the Technical Conditions for Wagon Transfers between Railway Undertakings and all necessary technical checks.

If all checks have taken place and no problems have been found, the train is ready to depart.

8.2.1 Checkpoints at borders

Every railway undertaking must make a technical inspection of the wagons at the border when taking over a train in order to guarantee its technical reliability. This obligation is governed by the *Technical Specification for Interoperability relating to Telematics Applications for Freight Services* (TAF TSI).

The basis for this technical wagon inspection is the *General Contract for the Use for Wagons* (GCU). The GCU specifies the mutual rights and obligations of Wagon Keepers (K) and Railway Undertakings (RU) regarding the use of rail freight wagons as a means of transport throughout Europe and beyond. All technical conditions for wagon transfers and inspections between railway undertakings are defined in *Appendix 9* to the GCU (2023).

To minimize the inspection effort on the borders, the International union of railways (UIC) established an *Agreement on freight Train Transfer Inspection* (ATTI). The ATTI Special Group (ATTI SG) sets the rules governing the transfer of wagons between participating RUs, based on the GCU (UIC, 2017). To facilitate international freight transport, the participating RUs undertake to comply with the current internal regulations, including appendices. The objective of the ATTI SG is to enhance cooperation between RUs, harmonizing and developing the relevant rules accordingly. It aims to allow better forward planning as well as to increase the quality and safety of trains subject to the agreement.

To main goal of ATTI is that the acceptance sampling and transfer inspection at the handover location is replaced by quality spot-checks. This means that between two ATTI participants the inspections at the borders can be omitted. There are 174 members of the ATTI (UIC, 2023).

8.2.1.1 Process description

For a train going from an intermodal terminal, through different countries and ending in another terminal the following stops and necessary operations are taken place/carried out, see Figure 80 Stops and operation opportunities for trains going cross border.

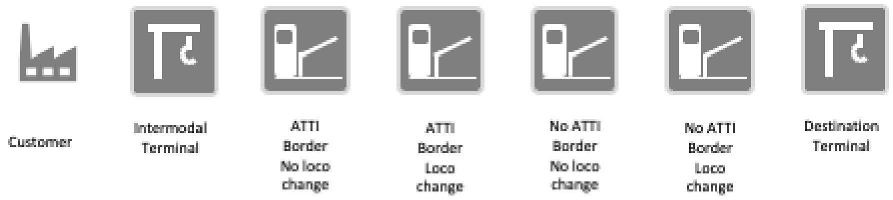


Figure 80: Stops and operation opportunities for trains going cross border

1. Intermodal terminal

Before a train can leave a terminal, the railway undertaker wagon inspector at the terminal must check the points in Table 27.

The technical wagon inspection is described in detail in the GCU (UIC, 2023). The APPENDIX 9 to the General Contract of Use for Wagons describes the Technical Conditions for Wagon Transfers between Railway Undertakings and all necessary technical checks.

If all checks have taken place and no problems have been found, the train is ready to depart.

2. First Border with handover to ATTI partner and continue with the same loco

When the train arrives at the first border and there is a handover of the train to an Agreement on freight Train Transfer Inspection (ATTI) partner and the previous railway undertaker is also ATTI partner and the ride will continue with the same loco there is no need for a technical train inspection.

If there is no change of the train driver and the train starts within 1 hour and there is no switch of locomotive – there is no need of a short brake test. If there is a change of train driver, a short brake test is going to be needed or a complete brake test if the last brake test is older than 24 hours. A short brake test can be done by one worker, while a complete brake test requires two.

The train can continue the ride without any further actions.

3. Next border with handover to an ATTI partner and a loco change

When the train arrives at the next border and there is a handover of the train to an Agreement on freight Train Transfer Inspection (ATTI) partner and the previous railway undertaker is also ATTI partner and there is a loco change there is no need for a technical train inspection at this border.

Whenever there is a change of the loco a new full brake test is necessary and after this brake test the train ride can continue.

For only a locomotive change a short brake test is enough if the last brake test is not older than 24 hours. One problem is that RUs don´t exchange time stamps about complete brake tests. In Hermes 2.1 there is this possibility, but no one in Europe, except ÖBB, is sending Hermes messages with v2.1.

4. Next border with handover to no ATTI partner and continue with the same loco

When the train arrives at the first border and there is a handover of the train to a railway undertaker who is not member of the Agreement on freight Train Transfer Inspection (ATTI) partner a full technical inspection needs to be done by the overtaking railway undertaker.

Before this train can leave the border station, the railway undertaker wagon inspector at the terminal must check the points in Table 27.

The technical wagon inspection is described in detail in the General Contract of Use for Wagons, GCU (UIC, 2023). The APPENDIX 9 to the GCU describes the Technical Conditions for Wagon Transfers between Railway Undertakings and all necessary technical checks.

If all checks have taken place and no problems have been found, the train is ready to depart.

5. Next border with handover to no ATTI partner and loco change

When the train arrives at the first border and there is a handover of the train to railway undertaker who is not member of the Agreement on freight Train Transfer Inspection (ATTI) partner a full technical inspection needs to be done by the overtaking railway undertaker.

Before this train can leave the border station, the railway undertaker wagon inspector at the terminal must check the points in Table 27.

The technical wagon inspection is described in detail in the General Contract of Use for Wagons GCU (UIC, 2023). The APPENDIX 9 to the GCU describes the Technical Conditions for Wagon Transfers between Railway Undertakings and all necessary technical checks.

If all checks have taken place and no problems have been found, the train is ready to depart.

6. Arrival at the destination terminal

There is no need for a technical inspection according to GCU appendix 9 in the destination terminal because the train arrived safely. The train will be unloaded and loaded and then checked before the next departure. After wagon inspector has handed over train documentation to consignee responsibility it is transferred to them.

8.2.1.2 Opportunities for Checkpoints

Main opportunities concerning Checkpoints on borders are:

- Support the train inspection on borders with defined checks of wagons and load for non-ATTI trains to minimize train stopping time
- Check the train composition:
    - total train length,
    - total number of wagons,
    - EVNs,
    - wagon order/train sequence (with a focus on where dangerous goods are located)
- Check that wagons do not cause damage to the infrastructure:
    - wagon outline dimension,
    - flat wheel,
    - bearings temperature,
    - damaged pantograph (if any),
    - type of load (dangerous and perishable goods),
    - type of loco (electrical, diesel or dual)

8.2.2 Checkpoints at terminals

Terminals and ports are highly dependent on correct and available information from all types of transportation mode. Today, the check of trucks, train wagons and full trains is more or less manual or semi-manual. This makes it difficult to fully rely on the information and thus to optimize the resources but also risk of incorrect information to customers. The ports and terminals can plan their activities prior to arrival when they receive correct information from the gate(s). The handover of information between the stakeholders will be easier when the information from the gates is automatically registered.

8.2.2.1 Process description

Before a train leaves a terminal, the checks are carried out according to in Table 27 and thus the following data must be registered: train number, timestamp, wagon and locomotive numbers, length and weight of the train, payload weight, weight and other information about dangerous goods (if applicable), and sequence of wagons in the train. The wagon sequencing/data check can take around 20–30 minutes. A manual check is made by the RU before leaving the terminal. The wagons brake system must be pressurized with air before the test and that takes some time. After the brake test is performed, the driver makes a rolling brake test when the train is about to leave while the train has some velocity before entering the main track. After brake test the RU must check the parking brake is off. There is an additional train building check carried out by a wagon inspector who is responsible for giving the allowance for the ride. A proper and detailed wagon inspection takes more than 60 minutes for an approximately 400 m long train.

It is also possible to include information about brake type (carbon or not). A visual control of loading status is performed as well, to check if some of the cargo is shifted outside allowed loading gauge or if some wagons seem to be overloaded. It is of significant importance to check and secure semi-trailers with king-pin.

During the visual inspection of the train, the inspector verifies the state of the brakes, the coupling sleeves, the hitch spindles, the suspension leaf spring, the thickness of the brake pads, if any screws are missing, and that the wagon does not exceed the gauge. Brake test will take some 30 minutes depending on train length.

In order to make train departures more reliable to hit the planned departing time the checking of technical components can be more efficient and precise. Then delays can decrease and more trains can be handled and thus more space for trains can be achieved. Also, the administration of the terminal is in some sites inefficient and mostly manual and can be automated in order to speed up the operations.

8.2.2.2 Intermodal loading unit (ILU) ride story

This document describes an ILU being transported by rail, possibly over borders. The ILUs are part of the economic engine that the railway is built for, hence it is crucial to facilitate the efficient handling of ILUs to be competitive with e.g. road. The following simplified Value Stream Mapping describes the customer value added during the transport.

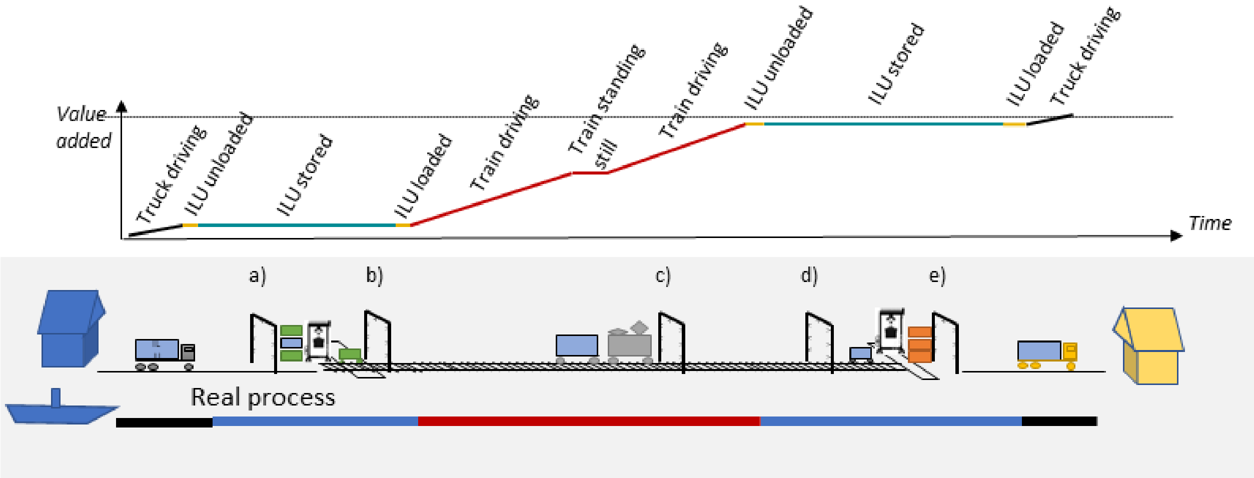


Figure 81: Value Stream Mapping with customer value added during the transport

The transport starts at the far-left end in Figure 81 where the ILU has reached a terminal by truck (road) or by ship. It ends to the far right where the ILU either reaches the end customer or is being further transported by e.g. truck again.

a) Reaching the first terminal

As it passes the gate to the terminal, the responsibility for the ILU is passed from the shipper to the terminal authorities. At this point it is necessary to check the ILU for damages and to get all "paperwork" in order: placards read and checked that they are correct according to stated cargo, customs control etc. To facilitate this, many terminals use gates and cameras to take photos of the ILU, in case the ILU is later damaged. This is to make sure that 1) the ILU was intact when it arrived and 2) the ILU is intact when it leaves the terminal. Most of the systems do not have a damage recognition software but store the photos if there is a claim afterwards by the customer.

An important note here is that (sea) containers have standardized measures and codes, while inland ILUs could be of very different formats and sizes. Also, the codes of inland ILUs vary a lot and are not standardized. This means that, for example, graffiti can be misinterpreted as a code (when nothing is known about the format or structure of the code that the OCR software is looking for).

The ILU has then to be unloaded and possibly stored waiting to be booked onto a suitable train. Storing must be done in a safe way according to regulations about dangerous goods (certain goods cannot be stored together). This is performed by the terminal operator, and different data is stored in the Terminal Operating System (TOS).

As a train is about to get loaded, the different ILUs should be reachable by the loading gear at the terminal to make the loading efficient (and thereby lessen the time the train has to be at the terminal). This could either be trucks, reach stackers or cranes. In either case, a loading scheme has to be planned. A good plan will load the ILUs efficiently. It is crucial that the loading order of the ILUs is correct.

b) ILU leaves first terminal

As the train leaves, all ILUs should have been checked that 1) they are on the planned position in the train (crucial for e.g. safety reasons as some dangerous goods cannot be loaded close to each other) 2) all ILUs are still intact 3) all ILUs are safely secured to the wagons (e.g. the king-pins of semi-trailers are firmly locked to the wagons).

If possible, a video gate can speed up the process of checking that the ILUs are intact by the exiting gate. However, it can be hard to read all ILUs since inland ILUs can be of very different formats and have local coding. This makes automatic OCR analyses of pictures harder than e.g. at ports. For example, semi-trailers have their registration numbers at the back, making it hard to take pictures of the registration plate.

c) ILU being transported

As the ILU is transported, the RU and IM are responsible for the ILU. When borders are passed, possibly the cargo must be declared and a new IM takes the responsibility. As this happens, and as different countries may have slightly different rules, the ILU may have to be checked, hence the interest in Checkpoints (Figure 81).

d) ILU arriving at the railway destination terminal

When the train arrives at the receiving terminal, the ILUs should be checked for damages as the responsibility shifts to the terminal operator from the RU and IM. The train is checked that the loaded ILUs conform to the loading list of the train. This could take a couple of hours if performed manually.

The order of the loaded units is also important as the unloading plan for the truck/reach stackers/crane is affected by the positions of the ILUs in the train.

At the terminal, the ILUs are either fetched soon after the arrival, in which case they can be stored nearby the unloading (for example, a place reachable by the crane). If the pick-up time of the ILU is not yet known, it may have to be stored in a storage in which case it has to be moved from the nearby area of the train to another position in the terminal. The storage position depends on, for example, the content of the cargo.

e) ILU checked out from last (railway) terminal

The container is stored until an "agent" (either the customer or someone hired to do the last transport) announces that the ILU is to be fetched. The ILU is removed from the storage, either by the agent themself or by terminal personnel, and the paperwork is performed. The ILU is once again checked for damages (as the responsibility is once again moved) and the ILU is possibly passing a photo portal before exiting the terminal. Customs control may apply at checkout. The Terminal Operating System (TOS) is the central data system in this process.

8.2.2.3 Opportunities for Checkpoints

Below follows identified opportunities for Checkpoints at intermodal terminals.

Processes possible to be automated and/or (partly) replaced by Checkpoints:

Checking of wagon sequence, wagon and ILU data reading (and comparing with TOS-data, parts of the technical wagon inspection and dangerous goods. Sharing of train data between terminal and train operator in an automated way.

Desired information to gather with the Checkpoints:

- Train numbers (requires matching with data from other systems)
- Timestamps

- Wagon and locomotive numbers (EVNs)
- Loading unit codes
- Length and weight of trains
- Payload weight
- Information about dangerous goods
- Sequence of wagons and loading units in the trains

Challenges/barriers:

It is very important to ensure the quality and precision of data coming from Checkpoints, especially since this is a safety issue. The detection rate shall reach a level that is sufficient for the users to improve their processes.

The potential reduction of labour force on a terminal might be limited, due to the fact that the staff on terminals makes other things than inspecting trains.

Potential benefits such as savings in terms of time/resources:

Beside technical inspection, benefits of time-saving planning at terminals will be a result. It is hard to set any numbers, but precise planning using reliable data from Checkpoints may save resources in terms of staff and infrastructure facilities (tracks, space etc).

Contribution to make freight traffic more seamless:

If the Checkpoints are providing the same level of safety as the technical train inspections, there would be a great time saving, more and better wagon data, better maintenance planning for wagons, faster hand over times of trains, better customer service, increased transparency and a reduction of the number of employees.

8.2.3 Checkpoints at yards

8.2.3.1 Process description

As stated in the introduction of chapter 8.2, checks required before a train departure are stated in Table 27 and the procedures are the same for all of the three considered operational stops; borders, terminals and yards. Thus, before starting a train from a yard some requirements are to be met: Train no, Time stamp, wagon and loco no (EVN), length and weight on train, pay load weight, UN-number (if applicable), weight on hazardous goods, and sequence (of wagons) in the train.

A visual control of loading status is performed as well, if some of the cargo is shifted outside the allowed loading gauge or if some wagons seem to be overloaded. For border crossing trains there is also the technical check of the wagon in regards to the GCU. Additionally different brake tests are necessary to ensure a safe ride.

A manual check is made by the RU before leaving the yard. The train (wagons) must be filled with air pressure before the test and that takes some time. In some yards there are stationary facilities so the loco can wait to connect to the train. After that a brake test performed before take-off and the driver make a brake test when the train is about to leave and the train has some velocity before entering the main track.

8.2.3.1.1 Single Wagonload ride story

Single Wagonload (SWL) is a system that collects wagons from multiple origins of shippers, consolidates them into a freight train at the origin marshalling yard and transports them by rail to destination marshalling where the rein is split up and wagons shunted to multiple destinations to consignees, as Figure 82. Stops at intermediate marshalling yards can also occur.

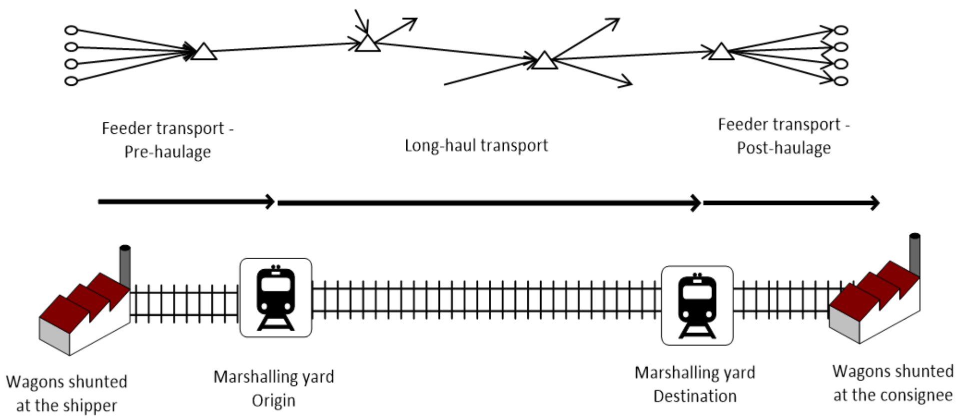


Figure 82: Illustration of Single Wagonload (SWL) traffic

(modified from source: (C4R D2.1, 2017))

It can be one wagon in a specific transport connection (from Origins to Destinations, so-called OD pairs) or groups of wagons. Typically, the wagonload transport starts with feeding single wagons or wagon groups from their origin to the first collecting spot. In the next step, the wagons are assembled to a full train for the respective line haul. After the transport, wagons or wagon groups are distributed to their final destination. Access points for wagonload are customer sidings, public freight stations, terminals or rail ports as well as river ports with rail connection. Border-crossing line-haul trains regularly connect marshalling yards and build the backbone of the international wagonload network.

During the transportation the wagon(s) undergo shunting at the origin, then running in a local train or feeder train to a local flat yard. There the wagon(s) are assembled in larger units or trains. From the local yard the wagon(s) are running to a hump yard.

On the marshalling yard, the wagons are classified or organized into long haul trains. The composition of trains consists of multiple OD's and different customers goods.

8.2.3.1.1.1

8.2.3.1.1.2 Wagons used

The wagons used in SWL differ between wagon owners and train operators, it can be the rail companies own wagons or it can be wagons owned by others. Prior to Cotif99, *Convention concerning International Carriage by Rail* (OTIF, 2023b) these wagons were named private wagons. There are numerous wagons owners, some rent out on long term basis and some on short time. The wagons can be of many shapes, there are single boogie, double bogie or more bogies. The wagons are divided into open, closed (box), flat and a range of special fleets.

In the customer contracts it can be stated which type of wagons can be used and that can be any of above mentioned. The final rate for the transport is decided when the SWL transport is called-off from the contract. It depends on access of wagon type and, if stated in contract, the payload. There may also be some priority rules in the contract.

8.2.3.1.1.3 Train classification

When the trains arrive to the hump yard the classification process begins. Normally the yard consists of three parts; the arrival zone, the classification tracks and the departure zone. The order of trains running over the hump is decided for numbers of reasons. The factors are booked or transfers between the arriving trains and departure ones. If all trains are in the right time the transfer will be done according to operational plan. However, the operational plan is often changed due to various reasons. It can be late drivers, failure on vehicles, main line situation or lack of free track utilization. Not a single day at yard is the same as the day before, due to the concept of SWL, whose competitive edge is the capacity from all to all. Planners must have all these factors in mind in order to find the best solution for the customers. At a big busy yard, it's a complex puzzle to solve.

After the classification has been finished, the trains move to the departure zone where the technical procedures are done e.g. brake test or inspection. The inspection may also be done at the arrival tracks.

8.2.3.1.1.4 Freight contract

In the contracts, the price of transport is displayed as well as type of wagon(s) possible to use and the OD pairs. Normally there is a certain volume for the contracts that should be fulfilled, but that may vary between rail companies. In some contract the customer may have certain transport plans stated that not shall be broken.

8.2.3.1.1.5 ETA, deviations and customer alerts

When the booking of a SWL transport is made the customer receives an ETA. This ETA can be very precise or a specific time space depending on the operator's ability to plan and collaborate with others, especially in border crossing operation.

If a deviation occurs, the customer will be informed and the rules for that varies in terms of time alerts, the customer's own needs and possibly also how to deal IT-wise.

8.2.3.2 Opportunities for Checkpoints

Below follows identified opportunities for Checkpoints at yards.

Processes possible to be automated and/or (partly) replaced by Checkpoints

Checking of wagon sequence, wagon master data reading (and comparing with our own base data base), checking of axle sound (flat spots on wheels), wagon weight check and distribution per axle and parts of the technical wagon inspection, dangerous goods.

Desired information to gather with the Checkpoints:

- Train numbers (requires matching with data from other systems)
- Timestamps
- Wagon and locomotive numbers (EVNs)
- Loading unit codes
- Length and weight of trains
- Payload weight
- Information about dangerous goods
- Sequence of wagons in the trains

Challenges/barriers:

It is very important to ensure the quality and precision of data coming from Checkpoints especially because this is a safety issue.

It might be limited reduction of labour force on a yard due to the fact that its lots of staff on yards and multiskilling among people.

Potential benefits such as savings in terms of time/resources:

Beside technical inspection benefits time saving planning on yards could be a result. Hard to set any numbers but precise planning upon reliable data from Checkpoints may save resources. In terms of staff and infrastructure facilities (tracks, space etc).

Contribution to make freight traffic more seamless:

If the Checkpoints are providing the same level of safety as the technical train inspections there would be a great time saving, more and better wagon data, better maintenance planning for wagons, faster take over times of trains, better customer service and transparency with additional data and fewer staff at the stations.

8.2.4 Connection from Checkpoints to traffic management on main lines

Freight trains are trains that depart from point A and are destined for point B. At point A, terminal A, the goods are loaded and at point B, terminal B, the goods are unloaded.

The infrastructure manager (IM hereinafter) is the company responsible for providing the path on the track, so that this train can circulate between the two points, with safety and punctuality conditions.

The train management system (TMS hereinafter) will be the tool used by the infrastructure manager to:

- manage the request for the track path by the operator prior to its circulation.
- manage the entry into the train track path, with all the information about it that allows it to circulate safely: goods being transported, length, weight, etc.

First step, track path request: the infrastructure manager must know in advance a series of information about the train, which will allow the IM to provide the appropriate track path. Later this information will be expanded with more information, so that this train can access the path.

Second step, obtaining the path: with this prior information, the IM infrastructure manager generates a train number, as well as a path on the track, for its departure. All this information will be collected in the TMS.

The automatic inspection gantry (Checkpoints hereinafter) will confirm or validate the information that has been entered into the TMS.

If these two pieces of information, that entered in the TMS and that of the Checkpoints, do not coincide, there will be traffic management problems. For example, in the case of measuring in the Checkpoints a train length greater than that declared in the TMS, there will be no diversion tracks to remove the material on commercial tracks, causing problems in the normal performance of circulation.

Table 28 includes the main information *currently* shared by RU and IMs for traffic management and the *desirable* information that can help the digitalisation of this process;

related to the *possible technologies* that may be used to monitor or collect this information and the intended *use of these data*. Table 28 has been analysed from the point of view of *FP5-TRANS4M-R* (freight traffic) and *FP3-IAM4RAIL* (passengers/freight traffic).

Required information TMS	**Data** used**	**Possible Technology**	**Focus of FP 5**	**Focus of FP 3**	**Use of data**
Train operator	Currently	Not with WMS (Wayside Monitoring System) as Locomotives can be on loan	no	no	operation
Origin / destination	Currently	Not with WMS	no	yes	operation
Type of dangerous/non-dangerous goods	Currently	Checkpoints Detection of placards	yes	yes	Operation / Maintenance
Departure/arrival time	Currently	Checkpoints	no	yes	operation
Total length of the train, wagon and locomotive	Currently	Checkpoints or Wheelset counter or Wayside acoustic system	yes	yes	operation
Number of total axles	Currently	Checkpoints or Wheelset counter or Wayside acoustic system	no	yes	operation
Number of axles per wagon and locomotive	Currently	Checkpoints or Wheelset counter or Wayside acoustic system	no	yes	Operation / Maintenance
Total weight / wagon / locomotive	Currently	Weighing in Motion or Track weighing of wagons	no	yes	Operation / Maintenance
Wagon / locomotive EVN	Currently	Checkpoints Simple OCR-detection	yes	yes	Operation / Maintenance
Brake type (Passenger or freight)	Currently	Checkpoints Check the G / P lever position	yes	yes	Operation / Maintenance
Towed / braked mass	Currently	Checkpoints	no	yes	Operation
ATP* type (ERTMS/LZB/ASFA)	Desirable	From the vehicle registration (e.g. database ERATV) https://eratv.era.europa.eu/Eratv/Home/List	-	no	Operation
Maximum locomotive/wagon	Desirable	Checkpoints reading the	Yes (especiall	no	Operation

speed (allowed and current speed)		inscriptions	y for wagons)		
Locomotive or wagon maintenance date	Desirable	Not with WMS Data should be transferred directly	no	yes	Operation / Maintenance
Disc brake or shoe information	Desirable	Checkpoints Brake Pad detection Disks are not visible	Yes (only Brake Pad)	no	Operation / Maintenance
Brake shoe alarm	Desirable	Images and IA	yes	yes	Operation / Maintenance
Axle bearing alarm	Desirable	Wayside acoustic system	yes	yes	Operation / Maintenance
Maximum weight alarm per axle / wagon	Desirable	Track weighing Checkpoints (spring loading)	Partly (Spring loading)	yes	Operation
Car suspension alarm (hydraulic system and springs)	Desirable	Depends on damage type (images and IA)	no	yes	Operation / Maintenance
Pantograph alarm	Desirable	Checkpoints (only with camera from above)	no	yes	Operation / Maintenance

Table 28: Main information shared by IM and RU about TMS. Alignment FP5-FP3

*ATP automatic train protection

** Currently: data already used at different RUs; Desirable: information that is not identified by any Checkpoints

8.2.5 Considered use cases

Following the process considerations, use cases were identified and considered in terms of their benefits and the information required to gain a detailed understanding of each case. The use cases are presented below and the associated benefits are described based on the required process change.

Firstly, categories were created to identify the use cases and the rough classification of the relevant process topics was evaluated. The following figure (Figure 83) shows these categories. The relevant items from the process analyses were included under the categories. It can be seen that some topics, such as markings recognition, are relevant in almost all process steps. Based on this classification into categories, it was possible to

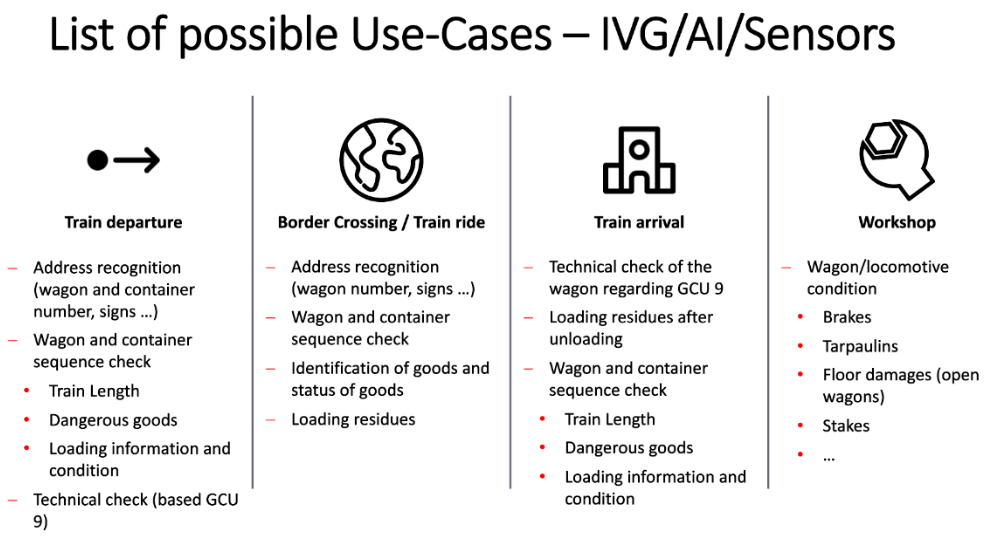


Figure 83: Categories of possible use cases

derive how the focus should be set with regard to the identification of use cases.

For the further procedure in identifying the individual use cases, the topics address recognition on wagons and cargo and the necessary checks for the release of a train (described in GCU Appendix 9), which are dealt with in the GCU, were prioritised on the basis of the present categorisation. In addition, other use cases were identified and included in the evaluation. In order to gain a common understanding of each use case, a template shown in Figure 84 was created to describe these use cases in a comparable way.

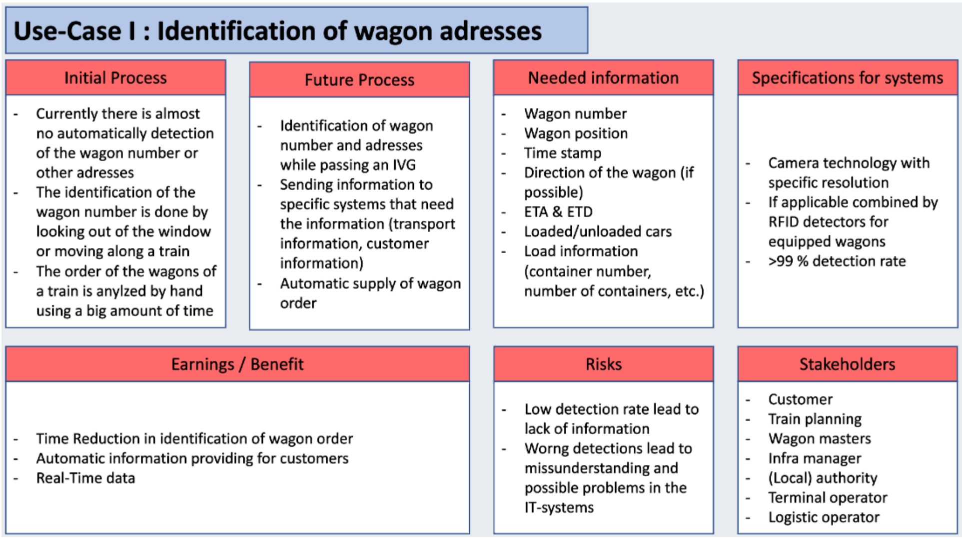


Figure 84: Template for the description of Use cases

During development, a large number of different use cases have been identified, based on the use of the Checkpoints, but also on the use of additional sensor systems. In the following, the use cases are listed in Figure 28 in relation to the technology to be used and then described in detail.

Use cases	Short information	Category
Identification of wagon markings / inscriptions	- Identification of wagon markings - System comparison of data - Increasing quality of information for Maintenance and operation	All
Loading residues	- Identification of loading residues - Decrease cleaning / waiting times for wagons - Increase efficiency in loading processes	Train arrival and departure
Identification of damages on wagons or goods	- Identification of damages on goods - Increase data quality for the use in insurance cases	Operation
Identification of goods types	- Increasing information quality for receiver and RU - Increasing efficiency in Unloading process	Train arrival / Unloading process
Bearing detection	- Identification of leakages and thermal traces - Avoiding of consequential damages	Maintenance and operation
Spring damage	- Identification of cracks	Maintenance

detection	- Increase safety	and operation
Spring loading detection	- Height measuring - Indication of overloading	Operation, Train departure
Brake Pad measuring	- Measuring of Brake Pad thickness - Increase of Lifetime - Decrease of maintenance costs	Maintenance and operation
Detection of unclosed doors and roofs	- Increase safety	Operation
Buffer detection	- Damage detection	Maintenance and Operation
Tarpaulin covers / Floor detection	- Decrease maintenance costs - Decrease costs for wagon transports to customers	Maintenance and Operation
Customer information	- Data transfer to all stakeholders - Interpretation of Cases	Operation
Axle analysis	- Digital / Optical check of Axle - Digital EVIC - Reduce time for checks - Continuous check to increase safety	Maintenance and operation
Information for infrastructure manager	- Essential information to wagons, loading and material - Increase safety in emergency cases	Operation
TOS-Integration	- Decrease waiting times for logistics operators - Increase efficiency in loading /unloading processes - Optimization of terminal resources, automating processes	Operation
Wheel Profile measurement	- Measuring of Wheel Profile (11 measures) - Increase safety - Decrease maintenance cost for wheel set - Increase Lifetime of Wheelset	Maintenance and operation
Wheel flat spots detection	- Detection of flat spots - Decrease damages on infrastructure and wagons	Maintenance and Operation

Table 29: Short description of possible Use cases

Presentation of use cases

In the following chapter, each use case is described qualitatively in terms of the current process, the future process, the benefits, but also the risks and the necessary technical specifications. Both the benefits and the technical specifications are considered here in broad terms, as these will be examined in more detail in the following chapters, and the detailed development of one or more use cases for the demonstrator will take place in the context of WP 29.

8.2.5.1 Identification of wagon markings / inscriptions

Figure 85: EVN on a freight wagon

The use case for marking / inscription recognition on wagons is to read all the information attached to the wagons, such as the wagon number, compare it with the system data and forward it to the recipients. An example of a wagon number (EVN) on a freight wagon is shown in Figure 85. The aim is to compare the wagon data with the system data in real time to ensure, among other things, a higher quality of information. In addition, the early provision of information is expected to reduce shunting times for customers and RUs.

Initial / Current process

At present there is almost no automatic detection of wagon numbers or other items (codes and placards) that are required to be detected. The wagon number is identified by looking out of the window or by moving along the train. The order of the wagons in a train and the information for dangerous goods are analysed and provided manually, which takes a lot of time. In addition, the infrastructure manager checks the data randomly and not in every case. All in all, only the detection rate does not exceed 90%.

Future process

Wagon inscriptions are automatically identified as they pass through the Checkpoints. The information is then sent either to a central system or to dedicated systems at individual RUs. This allows wagon sequences, dangerous goods placards and other information to be systematically compared and appropriate action to be taken.

Information provided by checkpoints

For the implementation of the use case, the following information is to be recognised when passing through the Checkpoints:

- Wagon number
- Wagon position
- Time stamp
- Direction of the wagon (if possible)
- Loaded/unloaded cars
- Load information (ILU number, number of containers, etc.)
- Dangerous goods information

Specifications for the Checkpoints

In order to recognise the required detection items, the Checkpoints must meet certain requirements. Only a sufficiently accurate recognition can be used for automatic OCR. Ideally, additional RFID readers should be installed to read out wagons equipped with RFID. In addition, the differentiation of wagons should work unambiguously to enable the use of the technology regardless of the installation location (free track, hump) and at different speeds up to 120 km/h. The recognition target for this use case should be over 95% in order to offer a significant advantage over the current process.

Earnings / Benefits

These use cases offer a wide range of potential benefits. For example, in addition to improving the quality of information, it is possible to optimise the provision of information to infrastructure managers and customers. They can use the data in real time to optimise processes such as the loading and unloading of wagons. This can reduce times throughout the production process and get trains back on the track faster.

Wagon number recognition also eliminates the need to send wagons to workshops for inspection or correction, as wagon markings can sometimes be changed on the track. By avoiding shunting in general, time can be saved, especially during train formation, and departure punctuality can be improved.

Another advantage is the quick detection of vandalism, as wagons are marked in the appropriate areas, as well as unauthorised changes to wagon markings by third parties.

Risks

The main risk in implementing the use case lies in the detection rate of the results. In order to be able to guarantee an appropriate process adjustment, the recognition rate must be close to 100%. This avoids possible additional steps in the process, as well as inconsistencies, incorrect wagon deliveries or incorrect information allocation in the freight documents. The greatest risk lies in the processing of potentially incorrect information in existing IT systems. This can lead to data inconsistencies and thus problems in the processing of systems that are also necessary for operations. Therefore, a countermeasure or a review of the results makes sense.

Stakeholders

The wagon marking information, such as the wagon number, is of interest to many parties. Below is a list of some of the potential interested stakeholders:

- Customer
- Train planning
- Wagon inspector
- Infrastructure manager
- (Local) authorities
- Terminal operator
- Logistic operator

Depending on the stakeholder, other information may be relevant and must be provided via the appropriate IT interfaces.

8.2.5.2 Loading Residues

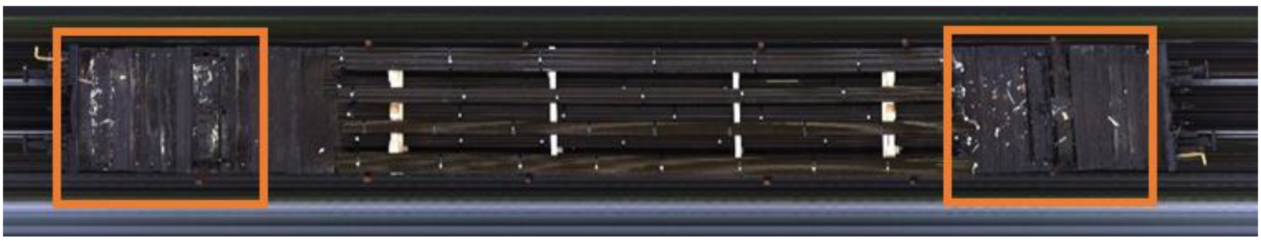


Figure 86: Loading residues on a freight wagon

The use case for the identification of loading residues can optimise the loading process of the customers and in long term reduce the number of wagons with loading residues. By using cameras that take pictures from above a new perspective of the freight wagon is given which is normally not easy to reach. An example of a freight wagon with loading residues is given in Figure 86. Unfortunately, the interpretation of loading residues is a mostly personal decision of the wagon master, customer or maintenance workers. This leads to a different measuring and classification of loading residues.

Initial / Current process

In the current process there is no information about the residues in the wagons. After unloading the wagon, the customer has to return it to the RU in a clean condition. In some cases, there are still loading residues inside the wagons. Sometimes, especially in winter, the residues are stick to the bottom of the wagon because of ice. But sometimes the customers didn't clean up the wagon before sending them back and so the next customer has to clean before he can load his goods on the wagon. This results in additional costs for the cleaning and the loss of time because the unclean wagon is only recognised during loading and thus loading has to be stopped until the load residues have been removed.

Future process

In the future process the identification of the loading residues is made by the Checkpoints. If the wagon passes a Checkpoint on return from the customer and loading residues are detected, the cost of cleaning can be claimed from the causer. After detecting a wagon with loading residues, the new customer can be informed before the wagon arrives so that he can calculate the time for the additional cleaning and optimate the loading process of remaining wagons by separating the unclean wagon. Also, if it is possible the wagon can be exchanged for a clean one, so that the receiving customer receives an empty and clean wagon.

Information provided by checkpoints

For the implementation of the use case, the following information is to be recognised when passing through the Checkpoints:

- Wagon number
- Time stamp
- ETA & ETD
- Status: Loaded/unloaded cars
- Loading residue information

Specifications for the Checkpoints

In order to be able to recognise loading residues in open wagons the Checkpoint needs a camera that takes pictures from above so the Checkpoints must have a crossbar at the top of the frame to mount the camera. Another option could be two cameras looking into the wagon from the sides above the wagon. In that case, no crossbar would be needed. Another technical option is the install of a Weight in Motion (WIM) systems which measures the load of every axle of the running freight wagon. This system is also useful for closed wagons.

Earnings / Benefits

The recognition of loading residues brings up various benefits. One is the reduction of the time for cleaning the wagons because the new customer is informed about loading residues before the wagon arrives and has the possibility to change his loading process. Another benefit is the cost reduction for the claim of resource. The most important advantage is that the causer of the loading residues can be identified and bear the costs for cleaning so that the number of dirt wagons will be reduced continuously (learning curve).

Risks

In addition to the advantages mentioned the use case also entails risks. On the one hand, the use is limited to freight wagons that are open at the top. On the other hand, the decision whether a wagon still contains residual loading is very subjective and depends on which products are to be loaded into the wagon next.

Stakeholders

The identification of loading residues is interesting and useful for different parties. The customer profits if he gets the information that a wagon is not clean early so that the sequence of loading can be changed. The use case is also interesting for the following parties:

- Terminal operator
- Train planning
- Logistic operator
- Railway undertakings

8.2.5.3 Identification of damages on wagons or goods (operation insurance)

Figure 87: Corrosion on a freight wagon

One of the tasks within intermodal transportation, and it is a task of great importance in the transportation of goods, is to ensure that the goods to be transported reach their destination without suffering any damage and are in perfect condition.

Intermodal transport includes different means of transport, such as sea, rail and truck. In each of these modes of transport, the loading and transporting company checks that upon entry and exit the goods are in perfect condition and have not suffered any damage. The wagon in Figure 87 is damaged by rust which was caused by humidity in combination with damage to the paintwork. If the corrosion expands along the freight wagon the carrying capacity and the safety of the freight wagon will be reduced. Therefore, such damage must be detected and repaired as soon as possible.

Initial / Current process

The containers of goods that enter the terminals can be damaged either during handling in the terminal itself or during intermodal transport, therefore, a task that would allow us to determine where the goods have been damaged would be through Checkpoints, which would be in charge of verifying that at the entrance of the terminal the goods enter without any damage, as well as that at the exit is the goods are in perfect condition. This entrance to the railway terminal can be sea or land.

Currently some terminals take photos of the goods upon entry and exit in an automated manner.

Future process

In the future, we intend that knowing the state of the goods can be done through an automatic system, which photographs the state of the goods at the entrance and compares it with its state at the exit, in order to determine that in rail transport, the goods have not suffered any mishap or damage. This system would use OCR cameras to associate the status of each container entering and exiting the railway terminal.

Information provided by checkpoints

- goods entry route
- loading unit number
- state of the goods at entry and exit

Specifications for the Checkpoints

Optical character recognition system:

- In the land terminal inlet and outlet
- In the railway terminal inlet and outlet

Earnings / Benefits

The damage that goods transported by the railway may suffer represents a high cost to the operator and a loss of credibility to the entire railway transport, which is why one of the benefits of the Checkpoints installed in terminals will be to guarantee the condition of the cargo from the origin to the destination, as well as being able to discover failures in the transport chain and being able to correct them to avoid new accidents and deterioration in the goods. This Checkpoints will detect differences in goods containers between the entrance and exit of the terminal.

Risks

In the night, with rain or with snowstorm we cannot be sure to have an accurate result.

Stakeholders

- Infrastructure manager
- Railway undertaking
- Loading company

8.2.5.4 Identification of goods types

Figure 88: Freight wagon loaded with metal swarf

Identifying different types of cargo can improve the quality of transport information and speed up loading and unloading processes. For example, the accurate identification of a goods type (e.g. type of scrap) helps the customer to immediately manoeuvre the wagon to the correct unloading point or to generate subsequent shunting activities of several wagons. In this way, unprofitable wagon times can be avoided and the wagons can be returned more quickly to actual economic transport operations. For example, the scrap type loaded inside the freight wagon in Figure 88 is metal swarf.

Initial / Current process

In the current process, information about the goods is recorded on transport sheets and entered into the systems. The correct completion of these sheets is relied upon, as it is not possible for an employee to manually or visually check each wagon. This can sometimes lead to inaccuracies in the transport data, for example because the shipper and the consignee may see differences in the goods being transported. In some cases, this can lead to unnecessary shunting by the consignee, particularly during unloading, because the wagon has been taken to the wrong unloading point based on the information available.

Future process

In the future process, the use of Checkpoints can support the verification process. By automatically visually inspecting the contents of open wagons, this information can be compared with the transport data and inconsistencies highlighted. With this advance information, RUs and consignees can react at an early stage and direct the wagon to the correct unloading point. A first evaluation of the process optimisation at DB Cargo in the area of scrap transport showed that the accuracy of the transport information can be increased from around 90% to over 95%.

Information provided by checkpoints

To implement this use case, the loaded goods must be identified. This requires a great deal of learning on the part of the system in order to be able to distinguish the individual goods in terms of shape and type. This identified information must then be linked to the wagon information (wagon number) in order to integrate it into the appropriate system interface.

Specifications for the Checkpoints

The specifications for the Checkpoints are fundamentally different here, as they depend on the type of goods as well as the wagon. For most of the goods transported, cameras are needed from above, as it is mainly bulk goods, scrap and other goods that are transported in open wagons (e.g. Ea wagons – an open wagon type used for the transportation of goods like scrap). Due to the high outer walls, it is only possible to see inside the wagon from the top. For some other goods (steel), the side camera can also be used if flat wagons are used.

However, the resolution of the camera must be high enough to see details.

Earnings / Benefits

As already described, the load check can not only improve the quality of information, but also avoid possible shunting. It can also be used to identify asymmetric or incorrect loads that affect wagons and track.

Risks

The biggest risk or challenge is the learning curve of such a system for different commodities. In most cases, goods are classified and valued slightly differently for each customer, so the necessary software has to be adapted for each type of goods. In addition, this tool is an extension of current transport information systems. With automatic goods recognition, shippers would not need to document this information as it is automatically recognised. However, this eliminates a database and therefore a fallback level.

Stakeholders

Stakeholders are:

- Railway undertakings
- Customers of railway undertakings

8.2.5.5 Bearing detection

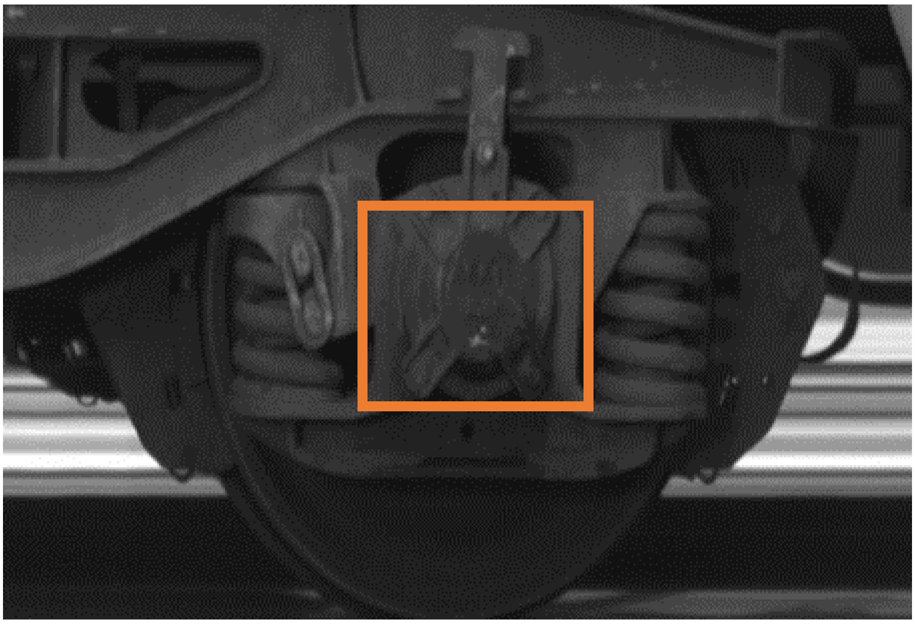


Figure 89: Bearing with leaking oil

The wheelset bearings of a vehicle are a safety-related device on the freight wagon for safe transport. To ensure that they are in good working order, the wagon foreman must carry out regular visual inspections during the outward journey. However, the wagon foreman can only detect leaks (Figure 89) or damage that has already occurred during his visual inspections. To prevent damage to bearings and wheelsets due to overheating, the Checkpoints can be used for thermal monitoring of bearings. This makes it possible to detect thermally stressed bearings at an early stage and initiate maintenance measures to prevent damage.

Initial / Current process

In the current process, the bearings and bearing housings are visually inspected during operation by the wagon inspector. For example, leaking oil as seen in Figure 89 could be detected by a visual check. Further checks are only carried out in the workshop. Therefore, the actual condition of a bearing is not known while the wagon is in motion. Furthermore, apart from checking for leaks, no thermal measurements are taken. An overheated or thermally stressed bearing can also only be visually identified by the resulting damage.

Future process

In the process supported by Checkpoints, damage such as leaks, fractures, cracks and thermal stress can be detected at an early stage. This allows action to be taken to prevent damage during transport. The resulting information must be made available to the next wagon foreman so that he can make a decision on the actual damage with the supporting data base. Another technical solution additional to a visual identification of bearing damages is the use of microphones to identify unusual sounds of damaged bearings.

Therefore, characteristic sounds will be compared. The combination of both systems can increase reliability.

Information provided by checkpoints

In order to check the wheelset bearings for insecurity, several points need to be checked. It is also important to be able to match the bearings to the car and wheelset.

To check for damage, look for leaks (liquids on the bearing), cracks in the bearing housing and thermal marks.

If a bearing is found to be damaged, this must be combined with the exact location of the bearing in order to determine its reliability. This requires the wagon number, axle number and installation side.

Specifications for the Checkpoints

A high-resolution camera is needed to check for damage. A thermal imaging camera is also required for thermal observation. This must also be set to provide a temperature profile over the entire bearing. Optionally, acoustic systems (e.g. ABD – Axel Bearing detector) can be added to the system to check for bearing damage. In case of HABD (Hot Axle Bearing detectors), position of the checkpoint to properly capture hot elements should be far enough from the starting location.

Earnings / Benefits

Early detection of wheelset bearing damage can reduce the time spent inspecting wagons and shunting them in the event of anomalies. For this purpose, the information must be communicated to the relevant persons in advance. In addition, consequential damage can be avoided and maintenance costs reduced. Wheelsets in particular, which are the most expensive item to maintain, are often damaged by defective bearings.

Continuous recording of the condition of the bearings can also be taken into account in maintenance and operational planning. This allows wagons to be better managed based on their current condition, avoiding the need for shunting or breakdowns.

Risks

The main risk in bearing monitoring is thermal assessment. In order to detect thermal overload, the wagon must have already travelled a certain distance. If such damage is detected during the journey, it can lead to direct intervention in the train's running and the stopping of an entire train. In this case, the adaptation of the wagon must be checked in detail. In addition, an inaccuracy is introduced by measuring at only one point during the journey. External influences can lead to increased temperatures, but these are not indicative of bearing damage. Covering the bearing at several points to check this seems necessary, but is partly in contradiction with the first point.

Stakeholders

Information about defective bearings is essential for the following stakeholders:

- Railway Undertaking
  - Wagon inspector
  - Maintenance / workshop
  - Safety
- Wagon keeper (Maintenance)
- Infrastructure manager

8.2.5.6 Spring damage detection

The aim of these use cases is to continuously check the condition of the suspensions and to act in case of damage. With the help of the Checkpoints, this check should be automated and continuous. The information from the detection is then used to support various people in the process to check the operational safety of the vehicle and to take action at an early stage if necessary. In addition, the continuous provision of information can be used proactively in various process steps, such as wagon planning or maintenance.

Initial / Current process

In the current process, the only time springs are checked for damage is during the technical inspection of the wagon before departure and during stops in the workshop. This inspection is carried out visually by the wagon technician or maintenance officer. If the wagon technician finds any damage to the suspension, the wagon must be taken out of service and discarded.

Future process

In the future process, suspension shall be inspected for damage such as cracks or breaks at an early stage. This information is to be made available to the relevant wagon foreman as soon as possible so that he can act accordingly.

Information provided by checkpoints

As with the applications already mentioned, the necessary information is information about the damage, the wagon number and the assignment to the corresponding wheelset as well as the wagon side.

Specifications for the Checkpoints

Cameras with high resolution are necessary for the detection of cracks and fractures.

Earnings / Benefits

Early detection of suspension damage can speed up the inspector's inspection and decision-making process, and thus the train provisioning process. In addition, early detection can prevent consequential damage to wheels and bogies, thereby reducing maintenance costs. Continuous monitoring also optimises wagon planning, as countermeasures can be taken earlier in the event of failures.

Risks

The risks in this application are mainly safety related. A trolley with a damaged spring cannot be used and must be discarded. If this information becomes known during the journey, a decision must be made on how to deal with it.

In addition, the camera can only inspect the outer springs. A crack or break in the inner spring cannot be seen, so visual observation in the track is essential. In addition, there are wagon types where the springs are not visible due to special design features.

Stakeholders

Interested persons are:

- Railway Undertaking
    - Wagon inspector
    - Maintenance
    - Safety
- Wagon keeper (maintenance)
- Infrastructure manager

8.2.5.7 Spring loading detection

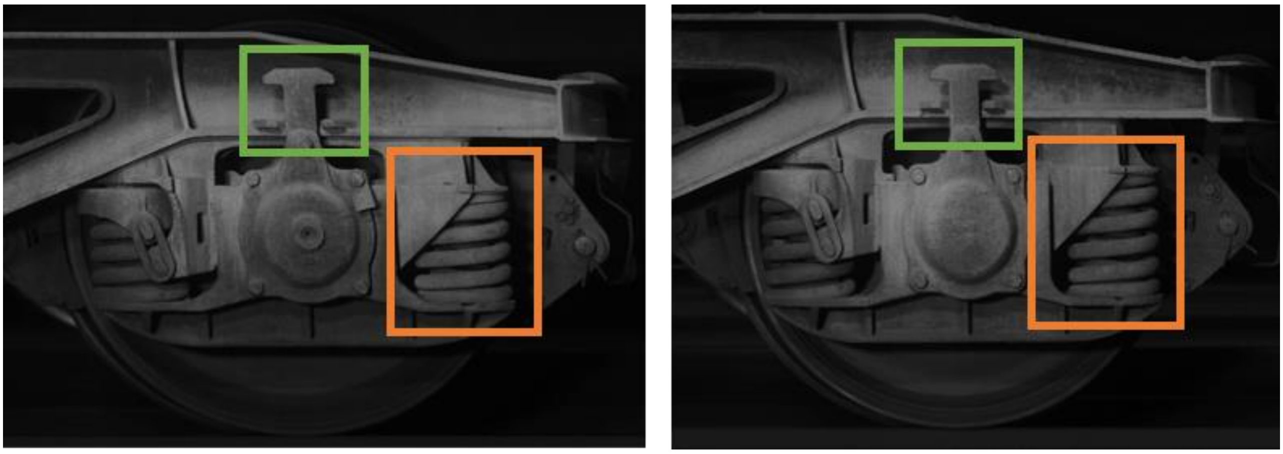


Figure 90: Loaded spring (left) and unloaded spring (right)

By measuring the height of the spring, it is possible to draw conclusions about the load on the wagon. In Figure 90 a loaded spring (left) and an unloaded spring (right) is compared to each other. As no measurement of the actual load is available, this test can be used to indicate whether the wagon is supposedly overloaded. This information can be stored in transport information systems, and RUs and infrastructure managers can take action.

Initial / Current process

It happens all the time that wagons are overloaded during loading, causing damage to the wagon and the track. This can be due to incorrect information on the wagon or improper loading. At present, the wagons can be weighed at the consignor's track scales, but no comparison can be made with the loading status of the wagon. In addition, the wagon can only be weighed as a whole, whereas the empty weight of the wagon is also taken into account.

Future process

In the future process, the loading condition can be determined via the spring height or the distance of the lift-off protection (marked by the green box in Figure 90). This information can then be integrated into various systems (e.g. TMS). It is also possible to measure the height of the springs on both sides of the car and the springs of both bogies that make up the car to compare them with each other and identify unevenly loaded or overloaded cars.

Information provided by checkpoints

Relevant information that would have to be provided by Checkpoints would be the measurement of the spring height, wagon number, axle number and wagon side.

Specifications for the Checkpoints

- Cameras with high resolution to measure the wagon spring height without and with load
- Validation components for measurement (Conversion of pixel into mm)
- Checkpoints in the inlet and outlet of the Terminal
- For weight and unbalance checks, the Weight in Motion (WIM) system is usually preferred because it is much less expensive than Checkpoints. Normally these systems are installed at terminal entry/exit points.
    - Maybe a combination of these systems could be possible to reduce the requirements for the Checkpoints.

Earnings / Benefits

The main advantages of measuring the load status are the early detection of possible overloading, the prevention of resulting damage to the infrastructure and the avoidance of possible accidents. It is also possible to compare the loading status with the transport information.

Another possible use of the information is for use case 8.2.5.6 Spring damage detection, as the height can be used as an indicator of broken spring equipment.

Risks

As in the previous use case, only the outer springs can be measured and not all springs are visible due to the trolley construction. The different spring types also play a role, as this can lead to misinterpretations by the system.

A major challenge is the correct measurement of the spring height, as this can lead to inaccuracies on pictures. A corresponding reference component to determine the scale is necessary here.

Stakeholders

Stakeholders are:

- Railway undertakings
- Wagon masters
- Maintenance / Workshops
- Infrastructure manager
- Customer (learning effect)

8.2.5.8 Brake pad measuring

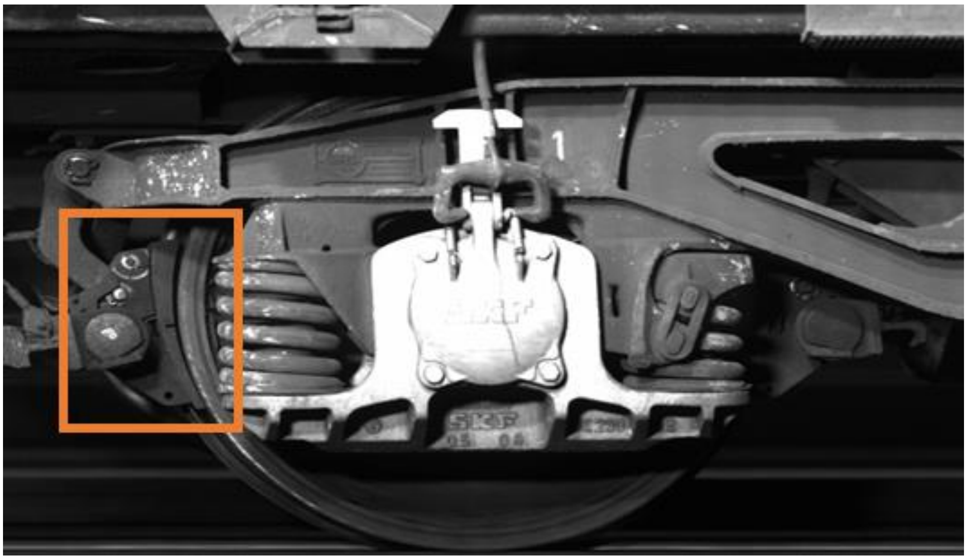


Figure 91: Worn brake pad

The brake pads of freight wagons are safety-relevant and highly stressed components. Regular inspection and maintenance are therefore very important. To increase the safety of the freight wagons, the wear of the brake pads is to be determined automatically by Checkpoints. The data obtained can be used to optimise the timing of brake maintenance so that the brakes will then be changed neither too early nor too late. This can reduce maintenance costs and conserve resources.

Initial / Current process

In the current process the measuring of the thickness of the brake pads takes place only inside the workshop. On the track there are only visible checks which referring to the groove on the brake pad that marks the minimum brake pad thickness of 10 mm. If the result of the visible check is not ok, the brake pads will be changed by a component-based maintenance. This poses the risk that the wear of a brake pad is detected too late, thus affecting the safety of the entire train. If the train must stop the customer is waiting for his goods which isn't a good image for the service provider. An unplanned maintenance could also cause waiting time because of not available spare parts. Additional there are already wagons in the workshop which cause waiting time until the damaged wagon could be repaired.

Future process

In the future process the thickness of the brake pads will be measured while the freight wagon is driving through the Checkpoints. Therefor the brake pads and the corresponding parts have to be indicated by the Checkpoints whereby also missing parts could be identified. The information of missing parts or worn brake pads is going to be saved in different systems Figure 91 a highly worn brake pad is shown as an example that could be detected by the Checkpoints.

Information provided by checkpoints

For the implementation of the use case, the thickness of the brake pad must be measured during the passage of the freight wagon through the Checkpoints. The requirements for the system are defined in more detail in specifications for the Checkpoints. In addition to the information about the thickness of the brake pad, the wagon identification number, the axle number and the wagon side must be recorded so that a clear assignment of the defective brake is possible.

Specifications for the Checkpoints

In order to measure the thickness of the brake pads, the camera at the Checkpoints needs a high resolution to obtain accurate results. The pictures made by the cameras will be analysed by a computer which converts the number of pixels into millimetres. Therefore, a reference component in the near of the brake pad is needed to calculate the correct scale of the image. In addition to the high-resolution camera, a laser beam optimises the results of the measuring.

Earnings / Benefits

The measuring of the brake pad thickness by the Checkpoints enables the change from a reactive to a predictive maintenance. Thus reduces the time for changing the brake pads because of the ability to plan brake pad changes. If a freight wagon passes Checkpoints in regular time intervals and the thickness of the brake pads is measured then, the data could by analysed and give useful statistical information. Anomalies can be detected, allowing conclusions to be drawn about the condition of the brakes for example if one brake is worn more than the others it has to be checked if the brake is blocked. With the collected data, a prediction of the averaged wear can be made for frequently travelled routes, allowing route planning to be optimised. The frequent of brake pad changes could be reduced by optimized route planning.

Risks

The accuracy of the result depends on the resolution of the camera. Thus, the result contains inaccuracies. The detection of the brake pads isn´t easy in every case. Sometimes the brake pads aren´t visible or the amount change due to different wagon types. The actual measured value has to be compared to the further measured values to make a plausibility check. The values should decrease constantly and only increase if the brake pad was changed in the workshop. The detection of cracks or visible crumbling isn´t that easy.

Stakeholders

The measuring of the brake pad thickness is useful for the following stakeholders:

- Railway undertakings
- Wagon inspector
- Maintenance/workshop
- Transport planning

8.2.5.9 Detection of unclosed doors and roofs

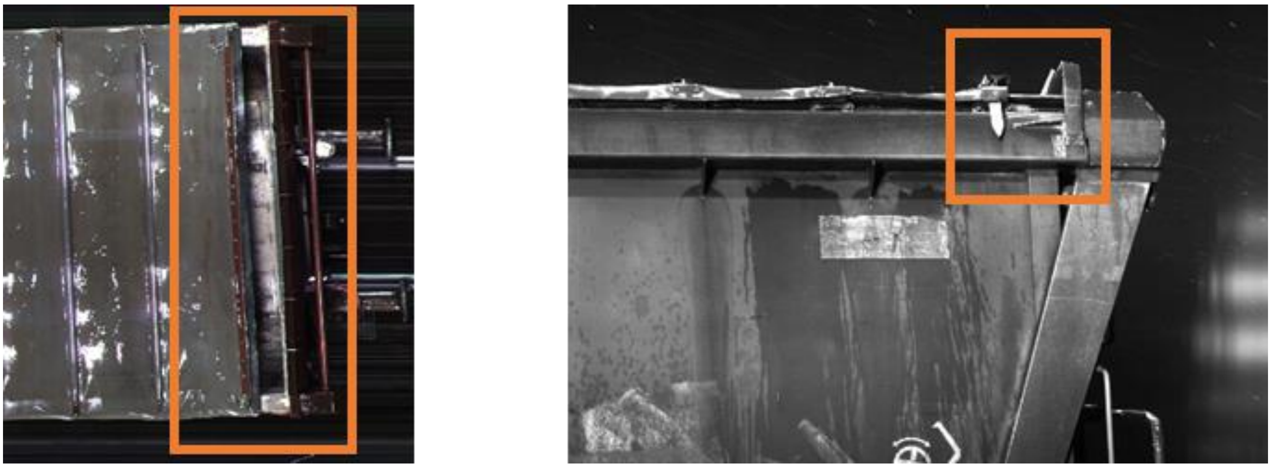


Figure 92: Top and side view of a wagon with an unclosed roof

The use case detection of unclosed doors and roofs supports the wagon inspector by checking the freight wagons before departure. If all doors and roofs are closed as prescribed the quality of the goods will be conserved and the safety of the train is ensured.

Initial / Current process

In the current process the wagon inspector checks the whole freight train for damages or unclosed doors/roofs before departure. Especially the closing status of roofs is quite difficult to see from the ground. Some wagons must not be moved when a door/roof is open. Controlling the doors and roofs is essential.

Future process

In the future process the pictures made by the Checkpoints will be used to detect open and closed doors as well as open and closed roofs. In Figure 92 an unclosed roof is shown from top and side view. The wagon inspectors are only able to identify open wagons from a side view. The pictures made from above will make it easier to identify open roofs because of the new perspective. If the AI locates an open door/roof the wagon inspector gets informed so that he could close the door/roof or sort out the wagon.

Information provided by checkpoints

To inform the wagon inspector about unclosed doors/roofs the wagon number and the open/close status is required. Both information can be detected by the Checkpoints.

Specifications for the Checkpoints

To identify open doors/roofs the Checkpoints needs cameras on the sides for doors and another from above.

Earnings / Benefits

If an open roof is detected by the Checkpoints and closed by the wagon inspector bevor the train departures the safety of the trail will be increased.

Risks

The most important risk of implementing the use case is the high variety of freight wagons and closing mechanisms. For training the AI a lot of different pictures are needed.

Stakeholders

The following persons profit of an automatic detection of open doors:

- Railway Undertakings
- Wagon inspector
- Transport planning

8.2.5.10 Buffer detection

Buffer detection also makes it possible to detect damage in advance and take appropriate countermeasures. To achieve this, it is important to perform various tests on the buffers from different perspectives.

Initial / Current process

In today's process, buffers are inspected for complete integrity, such as bolts, fasteners and buffer heads. This inspection is carried out manually by the train driver and maintenance staff.

Future process

In the future process, information about buffers can be recorded and made available in advance using cameras. This means that action can be taken earlier to avoid process delays.

Information provided by checkpoints

Relevant information is:

- Wagon number
- Cracks in the Buffer
- Wagon side
- Wagon direction

Specifications for the Checkpoints

To identify the buffer cameras from different angles are necessary. There is the need for a camera from the front as well as lateral and bottom-up cameras would be needed. Especially a camera from the front could be helpful to detect damages of the buffer plate. If there is only a view from the side not all damage types good be detected.

Earnings / Benefits

The main earning would be the time saving in the buffer compliance check as well as the risk reduction.

Risks

The main risk or challenge are the different and difficult camera angles that are necessary.

Stakeholders

Interested stakeholders are:

- Railway Undertakings
- Wagon Master
- Maintenance

8.2.5.11 Tarpaulin covers / floor detection

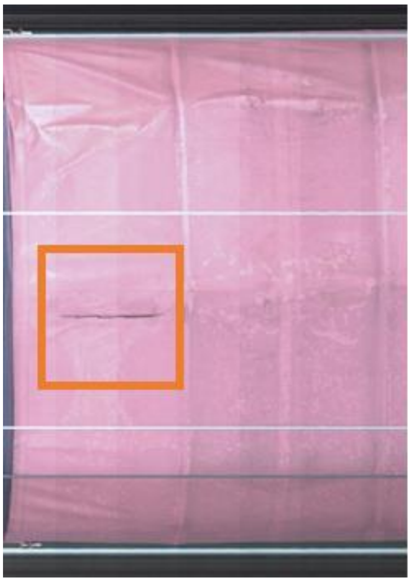


Figure 93: Tarpaulin cover with a cut (left) and damaged floor (right)

Damaged tarpaulin covers and floors as shown in Figure 93 can cause high costs, as the load can be damaged or the wagon is not accepted by the customer. In order to identify and repair damaged roof tarpaulins or floors as quickly as possible, the images of the Checkpoints should be used.

Initial / Current process

The inspection of the tarpaulin covers is only made by the employees in the workshop because a working platform is needed to see the roof of the freight wagon. Otherwise only damages located at the sides of the tarpaulin covers could be detected. The inspection of the floors is also only possible inside the workshop of if the freight wagon is designed open without side wall panels.

Future process

In the future process damages of the tarpaulin covers like cracks will be recognised while the train passaging the IVG. For open wagons, the condition of the floor will be checked to. If a damage is detected the information will be send to the wagon control and planning so that the maintenance of the wagon could be planned.

Information provided by checkpoints

For the identification of the freight wagon the wagon number is needed and the status of the floor and the tarpaulin covers.

Specifications for the Checkpoints

Similar to the use case loading residues the Checkpoints needs a camera which can take pictures from above the freight wagon to inspect the tarpaulin covers and floors. Also, an out-of-gauge detection system based on 3D scanning could be used as an additional detection system.

Earnings / Benefits

If a damage of the tarpaulin cover or the floor is detected before the freight wagon will be loaded/sent to customer the amount of damaged wagons provided to customer is reduced. Supplementary the number of damaged wagons will be removed because the maintenance could be planned in an optimized way. Another benefit of this use case could be the identification of goods that exceed the limit of the wagon.

Risks

One risk of the use case is that small cracks in tarpaulin covers and floors are hard to recognize for KI and also for the employees. The detection of damages of the floor are only possible for open wagons.

Stakeholders

Possible stakeholders for the use case are listed below:

- Railway Undertakings
- Wagon inspector
- Customer

8.2.5.12 Customer information

As described in several other use cases, a lot of information that is registered by checkpoints is relevant for customers of freight railway undertakings and their internal processes. To support these, the information should be consolidated and made available to the customers via a suitable platform. This use case describes the handling of the information, not its collection.

Initial / Current process

Customers of freight railway undertakings often need information about the location and status of wagons, loading units and goods, to be able to plan their operations. However, if such information is currently available to the customers, it might be out of date or scattered across several systems.

Future process

Complete information about wagons, loading units and goods is collected by Checkpoints and automatically made available to railway undertakings and their customers.

Information provided by checkpoints

All information registered, extracted or calculated by checkpoints that is relevant to customers, for example:

- Timestamps
- Wagon numbers
- Wagon positions
- Loaded and unloaded wagons
- Load information (loading unit codes, number of loading units, etc.)
- Dangerous goods information
- Loading residue information
- State of goods at arrival to or departure from terminals
- Goods types
- Overloaded wagons (height of springs)
- Damaged tarpaulin covers and floors
- Expected times of arrival and departure

Specifications for the Checkpoints

The information should be made available to customers and their business systems without unnecessary delays and in a standardised format.

Earnings / Benefits

Railway transportation becomes more competitive, since customers have reliable information about when their goods will be delivered and do not need to add buffer time in their plans to compensate for unexpected delays.

Risks

Risks arise from the distribution of data. Care must be taken to ensure that data is only made available to those who have the appropriate authorisation.

Stakeholders

Relevant stakeholders are freight railway undertakings and their customers.

8.2.5.13 Axle analysis

Figure 94: Coating damages on axles with corrosion

An automatic axle inspection system can detect damage to the axle at an early stage and reduce the amount of inspection work required in the workshop. The wagon passes over a camera system installed in the track or other sensors that check the axle for damage to the outer surface. For safety reasons, the results of the inspections can be used to directly influence the running of the train to avoid the risks of a possible accident.

The system can be installed either on the open track or in the approach to the station. The latter offers a better possibility to intervene in case of detected damage.

Initial / Current process

In today's process, axles are visually inspected for damage as part of the EVIC inspection. This inspection must be carried out in the workshop every time a wagon passes over a walk-in group. This inspection takes up a lot of workshop time as the axle is thoroughly checked for external damage. However, as the wagons are not regularly in the workshop, it is not possible to ensure that all wagons are regularly inspected, resulting in a residual risk to the running vehicles.

Future process

In the future, wagons can be automatically and regularly checked for damage. The inspection facilities can be integrated into the rail network, so that wagons can be regularly inspected. This means that part of the EVIC inspection can be moved from the workshop to the track, reducing the inspection effort in the workshop. The data from the system can then be fed into the system in real time, so that action can be taken in the event of major damage following image inspection. Coating damages shown in Figure 94 could be detected on the track and repaired in an early status before the axle is damaged by corrosion.

Information provided by checkpoints

Relevant information is:

- Wagon number
- Axle number
- Time stamp
- Information to the Axle status
  - Damages
  - Cracks

Specifications for the Checkpoints

High-resolution camera systems are one way of setting up such an inspection system. However, other systems can also be used or added. Possibilities include acoustic or X-ray based systems. However, these systems are subject to specific legal requirements. In addition, acoustic systems are not used for visual inspection.

Basically, if this use case is implemented, high precision resolution systems are required, which can be quite expensive and complex.

Earnings / Benefits

The introduction of an automatic axle inspection system would have great benefits, as it would reduce the huge inspection effort in the workshop. In addition, regular checks on the condition of the axles provide a better basis for optimising the use of wear parts. If necessary, studies with the systems can extend the service life of the axles, further reducing workshop time and material costs.

Other benefits include early detection of consequential damage and infrastructure impacts. If a severely damaged axle is visible, it can lead to an accident with serious consequences.

Risks

Risks to the system can arise mainly from too low a resolution, so that potential damage is missed or misjudged. In the worst case, this can lead to damage, but it can also have a huge impact on the operation of the train if the system fails. In addition, it is not possible to inspect the entire axle as some components are not visible and can only be examined in the workshop. It is important to talk to those responsible for the safety of the wagons and to identify options. Therefore, many changes in the process are necessary but the benefits should show that this could be very useful.

Stakeholders

Stakeholders are:

- Railway undertakings
- Workshop
- Wagon masters
- Infrastructure manager

8.2.5.14 Information for infrastructure manager

It is necessary for the infrastructure manager to receive information from the railway undertakings about the wagons and the cargo of the trains that use the railway. Since this information is currently not always complete and correct, an important aim of this use case is to improve the information quality. For example, the infrastructure manager must always be able to give correct information to the emergency service about the location of dangerous goods. With the help of Checkpoints, this information should be available without unnecessary delays, so that the infrastructure manager can react in the event of an error.

Basically, this use case describes the provision of data to stakeholders. The use case is based on the individual use cases already described for the detection of specific information.

Initial / Current process

In the current process, railway undertakings are obliged to provide the infrastructure manager with basic information about wagons and trains. This includes the next planned maintenance, train number, train length, weight, wheel profiles and other information. This information is passed on to all railway undertakings and infrastructure managers involved in the transport, for example at border crossings. The current process is based on direct reporting and sometimes has inconsistencies.

Future process

In the future process, some of the data will be automatically recognised by the Checkpoints and made available to the transport participants in a structured way. This will make it possible to check the accuracy of the data initially reported and to detect any discrepancies in the data.

Information provided by checkpoints

Relevant information is:

- Train number
- Date
- Wagon and locomotive number
- Length of the train
- Weight of the train
- Payload weight
- Information about dangerous goods
- Sequence of wagons in the train

- Condition of wheels
- Condition of pantograph

Specifications for the Checkpoints

The requirements for the Checkpoints result from the individual use cases for the detection of the respective data. However, it is important for this use case that the data are subject to a certain standardisation so that every railway undertaking and every infrastructure manager can handle the data (Rail Data - Train Composition Message (TAF TSI)). Checkpoints should be set up in the vicinity of marshalling yards, terminals and borders in order to capture data at important points in the network.

Earnings / Benefits

The main benefit of using checkpoints in this context is that more accurate and reliable data will be available for all stakeholders. This allows everyone involved in the process to work more efficiently without having to correct and recheck data. In addition, the reduction of unnecessary delays in the provision of data will reduce the risk for damages to the infrastructure. This leads to an overall increase in the safety and reliability of the rail system.

Risks

If the data are not accurate or not quickly available, their use might lead to accidents and damages.

Stakeholders

This information is relevant for

- Railway undertakings
- Infrastructure managers
- Regulators
- Emergency service

8.2.5.15 TOS-integration

Data collected by the Checkpoints is provided to the TOS and integrated to improve ETA/ETD calculations and automate information generation for logistics operators

Initial / Current process

To check the train composition, terminal staff move along the train or stand at a window to identify the wagon number (EVN) with its associated ILU code(s). This manual process is used for both receiving and dispatching, incoming and outgoing compositions. This process leads to a time-consuming train loading and unloading order. The information between terminal and train operator is done for a great deal manually and that is a source to misunderstanding and errors caused by humans.

Future process

In the future, the data generated by the Checkpoints can be made available automatically in order to achieve a more reliable order of loading and unloading. The terminal management system can process this information and compare and validate it with existing data. Corresponding deviations can then be reported to the staff in order to be able to act accordingly. When using automatically generated information, a smooth and quality assured process between the stakeholders can be retained.

Information provided by checkpoints

Relevant information for the terminal management system is the following

- Train ID (locomotive reference)
- Wagon number
- Wagon position
- ETA & ETD (from other systems)
- Loading status (Loaded / unloaded)
- Load information (container number, identification of the dangerous goods placards)
- Position of the load inside the wagon (open wagon types)

Specifications for the Checkpoints

The specifications for the detection of the necessary information are described in the relevant Use-Cases before.

Earnings / Benefits

The use of real-time data can reduce manual process effort and increase the reliability of data in the process. The reduction in effort can lead to a more efficient use of resources in the terminal to optimise processes. The information can also be used to support the digitalisation of transfer information process to the Traffic Management System (TMS).

Risks

Possible risks also arise here due to possibly incorrect data recording by the Checkpoints. This can lead to misunderstandings and make the process more complicated in some cases. Furthermore, there is currently no information about interested terminal operators.

Stakeholders

Relevant Stakeholders are:

- Terminal operator
- Logistic operator
- Infrastructure manager

8.2.5.16 Wheel profile measurement

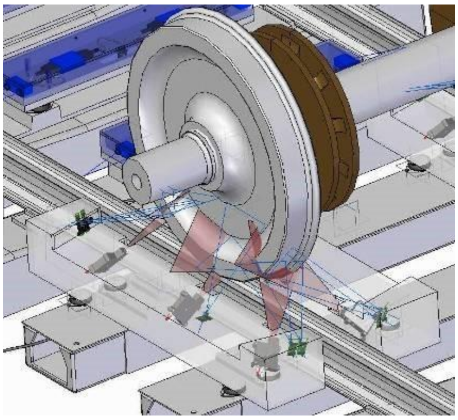


Figure 95: Possible wheel profile measurement system Source: Hitachi

Continuous measurement of the wheel profile can take the work out of the workshop, automate it and extend the life of the wheelsets. If it were possible to measure the wheel profile reliably on the open track, this would reduce the workload in the workshop and make the process more efficient. A possible profile measurement system from Hitachi is shown in Figure 95. This system uses a triangulation method of laser beam combined matrix cameras. In addition, the wheelsets' service life could be optimised through continuous measurement, thus reducing maintenance costs in the long term. DB Cargo can provide an indication of this, as regular block train traffic in Germany shows higher wear on one side. The service life of wheelsets can be significantly extended by countermeasures such as wagon rotation.

Initial / Current process

In the current process, wheel profile measurements are only carried out in the workshop. Depending on the workshop operator, different measuring systems are used, which means that there can be deviations between the measurements. The Wheel profile could be measured by a special calibre or scanned with a laser measurement system. Furthermore, continuous measurement of the wheel profile cannot be guaranteed as the wagons only come into the workshop for scheduled inspections at best.

Future process

In the future, the continuous recording of wheel profiles using cameras or laser-based systems will greatly improve the planning of wheelset deployments. The data from these systems can then be made available to vehicle owners and the transporting RU, allowing action to be taken in the event of risks or maintenance to be planned earlier.

Information provided by checkpoints

The relevant information for the new process is:

- Wagon number
- Axle number
- Wagon side
- Time stamp
    - Profile measurement date, the 11 different measurements as gauge, qR are shown in Figure 96.

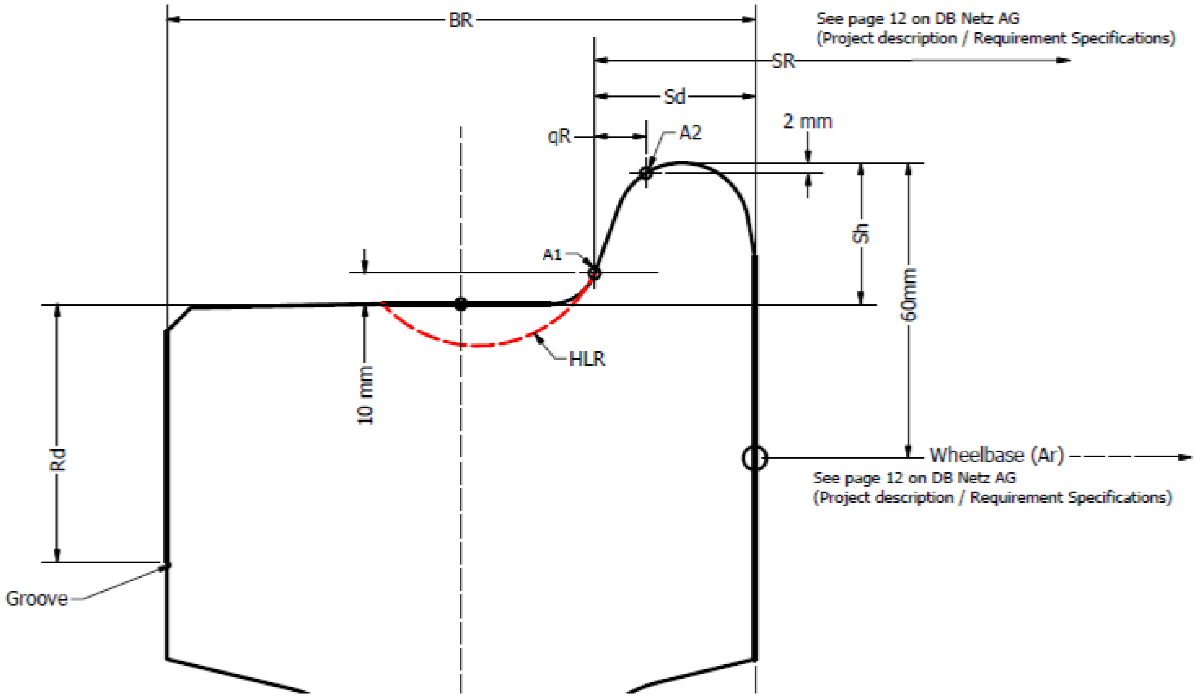


Figure 96: Main dimensions of a wheel

Specifications for the Checkpoints

A standard camera, as used by the Checkpoints today, cannot be used for this application. Other systems based on other technologies are needed.

Possible systems could be LIDAR systems or WILD (Wheel Impact Load Detection) systems. There are also proven systems that combine laser scanners with camera technology to capture the full wheel profile.

In principle, this use case is very demanding. Connection to a Checkpoint would be desirable, but difficult to map depending on the equipment of the Checkpoint.

Earnings / Benefits

The introduction of a wheel profile measurement system would offer great benefits. Amongst other things, the service life of the wheelsets can be greatly improved by optimising the application control. This leads to less wear and therefore less maintenance costs and wheelset replacements. As wheelsets are the most expensive item on freight wagons, costs can be massively reduced here. Another advantage is that intact wheelsets cause less or no damage to the infrastructure.

The use of this system can also be relevant for passenger transport, to prevent damage and possibly even increase the ride comfort of the vehicles.

Risks

A major risk point is the investment cost of the system. As very high demands are placed on the systems in order to guarantee the required accuracy of the data, a high level of development and calibration of the systems is necessary.

On the one hand, inaccurate measurements can lead to risks in rail traffic, for example by overlooking damage. On the other hand, inaccurate measurements can lead to unnecessary wagon suspensions.

Another risk is that systems based on laser and camera technology measure only one point on the wheel. It is therefore not possible to draw conclusions about the entire wheel. This risk can be reduced, but not eliminated, by continuous measurement.

The most serious risk is the failure of the system caused by dirt on the lens of the system because the system is installed on the ground of the track and therefore exposed to dirt.

Stakeholders

Relevant stakeholders for this information are:

- Railway undertakings
- Wagon keeper
- Maintenance
- Wagon master
- Infrastructure manager

8.2.5.17 Wheel flat detection

Flat spots on the wheels of rail vehicles cause damage to both the vehicles and the infrastructure. The out-of-roundness of the wheels causes vibration in the vehicle, which stresses the entire vehicle, but especially the wheelset and bogie. In addition, the flat spots cause increased stress on the infrastructure, as the wheels no longer roll cleanly over the rail but cause impacts. By avoiding the use of vehicles with flat spots, huge maintenance costs can be reduced. This can extend the life of both the vehicles and the infrastructure. There are several ways of detecting weak spots. One is the weighing-in-motion method, where the longitudinal and lateral forces of the wheel on the rail are measured and conclusions can be drawn about the condition of the wheel. Another is optical observation, which requires several cameras to record the wheel surface in its entirety as it rolls.

Initial / Current process

In today's process, flat spots are identified by the wagon foreman during the technical inspection of the wagon as well as in the workshop. Some automatic measuring systems are already installed on the European rail network. The flat spot is then measured, as very small flat spots often disappear due to the constant rolling of the wheel. Only if the flat is larger than 60 mm does the wheelset have to be replaced as the risk of damage becomes too great.

Future process

In the future, continuous measurement of the wheels will enable early intervention. One system that can be used is the Weight in Motion (WIM) systems which measures the force exerted by the wheel on the track by using strain gauges. A flat spot causes more force because of the bigger surface (compare Figure 97). A round wheel and a flat track are only touch each other in a narrow line. Because of local height forced the system is able to detect flat spots. By monitoring the measurements, developments can be mapped and action taken. The data can also be used to analyse and categorise routes or rolling stock where there is an increased risk of wheel flats. These can then be taken into account in train scheduling.

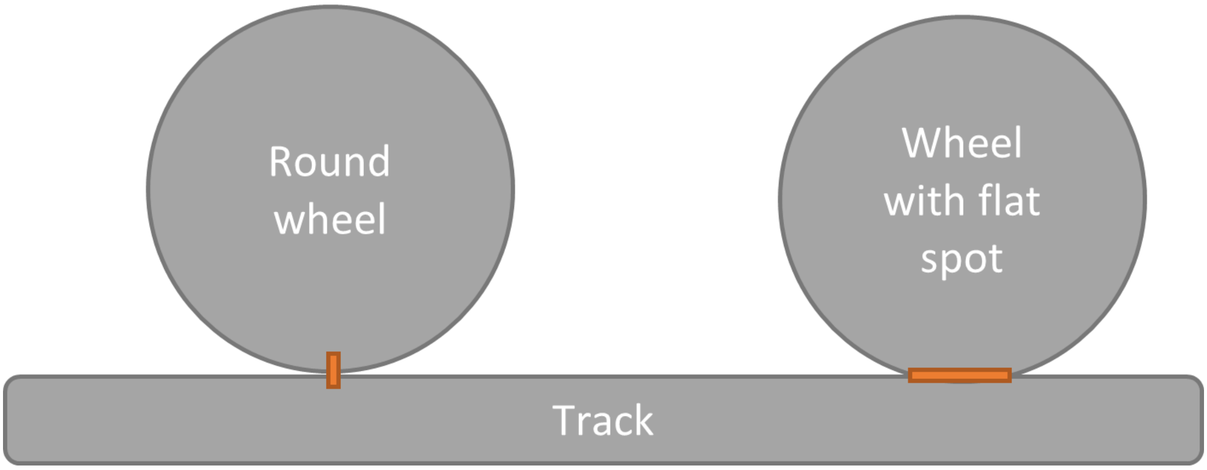


Figure 97: Contact surface of a round wheel and a wheel with flat spot

Information provided by checkpoints

The needed information for a flat spot detection is:

- Wagon number
- Axle number
- Wagon side
- Images or Force measurements

Specifications for the Checkpoints / system

- Weighing in Motion or Wheel Impact Load Detection (WILD)
    - If a weighing-in-motion system is used, the forces must be recorded accurately to minimise false readings. The exact deviation tolerances must be determined in a test run or similar.
- Checkpoints
    - Checkpoint cameras must be installed in the track to view the wheel surface from below. Several cameras are needed to cover the entire circumference of the wheel. In addition, the lighting must be adjusted to avoid glare but still provide sufficient illumination for detection.

Earnings / Benefits

The main benefits of a wheel flat detection system are increased safety and reduced damage to wagons and infrastructure caused by out-of-round wheels. Optimised vehicle planning and early intervention could extend the life of the infrastructure and the wheel.

Another advantage is that the system can also be used in passenger transport, where the same challenges exist.

The reduction of wheels with flat spots reduces the emitted noise which is a great benefit for the people living next to tracks.

Risks

The main risk is that the accuracy of the measurement needs to be very high to avoid unnecessary interventions during the train ride. Additionally, a new process must be described together with the security department. Therefore, a longer test must be made to validate the possible use of the system.

Stakeholders

Relevant Stakeholders are:

- Railway undertaking
- Infrastructure manager
- Wagon owner / keeper
- Maintenance
- Wagon masters

8.3 New functional and non-functional requirements for standardised checkpoints at borders and other operational stops

In order to understand what the Checkpoints should add up to, in this paragraph, functional and non-functional requirements are defined. These are not all requirements; more detailed requirements can be found from 8.4 and further on. These follow also from the use cases in paragraph 8.2.5. For the purpose of this overview, and the readability thereof, the use case for wagon number recognition is taken as a basis. Other use cases, such as damage detection and brake pad measuring, can be added on when selected within the scope of WP29.

These requirements consist of functional requirements and non-functional requirements. Functional requirements define the desired behaviour of the Checkpoint system. Non-functional requirements define how the system should function. They typically tell us something about the performance of the system. The requirements were ranked according to the MoSCoW method (Agile Business Consortium, 2023). This method helps prioritizing requirements in the following order: Must have, Should have, Could have and Won't have. The Must-haves are critical for the success of the project. Failing to meet any of these requirements, would deem the project a failure. This aligns with the concept of the Minimal Viable Product (MVP).

The Should-haves are important, but not critical. Often, they are not time critical and therefore not considered as a Must-have as they can be deferred

The Could-haves are desirable requirements, but not essential and only included when time and resources permit.

Lastly, the Won't-haves are requirements that will not be included in the project. However, they are mentioned as the stakeholders considered them and agreed to not include them in the project.

The ranking of the MoSCoW requirements was determined by a voting system. All participants were asked to vote for either M, S, C or W for each requirement. The MVP requirements were selected based on the highest votes in the Must category (8 votes or higher). This resulted in 12 detailed requirements, which are further elaborated in the next section. The Should- and Could-haves are mentioned afterward, but not expanded upon.

Must haves (FR = Functional Requirement, NFR = Non-functional requirement)

1. FR: The camera resolution is high enough to enable OCR reading of the smallest character on the wagon/container passing the camera on the track.
2. FR: The system shall identify for each wagon the following: EVN of passing vehicle, ILU/ISO codes of containers, orange-coloured plates, placards and ideally other cargo information (owner, weight, etc.) of the wagons passing the camera on the track.
3. FR: The system must identify dangerous goods signs on containers on wagons passing the camera on the track.
4. NFR: The system detection rate reaches 95% on a benchmark basis.
5. FR: The system needs to identify itself so that downstream systems know the origin of the data.
6. NFR: The system needs to put the information into a common well-known format.
7. NFR: The system works 24/7 in all weather conditions and <u>for trains/wagons that pass by until 140km/h, that break, stand still or accelerate in front of the camera.</u>
8. NFR: The system is installed at relevant sites for capturing rolling stock traffic.
9. NFR: The system shall not interfere with the normal train operation.
10. NFR: The system follows existing regulations (for example GDPR).
11. FR: The system is expandable with other sensors/measurement systems (RFID, Hotbox, wheel profile measurements).
12. FR: The system should identify:
    a. The position of each wagon.
    b. The direction in which the train is moving.

c. The total count of wagons.

Description of the Must have requirements:

The camera resolution enables OCR (optical character recognition) reading of the smallest character on the wagon/ILU.

The camera resolution must meet the requirements for Optical Character Recognition (OCR) to accurately capture the smallest text on wagons and containers. When considering camera resolution for OCR purposes, it's important to distinguish between automatic reading for machines and human verification. Automatic reading may tolerate a lower resolution, but during testing, it is essential for humans to be able to read the smallest characters to ensure accuracy.

The system shall identify for each wagon the following: EVN of passing vehicle, ILU/ISO codes of containers, orange-coloured plates, placards and ideally other cargo information (owner, weight, etc.) of the wagons passing the camera on the track.

The system is required to accurately identify specific information for each wagon, including the EVN of the passing vehicle (twelve characters) and the ILU/ISO codes associated with containers (eleven characters). It's important to highlight that the definition of "readable" codes refers to codes that can be read by humans. This definition is important as during the testing phase human verification is necessary, considering that not all wagons may bear a code (such as articulated and multiple wagons), or the codes may be obscured by graffiti.

The system must recognize dangerous goods signs on wagons.

Containers carrying dangerous goods have specific placards. The system must correctly recognize these signs and connect them to the information about the container, such as EVN, position of wagon. The dataset with EVNs can be reused to train this part of the algorithm, by including labels about dangerous goods signs, or a new dataset can be created specifically for these signs.

The system detection rate reaches 95% on a benchmark basis.

The system's detection rate on EVNs and dangerous goods signs needs to reach 95% accuracy rate on a benchmark database. This database needs to consist of a wide variety of data instances captured by Checkpoints at different locations, to make it as representative as possible. The system's performance will be assessed using this benchmark, allowing for clear comparisons and improvements among different implementations, more info on benchmarking can be found in section 8.4.1.

The system needs to identify itself so that downstream systems know the origin of the data.

When the system shares information with downstream systems, such as recognized EVNs, the number of wagons, and other specified requirements, it must incorporate an identifier. Given the presence of multiple systems and thus a continuous stream of information, it is **essential** that the system includes identifying information to ensure seamless further processing, thus clearly indicating the data's source.

The system needs to put the information into a common well-known format.

Given the system's transnational usage, data processing will take place in various downstream systems. All stakeholders possess pre-existing systems for handling railway information. When the information provided by the system is presented in a standardized format, it streamlines processing across all locations.

The system works 24/7 in all weather conditions and for trains/wagons that pass by until 140 km/h, that break, stand still or accelerate in front of the camera.

Given that freight trains operate 24/7 in various weather conditions, the system must demonstrate consistent performance in all circumstances. Challenges include the transition from day to night and resilience in harsh weather conditions such as rain and snow. These weather conditions can **present** difficulties for optical character reading (OCR) as they might obscure the characters on the wagons. Furthermore, the trains pass the system with different speeds up until 140 km/h. The trains can accelerate and brake while passing the system or even stand still. The system must be able to perform under all conditions.

The system is installed at relevant sites for capturing rolling stock traffic.

The system is expected to provide railway operators with location and status updates of freight trains by reading the EVNs, as specified in the associated requirements. Important locations for accessing this information include border crossings and rail yards, as the information has to be transferred to another operator or the train composition changes at these points.

The system shall not interfere with the normal train operation.

Given that trains may encounter multiple systems along their routes, the system should not cause any delays or holdups in the train schedules.

The system follows existing regulations (for example GDPR).

As the system is placed in a working railway environment, it must follow all the rules currently in place, such as maintaining a safe distance from the rails and adhering to safety regulations for maintenance. Furthermore, since the system will capture pictures or videos, it must also adhere to privacy regulations, like GDPR.

The system is expandable with other sensors/measurement systems.

In addition to data from cameras, other sensor systems have the potential to gather valuable information. Established sensor systems, like those for hotbox detection and axle counters, provide insights into the condition of the trains. A more recent technological implementation for freight trains involves the use of RFID tags, which can capture information about the EVNs of the wagons. This information can be used to cross-verify the results obtained by the camera system. By integrating various sensor types, the system becomes more resilient. In cases where one sensor may encounter limitations, such as a missing RFID tag or obscured codes due to graffiti, the overall system can still maintain robust performance.

The system should identify:

a. **The position of each wagon.**
b. **The direction in which the train is moving.**
c. **The total count of wagons.**

For further processing of the information captured by the system (EVNs etc.), the system should also know the wagon position within the train. Furthermore, the total number of wagons on the train and the direction of the train is relevant. For example at a yard, where it can automatically be determined whether a train is entering or leaving the yard when it passes the system.

Could have and Should have requirements:

1. FR: The system must capture high-quality images of wagon and container sides and tops for detailed visual inspection.
2. FR: The system is able to share the data / result with other systems.
3. FR: The user must have access to the data captured by the Checkpoints.
4. NFR: The data is secured.
5. FR: The data can be accessed transnationally.
6. FR: The system detects defective wagons.
7. FR: The system measures the wagon weight and detects if there is an axle unbalance.
8. NFR: The system has a maximum unplanned downtime of 30 minutes per year.
9. NFR: The system shall require minimum maintenance to work.
10. NFR: The system has an operational life of 30 years.
11. FR: The system should identify:
    a. Articulated and multiple wagons
    b. Intermodal wagons and wagons with integrated goods compartments
    c. Train speed

8.4 Technical specifications

This section specifies the technical specifications for the standardised railway checkpoints concerning image processing and other identification and detection technologies, as well as suggested standardisation aspects.

8.4.1 Image processing

Image processing technologies are based on the process of transforming images to a digital format and performing operations to acquire useful information from them. It involves applying various techniques to digital images to enhance their quality, extract information, and make them more suitable for further analysis or human perception.

Image processing systems usually involves a series of steps to obtain the information mentioned before. Those steps can be summarised as follows:

1. **Image acquisition:** the process begins with the acquisition of digital images, using digital cameras, laser scanners or other imaging devices. Using the proper configuration of imaging sensors, lights and other elements is fundamental for the further processing and analysis.

2. **Preprocessing:** for automating the information extraction in images, images obtained in the previous step should be prepared. This tasks commonly include the adjust of image size, scale, and colour.
3. **Processing:** once the image is prepared, multiple processing techniques can be applied in order to obtain features. Depending on the application, these tasks can include *Image Segmentation, Optical Character Recognition, Object Detection, Image Enhancement,* among others.
4. **Analysis:** the features obtained usually have no meaning by themselves. For instance, a segmented image, where every object is represented by a certain colour, cannot be used for automating a process or making a certain decision. Instead, this image can be used, for example, to compute the area of a certain object.

The information obtained from the analysis of the features after processing the image needs to be shared in some way with the rest of participants in the process. This point is further developed in the data sharing chapter. The importance of using a standardized protocol to retain all the relevant information from the wayside systems lies in the fact that every administrator and user of the Checkpoints needs to understand automatically the information and use it.

Referring to the application of image processing in rail freight transport, the images acquired from a *Standardised Railway Checkpoint* can be processed and analysed to cover a series of use cases with input from IMs and RUs. A first selection of applicable use cases can be listed as follows:

- **Identification of wagon numbers**
- **Identification of loading units**
- **Identification of dangerous goods**
- **Identification of damages in wagons and goods:** graffiti, brake pad analysis, status of open/closed doors, wheel profile.

The main technologies applicable on the processing step are described below:

OCR

In the previous EU project FR8Hub, traditional computer vision algorithms were used. Those methods were only viable for the requirements defined in the scope of that project.

Only recognition of wagon numbers, loading units and dangerous goods were applied during the project. For the recognition of numbers and codes, traditional *Optical Character Recognition (OCR)* was used. This technology enables computers to convert printed digits into machine-readable text.

The main challenge in applying this technique to the use cases described above lies in the variability of images. OCR algorithms relay on preprocessing - image binarization-, characters clustering and classification steps. In these terms, the variability in background colours, fonts and noise makes impossible to reach the desired accuracy level. That is why it is desirable to apply other techniques such as Deep Learning for Image Processing. However, this may also imply a reliability issue as fully automatic algorithms may simplify the process at expenses of data reliability.

Deep Learning for computer vision

In FR8Rail III, a continuation of the development of the Checkpoints, the needs of applying this technology in a real environment required the usage of more generalist algorithms. The project's demonstrators were focused on controlled scenarios, shunting yards (Nuremberg) and intermodal terminals (Gothenburg).

The increased variability of wagons and container types made it impracticable to use traditional OCR algorithms. Variability in character types, colour and background colour hinders the parametrisation of certain characters.

A first approach of Artificial Intelligence and Deep Learning methods were evaluated, validated, and used. These methods go beyond the traditional point of view, were features need to be parametrised in some way in the algorithm. Deep Learning algorithms are presumably capable of understanding what the image contains, automatically recognise these features as well as the patterns that shape the objects of interest in the image.

This knowledge is generated through a cyclic algorithm, called iterative learning. In this cycle, labelled data is fed to the learning algorithm, which automatically extracts those patterns and features of interest. These techniques make it possible to include images of different conditions or scenarios, making the trained models more robust to changes in the environment and with the capacity of adapting to new conditions and to iterative learn from new information.

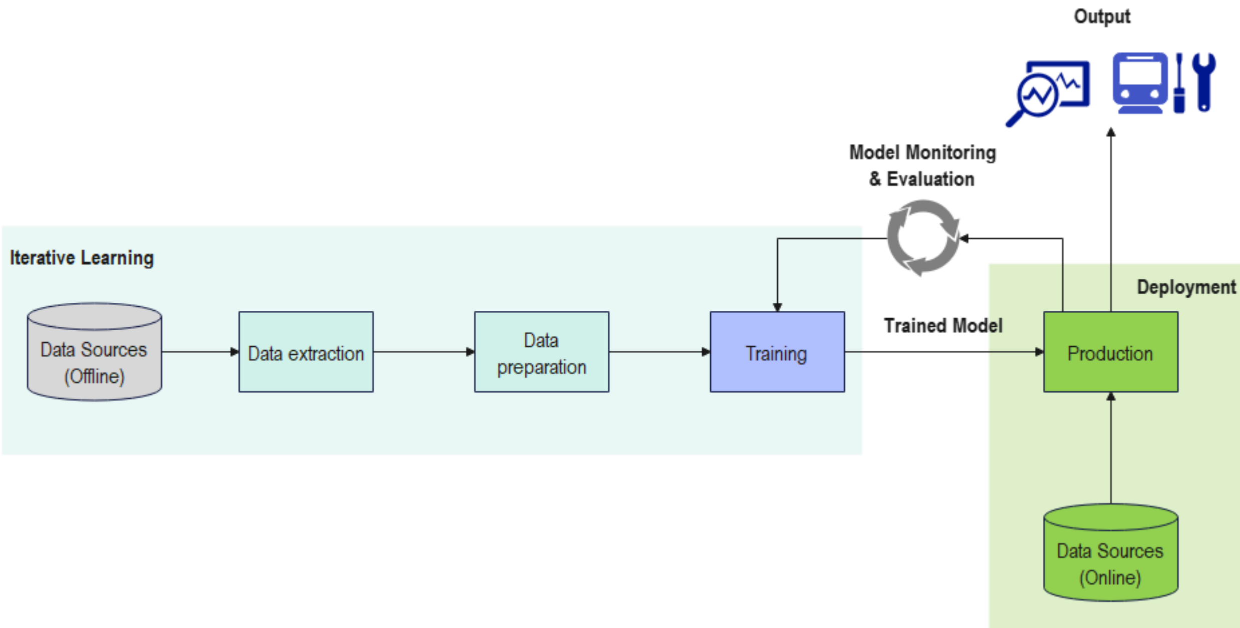


Figure 98: Deep Learning workflow

Based on the previous explanation, it can be assumed that supervised Deep Learning algorithms relies on having as much labelled data as possible. Some of the main applications of Deep Learning for image processing are the following:

1. **Image Classification**: Deep learning models, especially Convolutional Neural Networks (CNNs), are extensively used for image classification tasks.
2. **Object Detection**: used to detect and locate objects within images.
3. **Image Segmentation**: Deep learning models can segment images into regions or objects of interest, allowing for more precise analysis.

The following Table 30 intends to map the technologies described before to the mentioned use cases, discerning whether the technology is applicable or not.

Table 30 Mapping of technologies and UCs

	Train Composition		Dangerous goods	Damages on wagons and goods			
	Identification of wagon numbers	Identification of loading unit numbers	Dangerous goods information	Graffities	Brake pads	Status of open/closed doors	Wheel profile

Image Type	RGB/B&W image of wagon sides	RGB/B&W image of wagon sides	RGB image of wagon sides	RGB image of wagon sides	B&W/Laser image of wagon sides	RGB/B&W back images	B&W/Laser image of wagon sides
Image classification	Not applicable	Not applicable	Not applicable	Applicable	Not applicable	Applicable	Not applicable
Object detection	Applicable	Applicable	Applicable	Applicable	Not applicable	Applicable	Not applicable
Image segmentation	Not applicable	Not applicable	Not applicable	Applicable	Applicable	Not applicable	Applicable
OCR	Applicable	Applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable

8.4.2 Other identification and detection technologies

The use of detection technologies for monitoring and diagnosing major faults or performing predictive maintenance on rolling stock equipment is of paramount importance for railway infrastructure and fleet managers as it can improve the safety and reliability of railway operations.

The main technologies adopted by the majority of the systems are the following:

- **Strain gauge**: detects small dimensional deformations of a body subjected to mechanical or thermal stresses;
- **Accelerometer**: is a measuring device able to detect and/or measure acceleration;
- **Fiber Bragg Grating**: devices that optically measure physical deformations;
- **Laser Scanners Technology**: devices that measure the distance with a body and the surface profile, by exploiting the laser triangulation 3D principle;
- **Video Monitoring**: linear or matrix video cameras sensible in the UV, visible or NIR spectrum;
- **Thermographic sensors**: this technology is based on the image acquisition of the infrared spectrum;
- **Ultrasonic technology**: converts the energy into ultrasound or sound waves, above the normal range of human audio frequencies;
- **Acoustic Emission detector**: based on sound detectors; and

- **Radio Frequency Identification**: radio frequency reading technology with antennas and tags (mounted on rolling stocks) is used for identification of transits.

The identification and detection systems which are based on these technologies and are most commonly used are described in the next sections. They include:

- Weigh-in Motion system (WIM),
- Wheel Impact Load Detector / Wheel Defect Detector system (WILD / WDD)
- Hot Axle Box Detection / Hot Wheel Detection system (HABD / HWD)
- Acoustic Bearing Detection / Bearing Acoustic Monitor (ABD / BAM) and
- Wheel Measurement System (WMS)
- Radio Frequency Identification (RFID)
- On-board wagon and cargo monitoring system (WOBU)

Intelligent Video Gate Systems are based on video monitoring technology and have been discussed in the previous subchapters.

The Swedish Transport Administration has currently (last update 2022-11-23) 178 wayside detectors dispatched along the railway network. In addition to these detector installations, there are 250 standalone RFID reading points installed along the Swedish railway. The network is composed of 3 main systems: Hot-Box/Hot wheels detectors, Wheel Impact Load detectors and Bearing Acoustics Monitors. The number of detectors units is distributed as follows:

- SERVO/SATT, Hot-box/Hot-wheel detectors, 5 units
- FUES I, FUES II, FUES II+, Hot-box/Hot-wheel detectors, 23+55+31=109 units
- PHOENIX HB/HW, Hot-box/Hot-wheel detectors, 30 units
- PHOENIX WDD/WIM, Wheel Impact Load detector, 4 units
- Multirail SCHENCK, Wheel Impact Load detector, 26 units
- RailBAM, Bearing Acoustic Monitor, 4 units

In the following subsections a brief description with the relevant technical specification of some the systems is reported: this is not meant as an exhaustive review, but it's only to be used as a general indication for other identification and detection technologies (other than the Intelligent Video Gate – or in synergy) in relation with the possible use cases.

8.4.2.1 Weigh in Motion (WIM)

The WIM is a dynamic weighing system designed to weigh the wheels/axles/wagons of the whole train and to detect eventual imbalances and/or overloads of locomotive and wagons by measuring the force applied by each wheel to the rail.

The system can also be used to automatically quantify the weight of transported goods and/or detect residuals of raw material inside wagons.

The functioning of the system can be based on different technologies: strain gauge, accelerometer, and fiber Bragg gauge.

A proposed solution with minimum impact on the track and a simple installation is based on optical fiber sensors clamped on the rail foot and designed for detecting the vertical forces generated by the wheel/rail contact. System operation is guaranteed day and night and under any weather conditions.

The sensors are connected to the control cabinet housed in a shelter near the track via fiber optic cables. The cabinet acquires and elaborates the data. Dedicated software algorithms can estimate the weight of wheels, cars and trains and detects imbalances and overloads.

An overview of a global layout of a possible WIM system installation based on optical fiber sensing technology is shown in the next Figure 99.

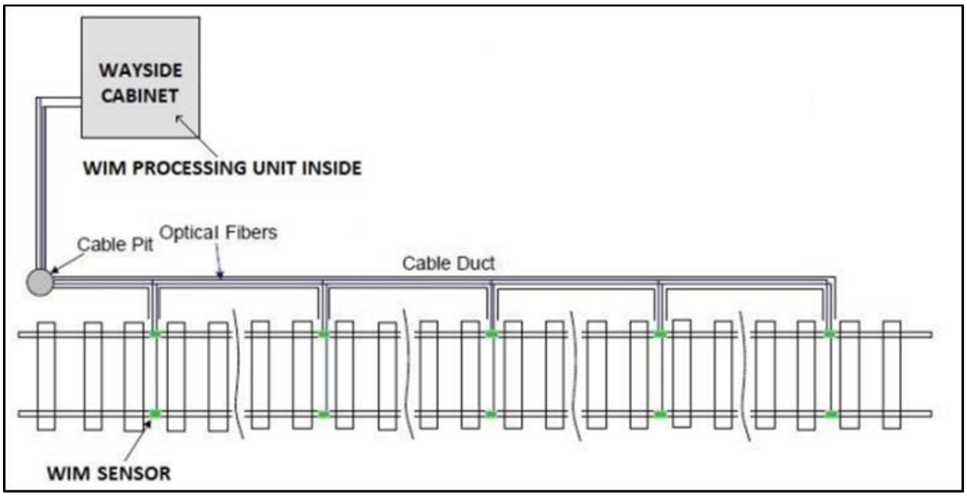


Figure 99: WIM Sensor layout: measurement area and in shelter parts (for reference only)

Technical specifications

1. The system shall measure and collect the weight and the unbalance of each rolling stock.
2. The WIM system shall provide the following measurements and data: transit direction, average transit speed, total number of axles, wheel gross weight, axle

gross weight, bogie gross weight, wagon gross weight, total train weight and total train length.

3. The WIM system shall compare the measurements and derived calculations to user's defined threshold values to check the presence of axle/wheel overloads, transverse axle imbalances, transverse wagon imbalances and longitudinal wagon imbalances.
4. The system shall provide measurements and alarms for overload and imbalance conditions.
5. The system shall have no speed limits for running trains during their transit in the measurement zone.
6. The WIM sensors shall operate also as system wakeup sensors, detecting arriving trains and allowing measurement acquisition setup.
7. System accuracy shall meet infrastructure manager requirements (e.g. load evaluation shall be precise enough for commercial scope)

The possible use cases covered by the WIM system include the detection of loading residues and the automatic integration of customer information but the system can be also used as an alternative to (or in synergy with) the Intelligent Video Gate for spring loading detection.

8.4.2.2 Wheel Impact Load Detector / Wheel Defect Detector (WILD/WDD)

The Wheel Impact Load detectors are systems that are used to detect high contact forces between the wheel and the rail.

A change of contact forces could result from surface defects (wheel flats, shelling, spalling, cracks), polygonization (ovality, periodic non-roundness, roughness) or profile defects (thin, high or wide flange and hollow wear).

The SCHENCK Multirail Wheelscan uses a system composed of eight special sleepers with strain gauge measuring sensors. The operating speed range lays between 10 – 250 km/h, with a measuring span of 5m and a weigh accuracy of 2%.

Another wheel defect detection implementation, based on the fiber optic sensing technology like the WIM system previously discussed, is the PHOENIX WDD/WIM which is composed of a series of twelve fiber optic sensors (per track) clamped to the rail. The speed operating range of the WDD is 20 – 500 km/h, an accuracy of +/-1% for the speed and +/-3% for the weighing accuracy, with a measuring area of approximately 7m. Even though the two systems have different functionalities, they can both provide common information, such as the estimation of the axle load, the wheel static load (average force measured around the circumference of the wheel) and the wheel impact load (the maximum of the peak force measured around the circumference of the wheel) for both the left and right sides.

Technical specifications

1. The WILD/WDD shall provide the identification and classification of different kinds of defects (including at least: spalling, shelling, flats, or out-of-roundness) along the rolling circumference of the wheels of rolling stock vehicles.
2. The WILD/WDD shall monitor the entire rolling of each train wheel by detecting the rail average impact force, maximum impact force, dynamic impact and dynamic factor.
3. The system shall record the measurement data of every wheel set that passes over it.
4. The system shall have no speed limits for running trains during their transit in the measurement zone.
5. The WILD/WDD sensors shall operate also as system wakeup sensors, detecting arriving trains and allowing measurement acquisition setup.
6. System accuracy and reliability shall meet customer's safety requirements: the system shall be able to detect a defect and provide the relevant alarm according to its severity.
7. System accuracy and reliability shall also meet rolling stock maintenance requirements: the system shall be able to predict the need of maintenance on specific wheels with mild defects and provide the corresponding warning(s).

The possible use cases where the WILD/WDD system can be adopted are related to the identification of damages on wagons and wheel profile measurement.

8.4.2.3 Hot Axle Bearing Detector / Hot Wheel Detector (HABD/HWD)

The Hot-box/Hot-wheel detectors are systems that are used to detect defective bearings in the late stage and hot/cold wheels due to brake issues, mainly to prevent derailments and ensuring safe operation of railways.

Depending on the systems' manufacturer, they can consist of Infrared measurements devices that will scan the surface of the axle-box and wheels with single beam, dual-beam, or multi-beam systems. A general layout of a special sleeper equipped with these sensors is provided in the next Figure 100.

In general, the detection of temperatures goes up to 150-180 °C for the hot-box and up to 500-600 °C for the hot-wheels detector. Considering the solution adopted by TRV, the specifications for the speed operating range, installation properties, data resolution, environmental conditions (operating temperature range, protection against weather conditions) differ between SERVO/SATT, FUES and PHOENIX HB/HW. However, three main features are commonly extracted from the temperature surface scanning of all these systems, i.e. the temperatures from the left and right axle-box as well as the temperature of the left or right wheel (depending on the train direction).

It should be noted that the SERVO/SATT systems no longer meet the requirements of interoperability and harmonization with other detectors, so that they are slowly being replaced by newer systems (for instance FUES and PHOENIX in Sweden).

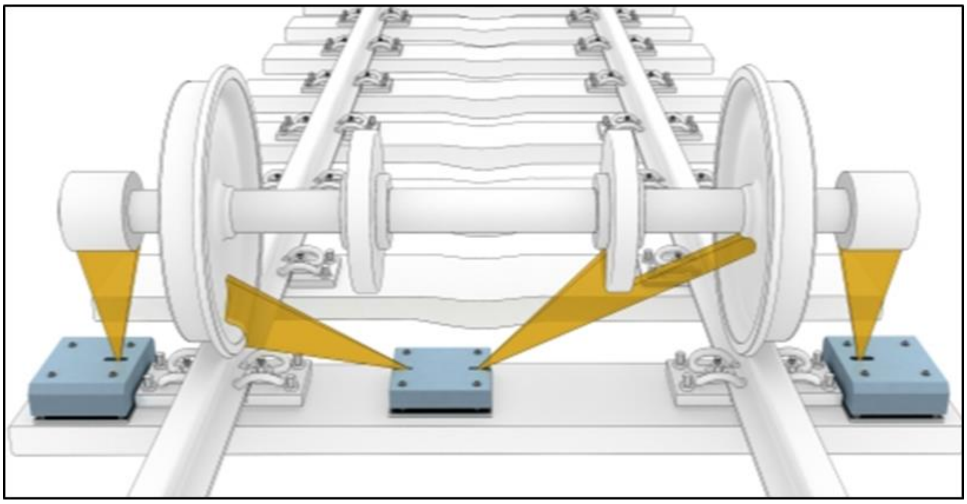


Figure 100: HABD/HWD sensor layout: Hot Axle Bearing Detectors are mounted at each side, Hot Wheel Detector in the center

Technical specifications

1. The system shall be able to automatically detect transit and acquire axle bearing and wheel temperature measurements until transit completion on the installation checkpoint.
2. The HABD/HWD shall associate axle bearing temperature for each axle with its unique identity.
3. The HABD/HWD temperature alarm thresholds shall have a preset range of temperature, with specific intervals.
4. The HABD/HWD shall analyze the entire train and provide measurements of all types of rolling stock in operation (this may require specific adaptations to the bearing design of the wagons and locomotives fleet).
5. The HABD/HWD accuracy and reliability shall meet maintenance requirements in order to provide warnings and suggest corrective actions.

The possible use cases covered by the HABD/HWD system are the identification of damages on wagons and bearing defect detection.

8.4.2.4 Bearing Acoustic Monitoring (BAM) / Acoustic Bearing Detector (ABD)

The Bearing Acoustic Monitoring systems are used to detect axle bearing faults and provide condition monitoring reports by identifying warning signs of potential bearing failures before they reach a point that may cause disturbances to the traffic and avoid possible derailments due to journal failures.

A possible implementation, is the RailBAM system which is located in trackside cabinets (for harsh environments). It uses acoustic measurements from a series of microphones alongside the track, and can listen to transiting trains within the speed range 25 – 130 km/h.

As a train approaches, wake up sensors trigger, the shutters protecting the acoustic open and the data acquisition begins by measuring the sound signatures emitted by the bearings and wheels, as well as additional information related to the train speed, wheel diameter and tag data.

The RailBAM system relies on recognizing distinct sound characteristics generated by bearing defects: when faults occur on bearing components, they induce structural responses that produce unique sound features associated with those defects.

The BAM/ABD system can take advantage of signal processing techniques to differentiate between structural noise, bearing damage, and even wheel flats, enabling the identification and categorization of faults. By pinpointing specific peaks corresponding to rotational orders, it becomes possible to track the deterioration of particular components like rollers, outer races, and cages, in a manner similar to how accelerometers are utilized in the bearing housing through an onboard monitoring system. To achieve optimal outcomes, it's advisable to position trackside sensor units on straight, well-maintained tracks to prevent interference from extraneous noise that might distort the readings.

The types of anomalies that can be detected by this system include:

- Rolling surface defects, including wheel flats and wheel roughness
- Roller bearing wear
- Cup/cone spalls
- Multiple and extended spalls

More details on the technical specifications of these systems are also available in the document "*D1.4 Wayside vehicle monitoring for Condition-Based Maintenance*" (FR8RAIL III, 2022b).

Technical specifications:

1. The system shall be able to automatically detect transit and acquire axle bearing sound until transit completion on the installation checkpoint.

2. The system shall raise an alarm if the detected sound suggests that the bearing has degraded beyond a predetermined threshold.
3. The system shall identify and classify any possible bearing defect including Rolling surface defects, wheel flats, wheel roughness, spalls.
4. The system shall allow threshold customization to fulfil maintenance requirements.
5. The system shall allow the operator to define a database of sounds and/or spectral characteristics to be used as reference for defect identification according to the rolling stock fleet characteristics.

The possible use cases covered by the BAM/ABD system are similar to those of HABD/HWD system and include the identification of damages on wagons and bearing defect detection.

8.4.2.5 Wheel Measurement System (WMS)

The Wheel Measuring System (WMS) provides automatic analysis of relevant wheel and wheelset parameters. Typically, the system is composed by sensing devices installed trackside, multiple wheel sensors for transit detection and speed measurement, a control cabinet installed at the closed shelter and additional equipment for diagnostic and additional functionality (e.g. a cooling system is usually required for correct sensor operation).

In general, this system uses a triangulation method of laser beams with matrix cameras to obtain the instantaneous measure of the wheel profile (see Figure 101).

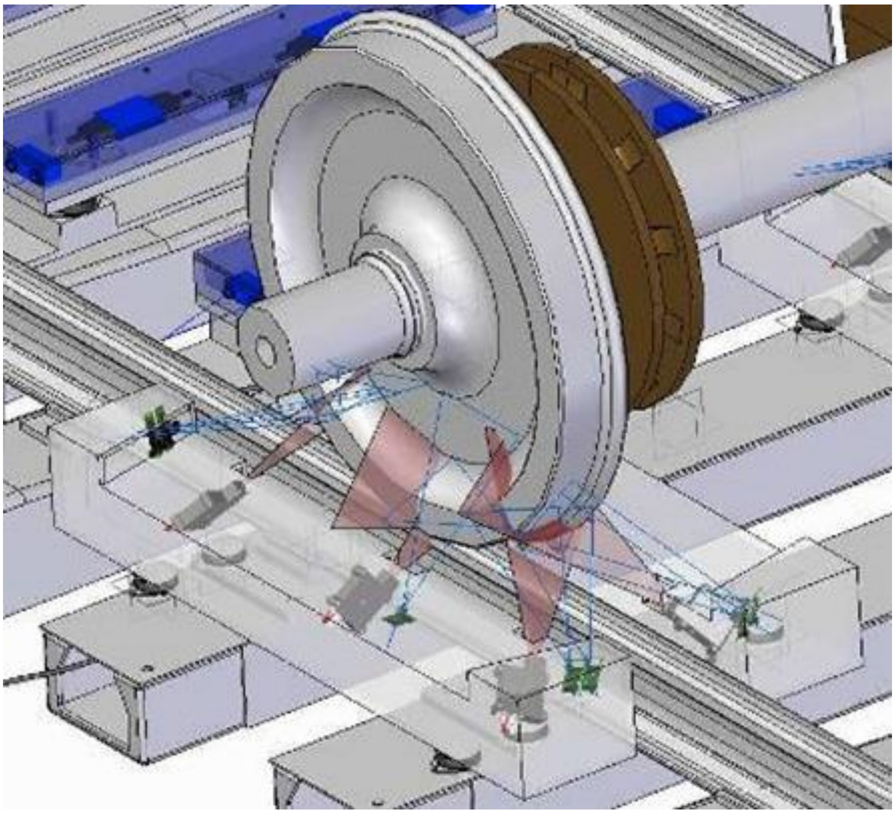


Figure 101: An example of Wheel Measurement System

Due to its complexity, specific care shall be taken in selecting the installation site in order to maximize the benefits from the rolling stock diagnostics that this system can provide.

Wheel measurement dataset includes multiple information that can be used to assess the status of the wheel and define a three-dimensional representation of the profile. They for example include flange thickness, flange height, flange angle, tread hollow, height of any developing false flange, width tread profile, diameter of each wheel.

However, it shall be noted that due to the laser technology itself, all of these parameters are acquired at a very specific section of the wheel that is transiting on the sensor, so the system is able to provide only a single measure of all these values on the entire wheel circumference. The highest the number of transits of the same train on the WMS sensors, the highest is the number of acquired wheel sections and corresponding accuracy in assessing the (entire) wheel status.

Technical specification

1. The system shall be able to automatically detect transit and acquire relevant wheel parameters of the entire train transiting at the checkpoint: flange thickness, flange height, flange angle, tread hollow, height of any developing false flange, width tread profile, diameter of each wheel.

2. The WMS system shall have different adjustable thresholds that can be used to assess each type of rolling stock in operation on the line providing warnings and alarms according to the detected defect.
3. The WMS alarms shall be activated when the measured data is outside of a predefined range.
4. Laser activation must not result in a risk for passengers and personnel near the track.

In addition to its specific use case, the possible use case covered by the WMS is the identification of damages on wagons.

8.4.2.6 Radio Frequency Identification (RFID)

The RFID tag reader automatically acquire the ID tag from all locomotives and wagons equipped with fixed ID-tags. It's a simple system including an antenna and a controller which is usually connected to other systems (like those described in the previous sections).

The RFID tag readers' antenna is able to detect and identify RFID tags in its proximity (tags are passive devices installed on each vehicle and provided with a unique identification number). RFID tag readers are installed close to wayside monitoring installation sites, see Figure 102.

By connecting automatic defect detection system to a RFID reader, it is possible to associate the acquired information to a specific asset identified by its individual ID.

Figure 102: Rolling Stock identification through RFID antenna (right) RFID tag mounted on a wagon within a distance of 70 to 110 cm measured from top of the rail (left).

Technical specifications

1. The RFID tag readers shall be able to read the tags on every vehicle that is transiting in front of the antenna.

2. The reader shall be configured to connect to the local controller supporting other identification and detection systems installed at the same checkpoint e.g. Intelligent Video Gate, WIM, HABD/HWD
3. The tags readers shall be designed and installed to work reliably in the ambient conditions of their installation without interfering with other RF technologies.
4. According to standard (GS1, 2013) RFID tags may be fitted on both sides of each vehicle (to the left part of the sides).
5. The tag readers shall read tags on vehicles

This system may be used to generally enable multiple use cases but its main application is for the integration of information to the customers.

8.4.2.7 Wagon On Board Unit

The data onboard the wagons contribute also to the digitalization framework for freight presented in this document and it is applicable to the wagon assets on board and infrastructure monitoring as well.

The Wagon On Board Unit is designed to acquire and monitor data from various sensors installed on the wagons, such as accelerometers, ultrasonic and/or strain gauge, as some of the example presented at the beginning of this section. That pursues enable efficient and reliable operation, in terms of rolling stock and logistics. The monitoring with sensors on each bogie and frame could be even complemented with train composition and positioning, which data could be combined and converged for a more accurate processing of the raw data and a more interesting digestion from the relevant stakeholders.

The visual representation, displayed in the Figure 103, provides a high-level overview of the system's architecture. It showcases the various components and their interconnections, offering a comprehensive understanding of how the system could be designed for sending the on-board data into the visualization and platforms, through a direct connection or by means of ad-hoc communication system on the checkpoints.

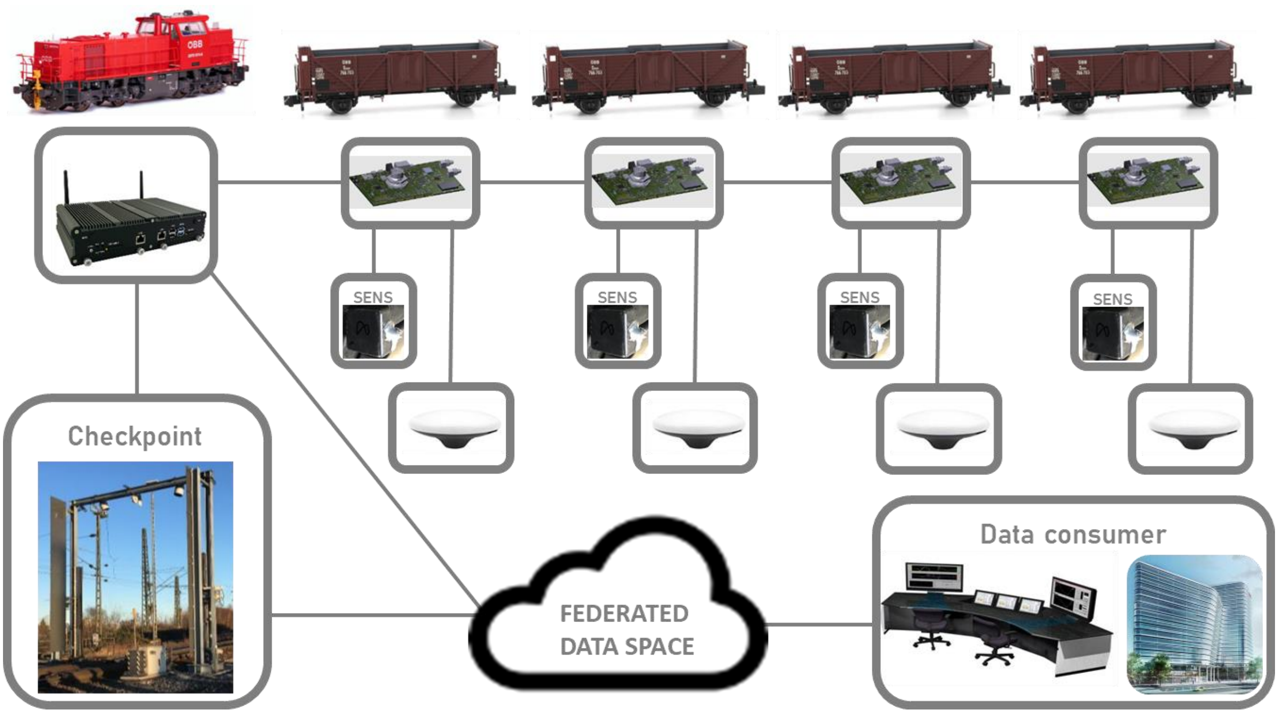


Figure 103: System architecture for Wagon On-Board Unit elements

For the operation and maintenance use cases, ensuring safe and efficient freight wagon operation relies on multiple parameters and elements such as springs, brakes, couplers, wheels, axles, or bearings.

For example, springs play a vital role in absorbing shocks and vibrations, enabling a smooth ride while safeguarding cargo and wagon integrity. However, the springs endure extreme loads and adverse conditions throughout their service life. Factors like wear, fatigue, weight unbalances, overloading and severe impacts can lead to deterioration and loss of functionality over time, negatively impacting wagon performance and potentially leading to accidents. Continuous monitoring of springs on freight wagons could offer multiple benefits compared to punctual readings. First, it allows a more accurate determination of the status which led to an early detection of any deterioration or damage to the springs, which helps preventing catastrophic failures and accidents. In addition, regular monitoring facilitates predictive maintenance, which means that springs can be replaced or repaired before serious problems occur. This not only improves safety, but also reduces operating costs by avoiding unplanned outages and optimizing maintenance schedules, minimizing disruptions and ensuring a constant flow of goods. Also, this spring monitoring functionality, working together with the wagon positioning function described above, potentially facilitates the detection of possible faults in the track structure.

Another example of function that benefits from the installation and processing of sensors on-board is the weight and weight balance estimation. Measuring the pressure, compression, distance or accelerations that occurs in the key elements of the bogie could allow the convoy operator to check whether the weight of the load is correct and if it is balanced or not. That is also relevant and related to the state of wear of the dampers themselves.

The example of the on-board data presented in the previous paragraphs needs to be delivered to the appropriate processing element or database, where they will be consumed by means of the federated data space that connects them with the data consumers.

The technical specifications and challenges, below, is related to the Wagon On-Board Unit but also to the communication of these data.

Technical specifications

1. Installation of Wagon on board unit on board
2. Installation, supply and connection of the communication system on the checkpoint, in agreement with the installation performed for Checkpoints data
3. Maintenance of physical elements on wagons and on the checkpoint
4. Consideration of harsh environment for electronics (Validation/homologation of non-functional requirements)
5. Needs of battery supply on-board
6. Communication technology architecture design and validation (possibilities opened: direct link with checkpoint and network communication such as 4G)
7. Standardization of the data format and time references.

8.4.3 Technical standardisation for image processing and other identification and detection technologies

8.4.3.1 Image Processing

The requirements for the image processing procedures as described in section 8.4.1, are listed in Table 31:

Functional requirement	Suggested / preferred checkpoint system and technology	Technical requirement statement

The system should detect an incoming train and slice each wagon	Detection system (LiDAR, RADAR, IR sensors, Image Processing)	R1) The system shall detect transits, estimate their speed and track in which they are -in case there are multiple tracks in the Checkpoint area- in order to trigger the image acquisition systems.
		R2) The system shall slice each wagon of the train for the image acquisition system to obtain a unique image per wagon.
The system should detect and recognize the different codes that identify wagons (EVNs) and loading units (ILU/BIC codes)	RGB or Grayscale cameras	R3) The system shall identify each wagon detecting and recognizing its EVN. In case the EVN is not readable in any of the wagon faces, the Checkpoints system must notify it.
		R4) The image acquire by the system should have enough resolution to allow OCR reading of the desired codes.
		R5) The system shall identify each loading unit in the wagon detecting and recognizing the containers' ILU/BIC code. In case ILU/BIC code is not readable in any of the faces of the container, the Checkpoints system should notify it.
The system should identify the wagons and containers composition for each train, determining the sequence in which wagons are detected and assigning the correct loading unit and its position to each wagon	RGB or Grayscale cameras, OCR systems	R6) The system shall determine the position of each loading unit in a specific wagon, assigning the containers' identification (ILU/BIC code) to the corresponding wagon (EVN) and train

Table 31 Image processing requirements

Benchmark

A benchmark refers to a standardized and commonly accepted set of data and evaluation criteria, used to compare the performance of different systems or algorithms. For image processing technologies, the usage of benchmarks is necessary for several reasons. They provide a way to implement standardized comparisons, in such way that different solutions' performance can be compared under the same conditions. Benchmarks are also commonly used to establish the metrics which will later define the objective of the systems.

In terms of the Standardized Railway Checkpoints, the number of checkpoints installed during demonstrators and the variety of images and data acquired by them brings necessity of defining a common framework for testing solutions. The importance of this framework lies in making it feasible to compare solutions developed under certain conditions or checkpoints. For instance, it is advisable to avoid evaluating different models with different datasets, each one compiling the features of a certain checkpoint.

This solution can be approached in two ways: by defining common benchmarks against which solutions will be evaluated or establishing minimum requirements for the implemented benchmarks. These criteria should include, at least, the following aspects:

- Dataset of images: every development should be tested against a previously defined set of images. Those images should meet some minimum requirements, which should be defined and validated including:
    - Resolution.
    - Image format.
    - Camera – object distance.
    - Camera angle.
    - Climate conditions.
    - Minimum number of images.
- Ground truth: the images to evaluate should be labelled. That is, if the performance of a certain detector is going to be evaluated, the correct or expected output of the system should be known beforehand. This way, every developed module will have a different ground truth, depending on the target of the module.
- Use case which will be evaluated: every use case should be evaluated using a specific benchmark. In such way, a model developed for detecting certain codes in the wagons cannot be evaluated under the same conditions, dataset, and metrics that a model developed for detecting defects.
- Metrics: which can provide an objective and quantifiable way to evaluate the performance of a solution. They also allow a direct comparison between different systems. One of the most common metrics used for evaluating is the *Accuracy*,

which measures the proportion of correctly classified features, out of the total features of the dataset. For the use case of recognizing EVNs, the Accuracy of a solution will be the percentage of EVNs correctly detected, against the total number of EVNs in the dataset. For computing the Accuracy in this case, the following metrics should be considered:

- True Positive: a code "AAAA" correctly detected as "AAAA".
- False Positive: the system detected a code which was not on the image.
- True Negative: the system detected no code in the image, and there was none.
- False Negative: a code in the image which was not detected

8.4.3.2 Other wayside monitoring systems

When the train passes the wayside detection systems, a switch will generate a signal that will ensure the system to record vibration, temperature, or acoustic data. To identify the train, RFID tag readers are mounted at each wayside location to identify the RFID tag number of each wagon. The signals generated by the wayside data acquisition module will be sent to a data processing unit that will process the data to extract specific features related to the condition of the wagons. Even for similar systems, the pre-processing techniques may differ from various manufacturers, leading to variations in the value of the extracted features. In general, each wayside monitoring system has an individual Inspection Management System to monitor the rolling stocks health status (for instance FleetOne for RailBAM). The data generated from the different wayside systems is then gathered in Trafikverket's data management system for wayside monitoring called DPC III (DPC stands for Detektor-PC). The gathered data is composed of information related to general information about the passing train as well as common information related to the status of the wagons (wheel, axles, bearings) for detectors of the same type (I.e. HB/HW, WILD or BAM):

Train/wagon information common to each detector:

- Detector location
- Train ID
- Occurred date time (YYYY-MM-DD HH:MM:SS)
- Train velocity (km/h)
- Number of axles in train
- Train total length (in meters)
- RFID tag number
- Axle number from front of train

- Vehicle fixed axle number
- Boolean indicating which type of detector is active (HB/HW, WILD or BAM)

Hot-Box/Hot-Wheels systems (SERVO-SATT, FUES; PHOENIX):

- Hot-box left value (°C)
- Hot-box right value (°C)
- Hot wheel left value (°C)
- Hot wheel right value (°C) (*Only one of the value from the Hot-Wheel is given, either left or right side depending on the direction of travel)*

These features are related to the standard EN 15437-1:2009+A1:2023 that defines alarm levels based on hot temperatures alarms, warm temperature alarms and differential temperature alarms.

Wheel Impact Load detectors (SCHENCK; PHOENIX):

- Train total weight (in tons)
- Axle load (in tons)
- Left wheel damage mean value (kN)
- Right wheel damage mean value (kN)
- Left wheel damage peak value (kN)
- Right wheel damage peak value (kN)

The measured peak and mean values can be used to calculate the dynamic load (difference between peak and mean) the load ratio (peak divided by mean). In the DPC, the low and high alarms are generated when the peak, dynamic and ratio surpasses specified threshold values. The type of alarm threshold will depend on the wagon type and load, i.e if it is a normal loaded or unloaded wagon, a locomotive or an unknow vehicle.

Bearing Acoustic Monitor (RailBAM)

In comparison to HB/HW and WILD that will provide scalar values related to forces or temperatures (related to European or Swedish standards), each wheel/bearing that passes a RailBAM system will be assigned a descriptor related to a specific fault. The descriptor is defined as **PREFIX(TYPE/LEVEL/DESCRIPTOR),** where:

- **PREFIX** : noise that may interfere with bearing or wheel fault detection
    - **Clpd** – Clipped signal
    - **Shrk** – Tonal noise¨
    - **FBS** – Flanging, Braking, Slamming
    - **NOISY** – Unknown noise
- **TYPE**: type of fault
    - **RS** – Bearing Running Surface fault
    - **LF** – Bearing Looseness/Fretting
    - **WHLFLT** – Wheel Flat
- **LEVEL**: severity of the fault
    - **1** – Severe fault
    - **2** – Moderate fault
    - **3** – Minor fault
    - **4** – No fault identified
- **DESCRIPTOR**: detail about the fault (only applicable to RS faults)
    - _**r**: clear roller fault
    - _**p**: clear cup fault
    - _**n**: cone faults
    - _**m**: multiple faults
    - _**e**: extended fault
    - _**s**: extended fault

Examples of faults descriptors:

- **RS2_r Clear Running Surface Roller fault of level 2**
- **NOISY(LF3) Looseness/Fretting of level 3 with noise**
- **WHLFLT1 Wheel Flat of level 1**

8.5 Interoperable IT systems for data management and processing

Data that are collected by checkpoints can be useful in processes and IT systems of many different organisations in the railway sector, for example infrastructure managers, railway undertakings, customers of railway undertakings, terminal operators and workshops. Therefore, it is important that the collected data are made available outside the organisations (often infrastructure managers) that own the checkpoints. This section describes this data sharing, in particular which data that must be shared in order to fulfil the needs of different processes and what needs to be standardised in order to make the data sharing smooth and efficient.

The shared data may have been collected by a checkpoint at the site (for example a border crossing, a terminal or a yard) where they are used, but they may also come from checkpoints in other places, where a train or wagon of interest has previously been. Using data from other locations makes it easier to plan operations in advance, already before the train or wagon has arrived.

Below, the data that must be shared to fulfil the needs of different processes are listed in two categories: data that correspond to the minimal viable product (MVP) described in section 8.3, and other data. As this categorisation shows, checkpoints that are intended to provide data for these processes must collect more data than the MVP does. The section concludes with some remarks and requirements regarding standardisation.

8.5.1 Data sharing for cross-border transports

As described in section 8.2.1, train inspections at borders are a responsibility for railway undertakings. Therefore, if data collected by checkpoints are to be useful in simplifying the processes at borders, they must be shared with the railway undertakings. Below, the collected data that are of interest in these processes are listed.

- Data corresponding to the MVP:
    - Identity of the checkpoint where the data have been collected
    - Total number of wagons
    - Wagon numbers (EVNs)
    - Position of wagons in the trains
- Other data:
    - Timestamps
    - Train numbers
    - Length of trains
    - Information about dangerous goods (substances, hazards)
    - Information about perishable goods
    - Wagon outline dimensions
    - Flat wheels
    - Temperature of bearings
    - Damaged pantographs
    - Locomotive types

8.5.2 Data sharing for management of terminals

As described in section 8.2.2.1 and section 8.2.2.2, terminal operators need information about arriving trains and loading units in order to plan transshipment and storage. The data from checkpoints that should be shared with the terminal operators and their terminal operating systems follow below.

- Data corresponding to the minimal viable product, MVP:
  - Identity of the checkpoint where the data have been collected
  - Wagon numbers (EVNs)
  - Loading unit codes
  - Position of wagons and loading units in the trains
- Other data:
  - Timestamps
  - Train numbers
  - Loading unit types (container, semi-trailer, ...)
  - Length and weight of trains
  - Payload weights
  - Information about dangerous goods (substances, hazards)
  - Information about damages

8.5.3 Data sharing for management of yards

As described in section 8.2.3.1 and section 8.2.3.1.1, the railway undertaking or yard operator that is responsible for the classification at a yard needs information about arriving trains and wagons, in order to plan the classification process. The data from checkpoints that are of interest for this planning are as follows.

- Data corresponding to the minimal viable product, MVP:
  - Identity of the checkpoint where the data have been collected
  - Wagon numbers (EVNs)
  - Position of wagons in the trains
- Other data:
  - Timestamps
  - Train numbers
  - Length and weight of trains
  - Payload weights
  - Information about dangerous goods (substances, hazards)
  - Information about damages

8.5.4 Data sharing for workshops

As described in many of the use cases in section 8.2.5, data collected by checkpoints can be very helpful to guide the maintenance of wagons at workshops. Data that should be shared with workshops are as follows.

- Data corresponding to the minimal viable product, MVP:
    - Identity of the checkpoint where the data have been collected
    - Wagon numbers (EVNs)
    - Position of wagons in the trains
- Other data:
    - Timestamps
    - Train numbers
    - The status of:
        - Bearings
        - Springs
        - Brake pads
        - Buffers
        - Tarpaulin covers
        - Floors
        - Axles
        - Wheels (profiles and flat spots)

The data should be automatically sent to the workshop management system when a wagon has passed a checkpoint, so that any maintenance tasks can be planned according to the current working status of each workshop. If there are critical damages, it is necessary that the workshop receives that information as soon as possible. If the workshop would have to pull the data from a data-sharing platform where they have been made available (instead of automatically receiving them), the time to react would be much longer.

8.5.5 Data sharing for traffic management

Presently, wayside detectors (as described in section 8.4.3) serve the purpose of identifying deviations that surpass predefined thresholds concerning factors like temperature, load levels, and emitted sounds. When such anomalies are detected, vehicle alarms are generated and relayed to the traffic management system (TMS). The current information shared to the TMS is:

- Detector location
- Timestamps
- Train number
- Wagon numbers
- Alarm levels related to the status of
    - Overheated bearings
    - Overheated wheels
    - Highly degraded wheels
- Alarm wagon position
- Alarm axle position and side

When an alarm goes off, the remote train dispatcher contacts the train driver and shares the information about the status of locomotives and wagons. This information can encompass speed restrictions or directives to set aside wagons for more extensive inspections and to verify that the alarm does not come from a defective detector (detector functional alarms that will result in false alarms for freight wagons). However, this reactive process can disrupt the flow of traffic and reduce the network's inherent capacity.

To mitigate this disruption, a proactive approach should be adopted. This entails making predictions about the future condition of individual wagons by conducting an in-depth analysis of data collected by these detectors. Data related to changes in wagon condition from wayside monitoring can be integrated with information derived from Intelligent Video Gates. For example, changes in load signatures detected by the wheel impact detectors can be cross correlated with images of the bogie spring status from the gates.

Wagons displaying signs of deterioration could then be identified and taken out of operation before they have a chance to disrupt the flow of traffic. The initial step in this process involves transmitting predictions about the wagon's condition to the TMS. The subsequent step would be the integration of this information into a connected driver advisory system (C-DAS).

8.5.6 Standardisation of data management and processing

Regarding data-sharing general concepts, alignment work is being carried out with Seamless Data-Sharing work packages, whose focus and preliminary work can be found in this deliverable in Chapter 10. The final conclusion is that an International Data Space-based architecture is foreseen to be used for data sharing, which means that there is not a centralized platform where data are collected, but data are shared in a trustful way while keeping control of the data sources. Railway-focused Federated Data Space is being developed within the FP1-MOTIONAL project (WP31), as the relevant environment that enables data sharing. As stated in the Industrial Data Spaces Reference Architecture Model (IDS-RAM), data exchange is only carried out once the data provider and consumer have agreed on the access policies. In practice, both data producers (or data publishers) and data consumers would need to implement IDS connectors specific to their use case. The use cases described in Section 10.6 have the ambition of using data spaces to share data between data providers and consumers. Details about the process, main components and so on can be found more in detail in Section 10.6 (Data sharing mechanism).

Additionally, work is being carried out regarding data formatting. This is related to the Conceptual Data Model (CDM), mainly pushed in the FP1-MOTIONAL project as part of the Transversal Topic. There are alignment efforts in this topic as described in Section 10.11

According to a preliminary analysis, it should be possible to build components in Deplide for data spaces and thus to use data spaces to share data from the type of gate already installed in Gothenburg. This is promising for the continued development work within this project, and for most purposes, data collected by checkpoints will likely be shared through data-sharing platforms using the data space approach. As described above, however, there is a requirement that data are actively sent to workshop management systems and traffic management systems and not just made available on a platform. In these cases, the role of the platforms would be to serve as a common enabler to share the data from the checkpoints to the different receiving systems, so that the checkpoints declare the catalogue of data once in the data space, and this can be consumed by several receiving systems.

The data-sharing platforms and message formats that will be used must of course be able to handle the information that needs to be shared for the different purposes described above. Since the intention is to use message formats that are related to the conceptual data model, this model must include concepts that together correspond to all the information to be shared. All the mentioned requirements regarding data-sharing platforms and message formats must be taken into account by the System Pillar and others that are responsible for general standardisation efforts.

8.6 Harmonised procedures and regulations

The implementation of Standardised European Checkpoints implies harmonised procedures and adhering to current regulatory framework and identifying regulatory barriers. The harmonisation of procedures and standardisation of these Checkpoints are planned to be jointly addressed by the System Pillar sub-project Harmonized European Railway Diagnostics (Herd), FP5 T25.4/WP29 and FP3 WP7 where Checkpoints are also being developed but where passenger trains are also included and where the focus is on maintenance of rolling stock rather than freight operations.

The main regulations identified thus far in T25.4 that the concept needs to relate to concern inspections for cross border traffic and handling of dangerous goods. Regarding cross border traffic, the implementation of Automated Freight Train Transfer Inspections (ATTI) at borders has already been harmonised all over Europe. The integration of Checkpoints or other wayside monitoring systems (WMS) seems to make sense as the ATTI does not yet provide the integration of WMS data. Therefore, it is recommended that the System Pillar take action here. It should be noted that when partners are not bounded by ATTI (UIC, 2017), GCU Appendix 9 (GRU, 2023) is applied.

Regulations regarding data exchange and image analysis will also be taken into consideration in WP29 and task 29.1 e.g. GDPR in regards to face recognition of drivers and passengers and ownership of data and the business model for data exchange.

Concerning management of dangerous goods, strict domestic and European regulations (e.g. Directive 2008/68/EC on the inland transport of dangerous goods) apply for handling and sharing the associated data. This applies also for the physical handling of dangerous goods as elaborated by the process descriptions provided in section 8.2 e.g. storing of dangerous goods must be done in a safe way according to regulations about dangerous goods (certain goods cannot be stored together).

9 Multimodal Integration

9.1 Introduction

Multimodal Integration has the primary objective to further ease the access of freight to rail. Simplifying processes for the search and booking of existing intermodal services. Enabling a simplified booking for various services of different service providers and finally to enable a digitally supported establishment of new services on rail, where today either capacity is at its limits or no adequate service is existing.

In the realm of freight transportation, the concepts of multimodality and intermodality have garnered significant attention. Multimodality refers to the ability to use different modes of transport (ship, rail, truck, barge and aircraft) for a single shipment, while intermodality is often characterised as the integration of at least two modes of transport in a transport chain, from origin to final destination (Giusti 2019). The most common formulation for Intermodal Freight Transport was introduced by European commission as "the movement of goods in one and the same loading unit or vehicle, which uses successively several modes of transport without handling the goods themselves in changing modes" (Commission of the European Communities, 1997). By leveraging the distinct advantages of individual transportation modes, intermodality fosters enhanced transport efficiency and improved cost-benefit ratios for complex logistics processes.

The objective of this work package is to increase efficiency and to simplify access to those complex logistic processes. To measure this efficiency the partners of work package 31 have decided to showcase three examples on which we can measure/assess the before and after process duration. Another important factor, which is more complex to measure is the user experience of the herein described systems. Therefor and where possible the partners will try to analyse the user experience. A possible solution to measure user experience and user acceptance is e.g. the NetPromoterScore. At least for the use cases that will be described in section 10.4.2, it is envisaged to do user surveys to evaluate the NetPromoterScore.

In order to raise these efficiency potentials and to increase the modal split of rail freight transport, one of the objectives of the project is to implement software solutions for innovative and integrated multimodal transport planning, management and operation system including innovative routing engines on loading unit level (e.g. container, trailer, etc.). By standardising the formats and the services descriptions and adapting the transport planners, services from various/all service providers could be combined and a European overview of rail freight services is enabled.

For this work later in the project, it is necessary to know the different kinds of systems and modules, customer requirements and user roles of these systems and to analyse how the different systems involved in the offer of an intermodal chain can be combined seamlessly. The aim is to define further development needs for specific missing functional and technical requirements to create a seamless multimodal experience.

9.2 Status quo

As of today the usage of Rail in Freight is still around 20% only. This has many reasons, but one main factor is for sure the related complexity to find and book such intermodal or multimodal services.

In the course of this project, it is vital to understand the status quo of the various ongoing projects in European union with a similar objective and the outcome of projects in the past on which we can build. In the grant agreement it was stated that we will analyse all systems and modules that are existing. This remains our objective and the strong interaction with the various stakeholders and market players is a significant factor to succeed with this objective. In the first period and within the deliverables 25.2 and now 25.1 we focussed on the major projects and initiatives and the various booking systems of freight operators.

Two main projects in Germany are InGa-Z and KV4.0. KV4.0 is terminated and was strongly driven by Kombiverkehr and DB Cargo a main contributor to Flagship Project 5. It forms some basic principles how systems shall communicate together and is there for one of the key elements on which the work package 31 will build on. KV4.0 included some of the largest freight operators on Rail in Europe and its commercial successor is pushed by the two largest intermodal operators in Europe.

InGa-Z has the aim to standardize processes and procedures in German intermodal terminals with real-time information from the railway network and 'terminal processes of stakeholders, as well to digitalize and standardise the check-in process in intermodal terminals. It builds on KV4.0 and elaborates further this concept.

The third large initiative that is currently ongoing in Europe is the Proyecto SIMPLE in Spain. SIMPLE is an ongoing project with an expected completion date in 2024. Nowadays is in its final demonstration phase, so its maturity level is advanced but not already finalized. This implies that it is difficult to include new functionalities or developments compatible with its level of maturity during the development period of the FP5 - WP31. Therefore, it is difficult to align it with WP31.

Especially the growing digitalisation of freight operators with own initiatives is closely followed and taken into account in order for work package 31 to not duplicate existing solutions, if they are customer neutral and accessible, but to focus on gaps in the current system landscape (including functions which are missing in the existing systems) and the harmonization of the various systems were possible.

Additionally, the Projects listed and explained in Chapter 11.3 are almost all, partly of relevance for a seamless multimodal booking experience and will be closely followed by the partners in this Work package.

9.3 Target Scenario

The target of work package 31 and in general of FP5 is to increase the usage of rail in freight, to simplify the rail access, and to simplify the related processes. The booking process could be in general relatively simple, but there are some constraints which have to be taken into account like the security and commercial checks which need to be done before a new customer can book a transport slot on one of the trains managed by an intermodal operator. It is a classical marketplace, where demand meets supply of services. With registration of users and offerings. The latter is getting more complex when customers search for price/route comparisons, as special prices might apply to some customers based on framework contracts, so that a split between regular price and special price is needed for transport planners and booking systems.

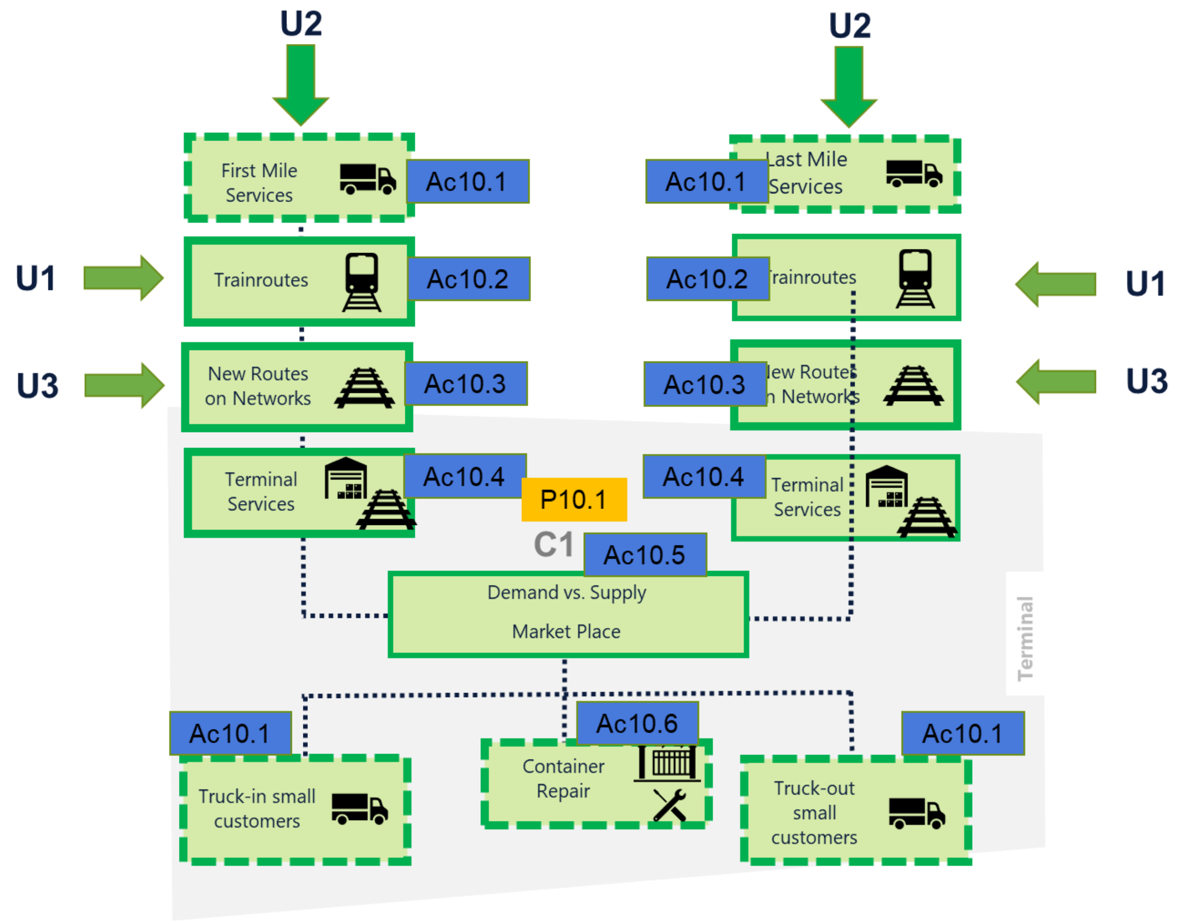


Figure 104: Multimodal chain with process steps and actions

Location	Ac10.1 – Last Mile Booking
Related processes	P10.1 Booking of multimodal services
Specified actors	Trucks, cargo carriers
Activities	Selection of transport subtractor (truck), agreement on service level agreements and terms & conditions

Location	Ac10.2 – Intermodal Service search
Related processes	P10.1 Booking of multimodal services
Specified actors	Infrastructure manager, railway undertakings
Activities	Selection of transport subtractor (train), searching for alternative routings (part of FP1 motional and WP seamless planning), agreement on service level agreements and terms & conditions

Location	Ac10.3 – Create new intermodal rail services
Related processes	P10.1 Booking of multimodal services
Specified actors	Infrastructure manager, railway undertakings
Activities	searching for free slots on networks (part of FP1 motional and WP seamless planning), negotiations with railway undertakings and agreement on service level agreements and terms & conditions

Location	Ac10.4 – Terminal Services Booking
Related processes	P10.1 Booking of multimodal services
Specified actors	Terminal Operators
Activities	Selection of needed terminal services to enable selected intermodal service and connections (linked to WP seamless planning), agreement on service level agreements and terms & conditions

Location	Ac10.5 – Demand and Supply matching
Related processes	P10.1 Booking of multimodal services
Specified actors	Terminal operators, infrastructure manager, railway undertakings, trucks, cargo carrier
Activities	Facilitate exchange of demand and supply between all stakeholders

Location	Ac10.6 – Repair of Container
Related processes	P10.1 Booking of multimodal services
Specified actors	Cargo carrier, terminal operators
Activities	Booking of container repairs, agreement on service level agreements and terms & conditions

The complexity arises out of different areas, and has different extends and challenges. That are the main reason for the use cases we identified in 10.4:

- Use-case 1 (U1) - Multimodal Trip Search
- Use-case 2 (U2) - Multimodal Booking Platform
- Use-case 3 (U3) - Configuration of New Freight Transport Services

Even if the main purpose of either routing loading units via existing trains services or to develop/implement new services where no train services exist, including the search to find possible gaps in the network to build a new intermodal service, is similar, the challenges are quite different. E.g. which combination and interchange rules have to be respected (timing & technical & commercial), how to combine different services depending on different agreements and framework contracts. These are the focus areas of use cases 10.4.1. and 10.4.3.

The use case 10.4.2. is to identify boundaries in between current booking systems and to demonstrate how to overcome them.

9.4 Use cases and demonstrators describing the "one system" approach and the data and interfaces requirements

The objective of the Use cases and demonstrators is to show how a seamless experience can be achieved in Europe for identifying and booking intermodal services. Therefor the Use cases target to show international services, if possible combined in one Web App, that can be booked via different platforms and real-time information that is shared between different platforms. In the same time the use cases and demonstrators shall describe and demonstrate which data is needed to achieve the use cases and what are potential barriers hindering yet a larger roll-out.

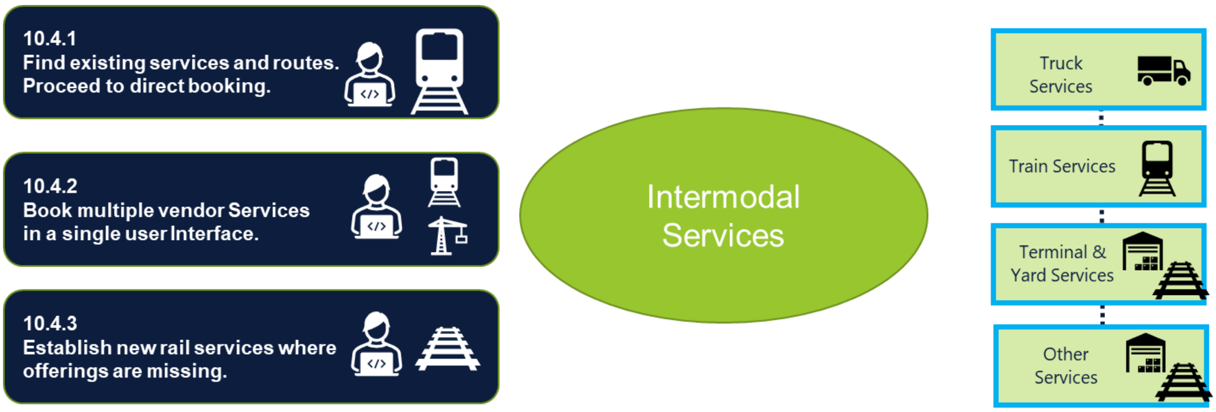


Figure 105: Use cases demonstrating how European shift to rail for freight can be facilitated

The 3 described uses cases are in a logical sequence and will demonstrate how digitally supported the European shift to rail for freight can be eased, taking into account the following requests:

- Customers (Shippers, forwarders, ...) do not want to call numerous potential service providers and check several web services to get an extensive overview on intermodal transport options (potentially combined from different providers by appropriate routing algorithms if this improves the offered connections/options for the customer.

- Even if customers prefer specific intermodal operators (e.g. because of framework contracts, ...) they require to receive a complete set of information from the respective transport planner application.
- When the intermodal transport combinations to be found in the transport planer application are provided by different service providers, the customers want to book and manage the separate services in one booking platform.
- This platform should be open to any kind of service provider
- If for the O/D request entered in the transport planner application no reasonable transport connection/ combination can be provided, either because there are no appropriate intermodal trains to be connected in the application or the existing trains are fully booked (in the majority of operating days), another system/platform should facilitate an easy generation of additional services on this (direct or combined) O/D connection. These new connections shall then be added to the transport planned, so that a continuously growing/completed transport offer is provided.

Consequently, to shift more freight to rail services **use case 1** is focussing on the needs of shippers and their forwarding companies as freight operators to understand which appropriate intermodal connections, potentially using different train services via hubs, exist today, can be booked (as they are not dedicated company trains) and which of them have still some free capacities (use case 1) **--> Multimodal trip search**

Use case 2 is then dealing with the subsequent booking and management functions for the customers but also for the involved service providers **--> Multimodal booking platform**

If the end customer demand cannot be fulfilled with existing services it is than **use case 3** that will digitally help to plan, coordinate, find and combine necessary resources needed (including possible available train paths on the railway network -> link to WP Seamless Planning and FP1 MOTIONAL) in order to try to build a completely new service to fulfil the market demand. **--> Configurator of new intermodal freight services**

It is the conviction of the partners in work package 31 and their affiliate entities and customers, that there will be not a single platform that will become the “one platform” but that it is needed to have a suite of different platforms, that are complementing each other and that do have on purpose overlaps. Those overlaps are not in competition, but the different platforms help each other to increase the service covering which is the most important for the sector and which is the main lever to increase the utilization and loading of existing multimodal railway services and to utilise available spare resources (including empty slots in railway networks) and therefor to maximize the usage of existing infrastructure.

10.4.1. Multimodal trip search module:

To overcome the lack of information about available multimodal transport options as alternatives to pure road transport, a demonstrator is intended, which is showing how easy existing or potential customers can identify suitable intermodal services by using an extended web based European routing and information system for their intermodal O/D transport requests (container, swap bodies, trailer). This demonstrator should show additional features that will be provided with the new system for intermodal planning such as the option to compare prices and transport time for various connections, or the environmental performance, and also pre-requisites and functions to book these connections using a single platform. Applied on the use case, the demonstrator should be used to identify all relevant intermodal transport options and to book a free slot on (an) existing train(s) going from North Italy to Germany or Sweden. Thereby, a platform based on HaCon's system HAFAS that is currently used for Kombiverkehrs European services should and will be used as a basis, so that the basis for the demonstrator can be set up in reasonable time. To ensure that all required information is included the system, including timetables and service information from different service providers, it must be designed as an interoperable tool with access to all different IT-systems that can provide relevant information.

In the first step, further data formats for timetable data will be integrated into the existing system. There are different formats for the commercial timetables which have to be consolidated and integrated. Besides different data formats, data can also be contradictory. This can be e.g. due to differences in the data provided by various national IMs during the train path construction or differences between operational and commercial timetables, or by simplifications in some of the original data sources (e.g. due to manual data processing, …) but there can also be differences in the commercial/operational data due to version differences or mistakes. Commerical timetables should contain additional information on loading and transfer times.

In future, it should be possible to connect further data sources and thus also offer the procedure and such standard system with its functionalities to e.g. all intermodal operators, with the trip planer being a "compatible" service either for own web services of the intermodal operators or as integrated/supporting tool for the various booking platforms, which offer/sell the services from different intermodal operators. A key step required to make the existing trip planner system(s) more compatible for the future is to add as input format a uniform standard format such as EDIGES. It needs to be analysed and assessed how this new standard (decided to be used by key market partners) can be optimally used and converted into the internal formats which are optimized for highly efficient routing algorithms. The required converters need to be capable to be adapted if minor adjustments of the market standard have to be done based on experiences gained in its initial application and usage. These flexible converters have to enable the processing of (potentially different) standardized data formats, significantly lowering the barriers for potential new customers and applications.

The following outlined goals and the connected requirements reflect a forward-looking approach to developing a transportation system that is not only compatible with various operators but also prioritizes seamless data exchange, standardization, and scalability. These aspects are crucial for ensuring the system's effectiveness, adaptability, and sustainability as it evolves and encounters increased demand and diverse data sources:

- Connecting Additional Data Sources: The plan is to expand the capabilities of the system by integrating with more data sources. This could include information from various (intermodal) transport operators, possibly making the trip planner(s) more comprehensive and versatile.
- Compatibility improvement: By connecting to more data sources, the aim is likely to improve compatibility with different transportation operators and their own systems. This could mean that the trip planner(s) becomes more adaptable and functional.
- Data interoperability: The emphasis on harmonisation and standardized data formats implies a commitment to making different data sources "speak the same language". This standardisation is crucial for seamless data exchange between routing, inventory, and planning systems. It ensures that data from diverse sources can be integrated and utilized efficiently. To achieve this, it is suggested to use a common standard format such as EDIGES.
- Application Programming Interfaces (API): APIs play a significant role in enabling the interaction between different software systems. Standardising APIs can enhance interoperability by providing a consistent and reliable means for systems to communicate and share data.

Scalable architecture a recommended wherever possible: The mention of a scalable architecture suggests a focus on designing a system that can handle increased data volumes and evolving user requirements without significant performance degradation. This scalability is essential for accommodating growth and changes in the system's usage over time.

If it turns out that data from different sources is overlapping regarding geographical coverage of thematical/vertical coverage, but is not complementary or is even contradictory, systems like e.g. the TPS integrator (as used already for passenger transport e.g. for the generation of the European Merits Timetable Data Set) are required to be used to analyse the contradictory data and to decide which information should be used for the common timetable and which not. This step of decision-making can be improved by a reinforcement learning process. This means that the completed decisions about the handling of contradictory data will be used by the algorithm as a basis for future decisions. Finally, this common merged timetable is stored in a common timetable data format. As these tools are currently focussed to handle/integrate/merge (international) passenger services, the tools would need to be adjusted to the specifics of freight transport if needed for the demonstrator use cases.

In the second step, restricted views have to be enabled. This means that customers who want to use such a system to sell their trains don't want to sell their contender's trains. So, they want to restrict their connection information and booking system to their own trains and those of their partners but not display their contendors' trains. This measure is necessary to ensure that train operators will provide their data for the demonstrator. Furthermore, filtering options must be developed in this step. These filtering options can be used by the future platform users to reduce the number of shown connections which makes it easier to find the best connection. The filtering options should be stored in the forwarders/logistic service providers profile because they only have or might want to have contracts with some dedicated intermodal operators but not with all.

To ensure reliable connections, it is necessary to consider transfer times at terminals which is the aim of the third step dealing with transhipment/transfer rules. Therefore, standard values for the necessary transfer time have to be defined. These values can then be adjusted individually for each terminal. Besides the times, it is also important to consider forbidden transfers that can exist due to missing connections or big distances between two trains in the terminal. Furthermore, the cost for interchanges must be considered in the prices for a whole connection, so, these costs must also be defined.

To enable an enhanced visibility of connections via intermodal services, it is required to enhance the intermodal transport planer also in this direction. For the visualization of connectivity, there should be a map as a result which shows for selected starting terminals all other points that can be reached within a specific time or with a maximum number of interchanges limited to a specific value. Such connectivity maps/functions were developed for passenger services, e.g. for real-estate platforms. The challenge for medium-/long distance intermodal freight connections that the number of possible connections through combination of single train services is quite high, so that even with the most powerful routing algorithm the ad-hoc calculation might take to long – an acceptable calculation time will be assessed in WP31. If an ad-hoc calculation of all possible connection takes too long (or is too resource consuming) for the selected terminal, this calculation can be done instead one time per day for every terminal. In this calculation, the transfer rules must be taken into account. The information on the connectivity should then be stored and so that it can be provided quickly.

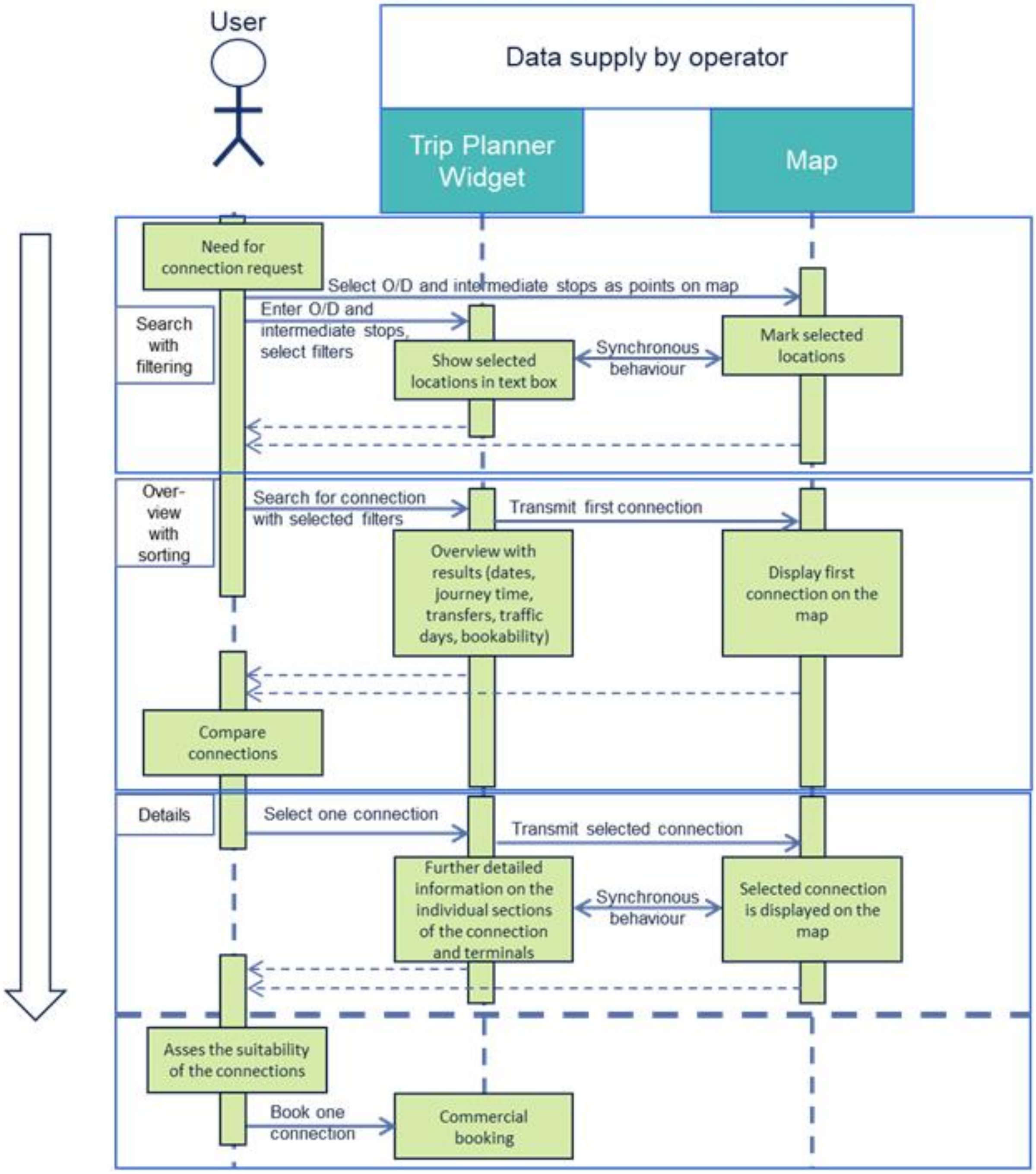


Figure 106: Sequence of the Trip Planner in terms of functional and procedural flow

Capacity-related information should also be considered more and more in future. This requires close cooperation with the customer/data supplier (combined transport operator) to analyze and clarify how the systems can be connected so that the capacities are either displayed on each selected connection or are used for the routing itself. For this requirement, the data must then be provided in the appropriate formats and content quality levels so that it can be integrated into the standard procedure. The addition of capacity information to the trip planner is an enriching step toward providing users with a more accurate result of transportation options. This feature not only enhances the accuracy of outcomes but also lays the groundwork for future developments, especially in terms of expanding sorting criteria and providing users with a more comprehensive understanding of their travel choices.

In connection with the described capacity feature, there is the limitation that the transport planner system currently processes only planning data for connection requests. However, this data lacks information about actual capacities, which is crucial for providing a comprehensive overview of transportation options. The goal would be to step-wise expand (with a frequently real-time data flow) the scope of information by incorporating capacity data into the connection results, if these can and will be provided by the operators (need to be assessed in 2024). This could involve comparing planned data with real-time data for each train. Connections with no available capacity or insufficient capacity based on individual requirements (loading gauge, dangerous goods, ...) may not be displayed, or they could be marked as "fully booked." This functionality ensures that users are presented with options that are realistically available for booking.

The required possibility of supplementing the information content per connection also has a further impact on the specific approach that can be achieved with extended sorting criteria. Such intelligent connection search could include a more user-specific handling of the results from the connection search:

1. Current Filtering Options: Some of the existing route planners allow users to filter results based on the fastest route, shortest route, and most environmentally friendly route. This indicates a consideration for factors like time, distance, and environmental impact, which might be of different importance for different users.
2. Integration of Price Information: The next step in development would involve incorporating price information for each connection. This addition would allow users to sort results based on cost, facilitating a more comprehensive decision-making process.
3. Potential future expansion of options for displaying results of the transport search (e.g.):
    a. Multiple Variants Display: The ability to show different variants of a connection based on user-selectable criteria like time, frequency, CO2

emissions, price, and more. This enables users to choose the "best route" based on their specific preferences.

    b. Standard Prices Display: Providing standard prices for connections is deemed essential. This adds transparency and ensures users have a baseline understanding of the costs associated with different routes. [To be noted: If later on users are registered and information about their specific framework contract conditions are available, these conditions might be used for adapting the standard price to a specific price].

4. Optional forwarding to booking platform(s): An optional feature mentioned is the ability to forward users to a (one of the various connected) booking platform(s). This streamlines the user experience by allowing them to seamlessly transition from route selection to the booking process.

In summary, the future development goals include not only the incorporation of provided train services from various operators and price information but also a significant expansion of the available criteria for sorting and comparing routes. The emphasis on user choice is highlighted through the ability to display multiple variants based on various factors. Additionally, the option to forward users to a booking platform enhances the end-to-end functionality of the application, making it a more comprehensive tool for transportation planning and decision-making.

As mentioned above and included in the GA, a proper calculation of CO2 and other emissions should be taken into account for either the routing or the filtering of potential transport routes and options. If such information can be used from general calculation tools and only has to be proper integrated including data gathering for the specific transport settings etc., or if specific calculation modules should be developed, could be analysed in the subsequent WP. Such assessment should take into account an analysis of the effect of different utilisation rates of the trains and other trains setting parameters. For the simple provision of information in line with the ISO certificates a more general calculation might be sufficient for a detailed assessment of effects connected to innovations leading to higher utilisation rates, more efficient train operation etc. a more detailed calculation might be needed (if the data which is needed is available). If such detailed parameters and calculations would be required and available the total emissions must then be distributed on the loading units considering their size and weight. But as mentioned above in the planning phase, the utilization is not yet known, so that for the initial connection/trip search, the average carbon footprint of all single trains used during a connection must be used as a basis.

Therefore, the existing trip planning systems currently display CO2 savings between road and rail transport, based on defined average values (e.g. EURO 6 standard for trucks).

But if appropriate data is supplied, it is also possible to expand these features as follows (especially for monitoring or reporting needs as well):

- An Improved CO2 calculator provides the CO2 emissions of a connection based on load weight, transshipments, and exact route.
- Necessity for follow-up analysis to save the CO2 savings made and to "verify" them using a supplementary calculator, i.e. to indicate how much CO2 was acturegardginally saved (incl. export option).

10.4.2. Multimodal Booking

As outlined in use case 1 the sophisticated trip search can link to direct booking possibilities. In order to reflect the requirement of an easy access to intermodal services, regardless if a service consists of several offerings of different stakeholders who do not necessarily cooperate, this use case 2 focusses on a multimodal and multivendor intermodal service.

The objective is to have a single User Interface where stakeholders can register themselves.

Terminal operating companies to understand on which intermodal services additional change over stops can be offered or additional terminal services can be offered such as intermediate storage place or repairs of Containers.

Trucking Companies to understand where last mile could be offered. The platform will explicitly not help to understand where railway legs can be substituted by truck services.

Freight operators, where first this term needs to be defined. Freight operators in this context are the ones commercially accountable for the journey or a leg of a journey. They can register to offer their services, such as taking over commercial risks, taking care of the invoicing, prepayments, customs declarations, booking of other needed services to execute a journey or a leg of a journey. Also, for freight operators the second objective is to understand where additional capacity is required or where they can purchase additional capacity in order to offer complete journeys.

Freight operators can be either independent companies or they can be in the same time Railway undertakings, terminal operators or trucking companies.

The most important aspect of this project and demonstrator is to understand how far a digital booking platform can go. Several examples in Europe have shown, that the platform provider often in the end became a freight operator or that the platform is owned by a freight operator. This than leads to again competition and constraints that many operators don´t want to offer their services on this platform.

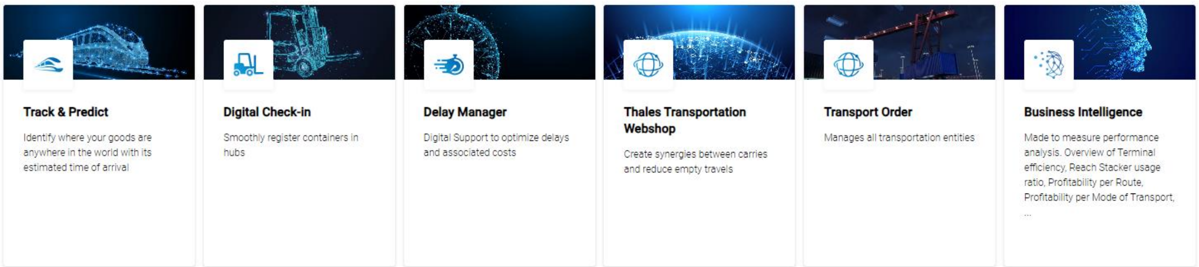


Figure 107: Market Place view

What are the technical barriers but more over what are the legal barriers and to jointly elaborate proposals of how to overcome them.

The use case will have the objective to allow seamless booking for a intermodal service involving services in 3 countries (Italy, Austria and Germany) for a service going from North Italy to Southern Germany and also to show how booking can be performed between Germany and Czech Republic.

The service involves transporting containers between specific terminals and handling their distribution and collection before and after sea transport.

Identified use case between Czech Republic and Germany

The use-case is centered around the intermodal service Hamburg-Waltershof (DE terminal) to Ústí nad Labem (CZ) Praha-Uhříněves / Česká Třebová (CZ terminals). The (current) railway undertaking is CD Cargo (ČDC DE (DE) and ČDC (CZ)) and the involved operator is Metrans.

The entire transport operation is managed by ČDC, with the formal handover/acceptance of licences taking place in Dresden-Friedrichstadt. Detailed data descriptions of the transport technology are available, allowing an accurate estimation of the ETI/ETA. However, specific data on the technology at the origin terminal in Hamburg-Waltershof is not currently available and the information provided is dependent on the readiness of the train to depart from the origin station.

An additional part of use case 2 is an automotive transport:

Where the end customer is Automotive Škoda Auto. It is about the Transport of cars from the Škoda Auto car factory (Mladá Boleslav, Solnice) to collecting in MY/terminal Nymburk (CZ). Therefor the intermodal service is Nymburk (CZ) – Děčín (CZ) – Emden (DE) and back, loaded trains from Nymburk to Emden and empty trains back. Nymburk is considered as a Škoda Auto terminal. The railway undertakings involved are CD Cargo (ČDC (CZ)) and DB Cargo DE with the handover/takeover between RUs in Bad Schandau (DE).

The czech terminal is operated by ČD Cargo (MY).

This czech part is closely linked to the Workpackage 27 where it is a combination of seamlessly booking services in germany and czech republic on rail and in terminals via a single and neutral user interface and to show in alignment with Workpackage 27 the optimised processes. Both together to reflect the market requirement of higher efficiency and increase utilization of existing assets.

Currently, there is a comprehensive data description of the transport technology available exclusively for the CZ section. In the direction from Nymburk to Emden, the Estimated Time of Arrival and therefor the enabler for the load interchange can be calculated, although the Estimated Time of Arrival (ETA) remains unknown. Conversely, in the direction from Emden to Nymburk, crucial information concerning the ETI/ETA for the DE section is missing, making only rough estimations possible. Additionally, there is a lack of essential data information from DBC DE for comprehensive planning purposes.

Within fixed time slots for available resources, the shift plan is predetermined to ensure non-stop or time-limited availability of resources. The aim is to achieve an evenly distributed workload throughout the shift, minimising peaks and troughs and ensuring efficient resource utilisation.

Conversely, in the floating time slots scenario for available resources, the shift plan is dynamically adaptable based on the requirements arising from current transport schedules. In this case, the aim is to dynamically allocate shifts according to the train timetable, allowing flexibility and responsiveness to changing traffic demands.

It will be measured the time consumption for a booking with versus the time consumption without the booking support.

The use Case 2 seeks to analyze a synergetic interaction with the Use Case 2 in FP6. This shall be analyzed thanks to at least 2 meetings per year and to evaluate possible synergies.

Freights delivery mainly relies on road transport, which generates congestion and more pollution than other modes, and rail transport in particular. Moreover, railway facilities are often underutilized, especially during off-peak hours. The main need is to implement new systems to deliver freight in a sustainable and low-cost impact, by considering mixed transportation of freights and passengers on the same train. Given the timetable of passenger trains, freight could be transported being picked up in specific wagons designated to allocate goods.

The main aim of Hitachi Support of this Use cases is to define and assess the tactical scheduling of cargo on passenger trains by addressing passenger priority and exploiting freight loading/unloading capacity while minimizing the transport costs. In this connection, given a set of freight to deliver and a set of train runs already scheduled, the aim consists of assigning goods to trains in order to use their unused capacity at the best. In doing so, the delivery requirements of freights, such as delivery priority, due dates, values, etc., are taken into account.

The identification and performance analysis of different rail-based cargo distribution layouts and plans, by considering real-time events and external information such as traffic schedules and restrictions, wagon type, loading/unloading constraints, will be performed.

Sequence:

1. The operator must schedule cargo delivery on a booking system;
2. The operator must specify the type of cargo, its departure and arrival station;
3. The operator must choose the KPI to be prioritized (low cost, low delivery delay, etc.);
4. The system must provide the optimal scheduling and allocation plan to meet the operational requirements.

INPUT AND ASSUMPTIONS:

- The customer needs could be fulfilled by existing freight services, but with higher costs.
- The timetable is pre-given and includes the number of cargo carriages in each train.
- Passengers and freights will not share the same carriages, but they have dedicated compartments, to guarantee the safety and comfort of passenger service as well as the efficiency of freight loading/unloading. It is assumed that all the goods that need to be delivered are uniformly quantified into standardized cargo containers with the same volume and weight.
- Freight type: small parcels, high value products, such as electronics
- Freights can be loaded/unloaded only at the origin/destination station or at intermediate passenger trains on the reserved train carriages. These activities are can be carried out during train stops without passenger/freights mutual interference.
- The time available for loading/unloading freights at each station is fixed, and determined by the passenger service requirements (i.e., dwell time at the stations).

CONSTRAINTS:

- Limited freight carriages capacity
- Limited stop times at stations
- Freight demand
- Freight delivery due dates
- Freight loading/unloading time and cost
- Service quality assurance

OUTPUT:

- The module will produce a set of viable passenger railway services during a certain off-peak period, in order to ensure the normal operation of passenger flow, to deliver freights, based on the input data and constraints.
- A comparison with the costs of direct delivery via trucks is also provided, also considering the carbon footprint.

BENEFIT:

- Improvement of the efficiency of the railway system, reducing underutilized railway facilities during off-peak hours, by implementing collaborative transportation of passengers and freights;
- Provide decision support system to logistic operators in optimizing the capacity allocation of goods by leveraging on existing passenger services and optimizing the costs;
- Integration and collaboration between all actors and services in the freight transport chain;
- Shifting freight demand to rail transport in favour of environmental sustainability also considering multimodal solutions;
- Digitalization and accessibility of freight transport.

10.4.3. Configurator of new intermodal services (Lead: RFI Participants: MII, TMI)

This use case is set out to demonstrate the third step of the booking process for seamless multimodal freight transportation services in Europe. The use case will develop an information system (platform) for the configuration of new intermodal transportation freight services in the case where the customer needs cannot be fulfilled by existing services. The platform will be based on the remaining capacity of railway infrastructures (e.g. the unsold tracks catalogue from the IM or remaining slots at the terminal) and build a new intermodal service that could satisfy the client's demand and that could be provided by an operator (RU). Demand resp. request will be expressed to Assets Warehouse and this system will provide response – asset will be booked or the request will be refused. Request will be sent by terminal booking system – see Figure 108 below.

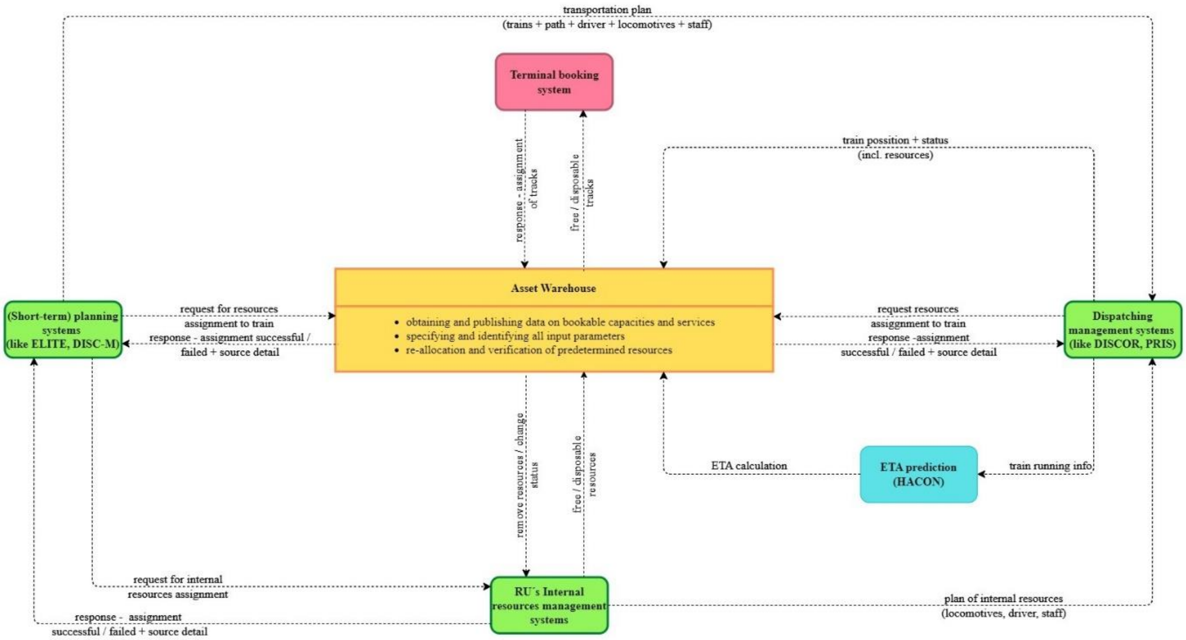


Figure 108: Asset Warehouse – Assets booking

The main goal of the transport configurator is to bring together the costumer with all service providers from the multimodal freight transport chain, generating benefits to all the involved stakeholders. The demonstrator aims to evaluate the feasibility to implement a module that can seamlessly construct new freight transport services that are born form actual client demands and availability of capacity, expanding freight rail transportation and possibly shifting demand from other modes.

The platform must be designed under the optic of interoperability since different actors will feed information coming from different IT systems and different data types. The platform must also be able to propose freight transport services based on the information provided by all service providers and on algorithms trained to design viable solutions that consider all the specifics of the freight transport chain (connections, transfer times, terminal and yard specifications, etc.).

The information regarding the capacity of the service providers will be fed to the platform on a periodic basis (the frequency may differ for each service provider as the processes differ greatly) and will be used as the foundation to build the new transport service.

The information fed by each actor should include (To be shared and approved within the technical table with all actors of the chain involved in the development of the modules):

<u>Infrastructure manager:</u> available tracks, taken from the catalogue of unsold tracks of the IM

<u>Terminal:</u> available slots at the terminal (tracks, handling, and container storages)

<u>Maneuvers (sole operator or self-production):</u> available slots for maneuvers

<u>Road transport operators</u>: avaliable slots for truck pick-ups/drop-offs.

Figure 109 shows the expected information flow for the new transport configurator module:

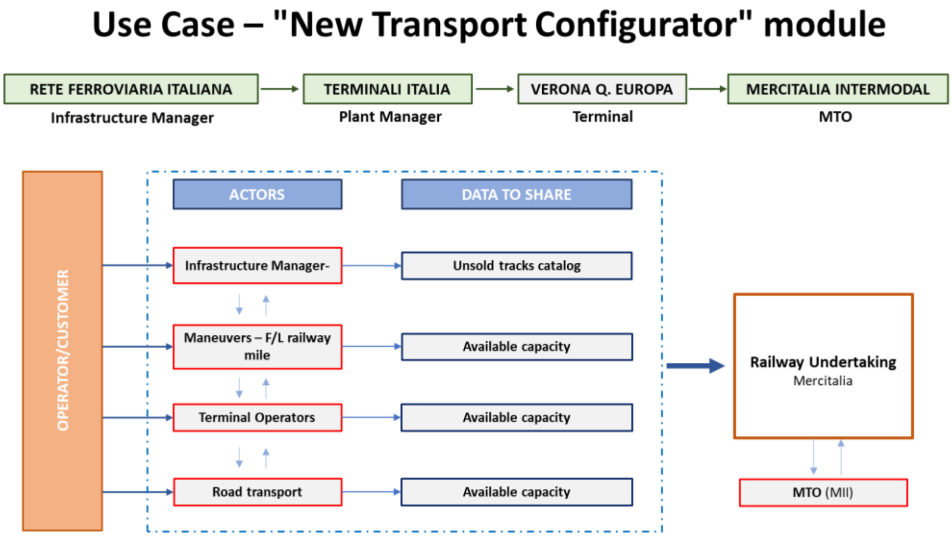


Figure 109: Scheme for the new transport configurator module

<u>INPUT:</u>

1. The first input should come from the first two booking modules, following the "One System" sequence approach. The user/costumer (could be a direct client, an MTO or a consultant) registers his profile on the platform and begins the search for the desired service, entering the data regarding the demand (This input must be shared and approved within the technical table with all service providers involved in the development of the modules):
   a. Origin and destination;
   b. Type of unit (semi-trailers, containers, etc.);
   c. Type of material, specifying whether ADR or waste;
   d. Quantity in terms of tons or volume;

f. Shipment departure and arrival time frame (i.e. the service must arrive between monday and wednesday in the morning).
2. Once the data has been processed, and in the case there are no services found in the other 2 modules that could satisfy the demand, the input arrives to the new transport configuration module. The module will ask of the user/costumer 2 additional inputs:
   a. Radius of distance around the origin and destination where the new service can be established (i.e. a service from Rome to Milan, with a radius of 60 km, could consider the terminals of Pomezia Santa Palomba and Gallarate as rail O/D relation);
   b. Estimated duration of the service the client intends to develop (i.e. 6 months)

Requirements for data transmission

The platform will thus receive heterogenous data from the different service providers at different times, regarding the remaining capacity of their infrastructure/services. As an example, the IM will send data regarding the unsold tracks as the catalogues become available. The user will also introduce data regarding their specific needs (i.e. quantity and type of material to be transported). In return, the platform will produce data regarding feasible new services based on the remaining capacity, that could satisfy the client's request. The requirements for data transmission include:

- Service providers (could include IMs, terminal managers, Maneuvers, Road Transport Operators) will transfer information directly from their IT systems to the platform regarding the remaining capacity of their infrastructure/services periodically, depending on how often the information about the regarding capacity is updated.
- The users will introduce data directly to the platform regarding the specifics of the service they are requesting.
- The platform will return data regarding a set of possible complete and viable freight transport services, based on the request made by the user and the remaining capacities from each service providers.
- The platform will also allow the different stakeholders to send data containing messages (i.e. operators could send offers to the clients to provide the services designed by the platform)

Data standards:

- Data standards are specific to each IT system (i.e. IM's management systems) that contains the information regarding the remaining capacity.

Data owners/providers:

- Each service provider (i.e. IM or terminal) will own and provide its own specific data regarding the remaining capacity of their infrastructure/service.

- The user/client will provide data regarding their specific service request

Data consumers:

- RFI
- FS Tech
- Service providers
- Clients

OUTPUT:

- The module will produce a set of viable services and solutions, based on the input data (based on calculation algorithms and optimization of solutions);

BENEFITS:

- Increase of intermodal freight services, shifting freight demand to rail transport in favor of environmental sustainability;
- Integration and collaboration between all actors in the freight transport chain;
- Digitalization and accessibility to multimodal transport.

Possible KPI to measure the benefits of the module:

1. Increase in Train Km, and relative reduction in the average distances travelled by road vehicles in support of the objectives imposed by the European Union. Growth in modal share for rail transport.
2. Decarbonization and reduction of CO_2 emissions through the shift of freight traffic to rail, with a consequent reduction in externalities (congestion, accidents) related to the reduction of road vehicles in circulation.
3. Increased use of wagons, resulting in fleet optimization and reduced downtime costs.
4. Optimization of production factors within the plants, thanks to the increase in the number of O/D relationships and frequencies.

9.5 Summary

The work package 30 has the aim to do a next and important step towards a more seamless freight on rail and a leaner approach to booking of services. Many constraints complexify freight on rail. The common objective of the partners in this work package is to identify those constraints within the use cases, to overcome some of the constraints and to explain why some of the constraints cannot be removed yet.

The desired outcome is there for a more collaborative ecosystem, enabled by digitalisation with faster processes.

10 Seamless Data Exchange

10.1 General introduction and background description

Transport is a global phenomenon with regional and local impacts. It involves a multitude of actors, and today there is increasing pressure for transport chains to be environmentally sustainable, predictable, seamless, and cost efficient. An end-to-end transport most often actually engages multiple transport modes involving visits to various transport nodes. This then requires a high degree of collaboration between the involved actors both within and often across national borders. Today, there is a call for better synchronisation within and between transport practices. Big hopes are being placed on digitalisation as an enabler and means for integrated and sustainable performance along the multi-modal supply chain.

Primary objective is to provide an overall framework that enables a seamless and harmonised exchange of data. This framework aims to facilitate an increased data availability and quality by reducing technical and administrative barriers for the generation and exchange of data. This framework will be built on existing developments rather than introducing new elements.

The approach to this mission above, there is a need of engagement of the multitude of stakeholders, and in this project is particularly important. Drawing from experiences derived from the ecosystem innovation arenas (Living Labs), initiated under the European financed FEDeRATED project, https://www.federatedplatforms.eu/ that conclusion was important[2].

10.2 The Purpose of Data Exchange

There is a need of different steps from paper to a fully digitalised process in the freight sector. The figure below shows an example of such steps from the checkpoints/video gates from the real process to a digital transformation.

[2] https://maritimeinformatics.org/wp-content/uploads/2022/11/2022-11-15_A-Federative-Approach-to-Digital-Transport-Ecosystem-Innovation.pdf

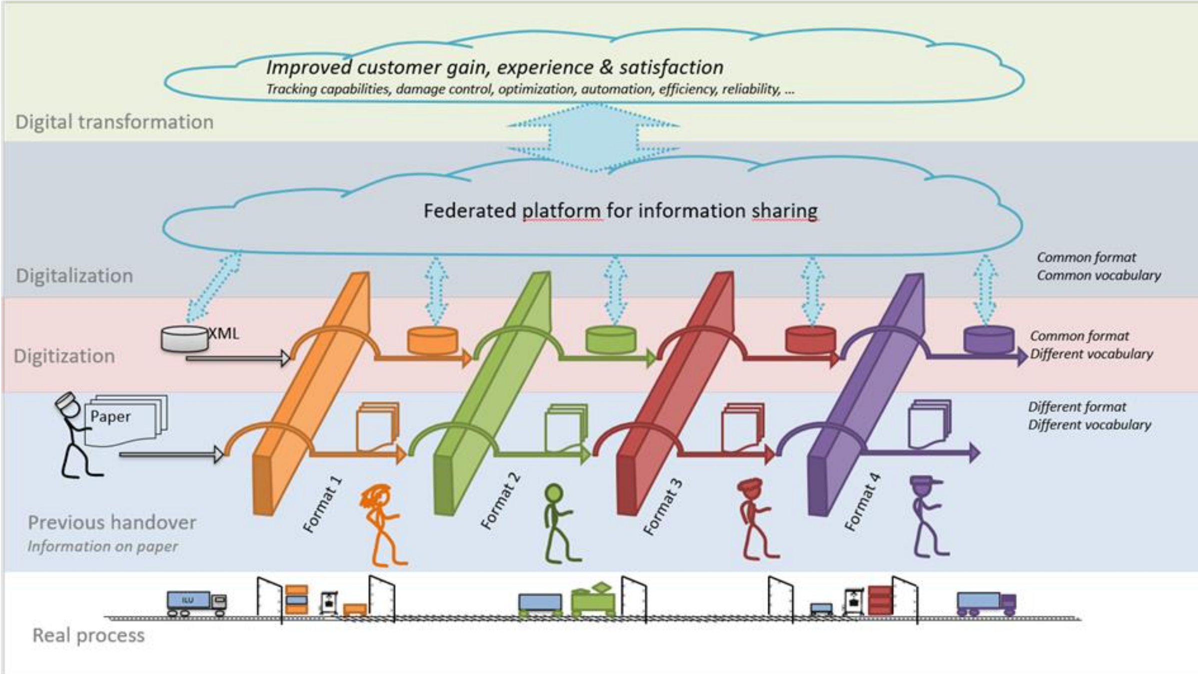


Figure 110: From paper to Digital Transformation

- Timely Decision Making: Operators can react quickly to disruptions, reroute traffic as needed, or adjust schedules based on real-time conditions.
- Efficient Border Crossings: With standardized and digitized documentation, customs and other inspections can be expedited, reducing delays and costs.
- Optimized Asset Utilization: Real-time data allows for better management of rail assets, from locomotives to wagons, ensuring that they are utilized efficiently.
- Enhanced Customer Experience: With accurate data, customers can be kept informed about the status of their consignments, improving transparency and trust.

10.3 Comprehensive Repository of Existing Systems and Standards Initiatives and Technological Solutions

Several European initiatives aim to foster a more integrated and harmonized rail freight environment. Technologies are driving the standardization of systems and processes. Further, digital platforms and interfaces are being developed to facilitate data sharing between stakeholders, ensuring that the right information reaches the right entity at the right time. A comprehensive repository (list) of existing standards/systems has been developed and is presented below.

10.3.1 Data platforms

10.3.1.1 Deplide

Deplide is a data-agnostic demonstration platform for ecosystem innovation in multi-modal transport chains. Deplide is based on solid experience from similar platforms in several large-scale projects within the maritime sector adapted to more generic multi-modal transport needs. It has been developed primarily to support demonstrator development with data sharing around a transport node, where main events along the supply chain occur. In addition, Deplide can collect and share data from several nodes along the supply chain to increase end-to-end supply chain visibility and similar use cases.

In the Shift2Rail project FR8RAIL III, information about trains and wagons registered by the intelligent video gate installed in Gothenburg, Sweden, was received and made available by Deplide. The plan is to use Deplide in the same role in this project, for the checkpoints that will be installed in Sweden. Deplide will thus contribute to seamless freight by making information that is important in logistics planning available to stakeholders such as terminal operators, railway undertakings and their customers. This information includes (but is not limited to) timestamps, wagon numbers, wagon positions in trains, loading unit codes and information about dangerous goods.

Link - https://www.ri.se/en/what-we-do/test-demo/deplide

10.3.1.2 DXI / KV 4.0

Digital data hub for intermodal transport chains.

KV4.0 will be one of the main data sources for WP28 (terminal data for loading units, such as "begin loading" and "end of loading") and WP31 (commercial timetable data). They receive data from terminals and can re-distribute it in the industry standard EDIGES-format. Currently, they only have a few terminals integrated, but more are planned. Kombiverkehr, who is also a partner in TRANS4M-R, is hosting the platform together with HUPAC, another intermodal operator.

10.3.1.2.1 RNE TIS

European train monitoring service for main line train data. They receive timetable data and real-time data (train position, train delay etc.) from the IMs and can display it in their system.

RNE TIS is one of the key data providers for WP28 (intermodal prediction systems). Hacon already has access to the common interface, which is used to receive and send data to TIS. Currently, TIS is sending timetable data and real-time train position information according to TAF TSI standards to Hacon for a few trains. This should be expanded to the network of all TRANS4M-R operators in the coming months. TIS will also send historic data to Hacon.

Link - https://tis-prod.rne.eu/

10.3.1.2.2 Hacon ETA Management Platform

Train monitoring and prediction as well as ex-post evaluation and analysis of transport and ETA quality.

In the ETA Management Platform (short: EMP), Hacon integrates terminal data (EDIGES from KV4.0 and other formats from other terminals) with main line data (TAF TSI from RNE TIS). The EMP matches timetable data with real-time data and thereby computes the basis for the ETA forecasts. The EMP can also send out train run forecast messages to other systems (such as Deplide, Proyecto Simple etc.). It also offers tools for analysis ETA quality, delay patterns etc.

Link - https://eleta.hafas.de

10.3.1.2.3 DP-Rail - Digital Platform for Rail Freight

Project which aims at transforming the current fragmented data exchange landscape through the set-up of a TAF-TSI compliant common interface enabling easy data provision and consumption for all RUs.

The project aims to develop a seamless, interoperable data exchange for the core rail freight sector by 2025 through a trusted digital ecosystem based on a TAF-TSI compliant common interface. It seems that the work of individual TRANS4M-R WPs (24,27,28, ...) overlaps with the objectives of this project, so it should be monitored further and, if necessary, cooperation should be sought.

Link - https://dp-rail.eu/

10.3.1.2.4 CESAR

Platform dedicated to freight transport related information exchange between intermodal operators and their customers for intermodal transport, and to track and trace information for loading units.

The platform is aimed to impulse multimodal freight transport in Europe by setting a common standardized interface where operators could communicate among them and with clients to provide multimodal freight services. The relevance to the project could lie in the information exchange between different actors of the freight chain in a standardized platform.

Link - https://cesar-next.com/#/home

10.3.1.2.5 RailFlow

Digital platform for intermodal freight transport based on rail. Platform and software as a service solutions for different steps of the freight chain.

The main similarity with the project is referred to the seamless interface (WP31) of different modules related to freight transport (e.g. offer of rail and intermodal services, capacity management, planning and monitoring of services).

Link - https://www.rail-flow.com/

10.3.1.2.6 Modility

Platform that combines demand and supply of intermodal freight transport services.

It is a similar platform to one of the modules expected to be developed in WP31 (booking module). It presents an origin-destination search, service selection and data exchange between client and service provider for intermodal transport services that could include intermodal solutions.

Link - https://modility.com/en/

10.3.1.2.7 railvis

Intelligent Digital Platform for assets. Actors can sell or rent their unused assets, such as rolling stock or route capacities. Registered users can see these offered assets in some kind of marketplace.

The main similarity to Seamless Freight is the asset warehouse, which is going to be developed in WP28 by CDC. However, CDC is already well-aware of the RU IT systems that will be integrated in an interoperable way, which is why railvis will not play a major role for Seamless freight.

Link - https://railvis.com/

10.3.1.2.8 PCS - Path Coordination System

The Path Coordination System (PCS) is an internet-based international path request coordination system for Path Applicants that fulfills TAF/TAP TSI requirements.

This RNE tool provides relevant data for the WP26 Seamless Planning of Rail Freight Services.

Link - https://rne.eu/it/rne-applications/pcs/

10.3.1.2.9 CIS - Charging Information System

The Charging Information System (CIS) is an web-based infrastructure charging information system which estimates the price for the use of international train paths, stations and shunting.

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/cis/

10.3.1.2.10 CIP - Customer Information Platform

The Customer Information Platform (CIP) is an interactive, Internet-based information tool, which provides precise information on the routing, terminals, specific track properties and infrastructure investment projects, as well as ICM lines and their re-routing options of the participating Rail Freight Corridors (RFCs).

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/cip/

10.3.1.2.11 CCS - Common Components System

The Common Components System comprises 3 elements to ensure the interoperability of European railway traffic:

- a common interface (CI) that supports the interoperable exchange of messages

- a central Reference File Database (CRD) that stores Location Codes and Company Codes required under TAF TSI regulation

- a certification authority (CA) which ensures secure communication between parties using the Common Interface.

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/ccs/

10.3.1.2.12 NCI - Network And Corridor Information System

The Network and Corridor Information Portal (NCI) aims to further facilitate easy access to information published in Network Statements (NS) and Corridor Information Documents (CID).

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/nci/

10.3.1.2.13 RFP - Rail Facilities Portal

The Rail Facilities Portal provides quick access to information on all kinds of rail facilities, in particular rail freight facilities, e.g. for the planning of rail services.

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/rfp/

10.3.1.2.14 ECMT - European Capacity Management Tool

The European Capacity Management Tool (ECMT) is an online application providing a centralised capacity supply and capacity model overview of railway lines and routes. The tool consolidates capacity needs and capacity restrictions on the railway infrastructure based on the information provided by infrastructure managers and Allocation Bodies. It offers capacity supply and capacity model visualisations and other related functionalities.

Depending on the data needs of the WPs, this data source may be relevant for seamless freight. RNE supports the DP-Rail project. Depending on the developments in this project, functions and data may be available in the future via the data interface that has yet to be developed.

Link - https://rne.eu/it/rne-applications/ecmt/

10.3.1.2.15 Kombiverkehr Webapp

Planning solution for combined transport.

The Kombiverkehr Webapp is the basis for route finding/planning services that will be further developed in WP31 (Multimodal Integration). Most functionalities will be extended both in terms of accommodating more timetables (if the data is available) and by extending their features (for example, improved CO2 calculator, route finding algorithm etc.)

Link - https://kombiverkehr.hafas.de/webapp-next/

10.3.1.2.16 YCS

Yard Coordination System, YCS, is a demonstration tool for improved communication and coordination between traffic management, marshalling operator and terminal operator regarding short-term planning of track usage at the arrival/departure part of the freight yard in Malmö, Sweden. The first version of YCS, which was developed in the Shift2Rail project FR8RAIL III, is a standalone tool without real-time updates from other systems. In the Europe's Rail project Motional, a new version of YCS will be developed. This version will, for example, include real-time updates of planned arrival and departure times for trains. YCS will get these data through Deplide (see above).

YCS makes coordination between the actors of the freight yard easier. This contributes to a more efficient track usage at the yard and thus to a decreased risk of delays and a better-working transport chain.

Link - https://www.youtube.com/watch?v=LR_QJG3OvXU

10.3.1.3 Data ontologies

10.3.1.3.1 ONTORail

OntoRail is a project initiated at the UIC, the International Union of Railways, aimed at fulfilling two main goals: 1. Leverage ontologies as a means to consolidate and enrich railways systems modelling knowledge into an encyclopaedia. 2. Provide ontology-based tools to promote and facilitate convergence and federation between models of the railway domain.

Link - https://ontorail.org/

10.3.1.3.2 RailwayCDM (R-CDM)

Definition and descriptions of common milestones for an intermodal transport chain (from traffic node to traffic node). Here, the meaning of CDM is "collaborative decision making".

RailwayCDM describes railroad transport processes for both cargo and passenger traffic as a set of states that are planned, estimated and achieved as transports progress, both in terms of physical movements and as service and administrative activities.

Link - https://www.youtube.com/watch?v=R-DEkD7qkl4

10.3.1.3.3 YardCDM Demo

Project based on the RailwayCDM concept, where all stakeholders relate to the freight yard in Malmö (TRV, Green Cargo, Mertz, DB Cargo, Hector rail) share data and information.

YardCDM Demo is a practical implementation of RailwayCDM involving a marshalling yard, a combi terminal and their interaction with the national railroad network and its connection to continental Europe through Denmark. As such, it's an excellent arena for development of ontological concepts within rail transports.

Link - https://www.youtube.com/watch?v=R-DEkD7qkl4

10.3.1.3.4 LinX4Rail Conceptual Data Model

Conceptual data model developed within the Shift2Rail project LinX4Rail.

The model is based upon four previously existing data models for the railway sector and aims to eventually cover all aspects of the railway system. Therefore, its use should be considered before additional models are created.

10.3.1.3.5 EDICT

Definition of milestones for terminals in combined transport and reason codes related to train monitoring

We use the milestones as last-mile measurement points for the ETA calculations. The reason codes could potentially play a role at a future point (once they are implemented). For now, we will work mainly with the already established reason codes for the main line transport.

10.3.1.3.6 ELETA

Basis for ETA calculation.

ELETA gives us the basis for receiving train-related information (timetable and real-time), computing an ETA and sending this ETA, all with TAF TSI messages. We build on this basis within WP28.

10.3.1.3.7 Digital Train 1.0 & 2.0

Definition of ETA-related terminology and milestones

Definition of ETA-related KPIs and quality measurements. We will use this as the basis to define the KPIs related to the intermodal prediction enabler as well as the ETA quality analysis.

10.3.1.3.8 EPCIS for Rail Vehicle Visibility Application Standard

The EPCIS (Electronic Product Code Information Services) standard defines a data model for visibility data (that is, data that describe events that happen to an object in a supply chain, as well as the time and location of these events). Also, it defines an XML syntax for these data as well as interfaces for delivering captured data to a repository and for requesting data from the repository. GS1 is the organisation responsible for the standard.

The EPCIS for Rail Vehicle Visibility Application Standard defines how to use EPCIS for tracking rail vehicles and for associating vehicle data with data captured by wayside monitoring systems (WMS). The standard is in use for tracking rail vehicles using RFID tags on wagons and RFID readers along railways, and could be used for delivering data captured by checkpoints.

Link - https://www.gs1.org/standards/epcis

10.3.1.4 Data formats

10.3.1.4.1 TAF/TAP TSI

European Standard for telematics applications. Used as the standard format for most train data running information and plan information, for example by RNE TIS.

This is the message (exchange) standard and the data format that we will use for the intermodal prediction systems. We receive TAF TSI train information and send the ETA via the train running forecast message.

Link - http://taf-jsg.info

10.3.1.4.2 EDIGES

Data format for terminal data. Used as a voluntary standard by parts of the industry. Ongoing initiatives to standardise EDIGES and make it TAF TSI compliant (by "translating" some message types).

This is the message (exchange) standard for terminals. Since EDIGES is not mandatory to use, we will have to find a way of how we can translate non-EDIGES messages. EDIGES messages are focused on a specific loading unit whereas TAF TSI is mostly train-related, meaning that we have to map the loading unit information to the train-related information.

10.3.1.4.3 UIC APP

"Old-fashioned" but still working data exchange between former state RUs (A30, A31, A40/41)

These are formats and communication channels for data exchange for train pre-advice (A30), wagon movement (A31) and consignment notes (A40/41) used by RUs. It was planned to replace them with TAF TSI messages, but this has not yet happened.

Link - https://www.raildata.coop/

10.3.1.4.4 PCS/PDM

Data format for transmitting planned train paths by RNE. Partially replaced by PDM (Path Detail Messages)

The planned train paths are transmitted via PCS and PDM 2 weeks in advance of the train operation. We expect that these messages will be almost exclusively in the PDM format.

Link - https://pcs-online.rne.eu/pcs/

10.3.1.4.5 TCMF

TCMF (Transport Collaboration Messaging Format) and its predecessor RCMF (Railway Collaboration Messaging Format) are used in several projects at RISE that are part of or related to the collaborative decision making concept

TCMF or RCMF will probably be used for sharing information collected by the intelligent videogates (checkpoints) that will be installed in Sweden.

10.3.1.4.6 RailML

Open-source railway markup language that enables heterogeneous railway applications to communicate with each other

Information that is important in railway freight, for example regarding timetables and vehicles, can be represented and exchanged using railML. However, there are no known plans to use railML in this project.

Link - https://www.railml.org/en

10.3.1.5 Ecosystems

10.3.1.5.1 GAIA-X

A European initiative aimed at creating a secure and sovereign data infrastructure for Europe. It is a federated data infrastructure that will enable the sharing and processing of data across borders and sectors. The project is a collaboration between government, business, and academic institutions across Europe. The project will provide a framework aims to create a trusted and secure ecosystem for data exchange that is based on European values, such as data protection, privacy, and transparency.

Link - https://gaia-x.eu/

10.3.1.5.2 International Data Spaces

IDS (central element of the GAIA-X architecture) is a framework that enables secure and trusted data exchange between organizations across different industries and countries. It provides a common architecture and governance model that ensures data protection and sovereignty, while also enabling organizations to benefit from the opportunities offered by digitalization and the data economy.

Link - https://internationaldataspaces.org/we/gaia-x/

10.3.1.5.3 Mobility Data Spaces

IDS focus on Mobility, more than 200 stakeholders from science, industry and public administration worked on the conception of the MDS. For long-term operation, acatech - National Academy of Science and Engineering has transferred the project to the DRM Datenraum Mobilität GmbH as a supporting company (non-profit GmbH). The MDS is funded by the Federal Ministry for Digital and Transport.

Link - https://mobility-dataspace.eu/

10.3.1.5.4 (FP1 TT) Federated Data Space

It refers to the work that is being currently carried out regarding the development of an IDS-based data space specific for the railway environment within WP31, to be used as a data-sharing enabler. It would be used as the final data-space for data-sharing in the different use cases.

10.3.1.5.5 FIWARE

FIWARE Foundation drives the definition – and the Open Source implementation – of key open standards that enable the development of portable and interoperable smart solutions in a faster, easier and affordable way, avoiding vendor lock-in scenarios, whilst also nurturing FIWARE as a sustainable and innovation-driven business ecosystem. Link - https://www.fiware.org/

10.4 Identification of general principles for data sharing and data structure

11.4.1. General principles for data exchange

Data sharing takes place in the vertical and horizontal collaboration between organizations to achieve common goals or to enable new business models by generating additional value out of data (e.g., in data marketplaces). Furthermore, data sharing implies a mode of collaboration towards coopetition. This sharing of data enables transactions with the data that become it in a shared data asset. This makes sense when establishing possible data structures, which allow the establishment of dedicated planes. Although the concept of data plane is created within the scope of this document, the nomenclature to be used follows the one defined by International Data Spaces (IDS) in its reference architecture [1]. Thus, we can establish an application data plane that includes, for example, the information exchanged between a machine and a machine learning model for performing predictive maintenance. In addition, it is possible to establish a metadata plane that should describe the syntax and serialization as well as the semantics of data sources (in this area, Conceptual Data Model-CDM, detailed in section 11.9 should be the base for this). Furthermore, metadata should describe the application domain of the data source. Another existing data plane is related to the transaction logs, also known as metrics. It contains the information used to monitor, observe, and audit entities and sub-systems. The following figure proposes a visualization of the different data planes.

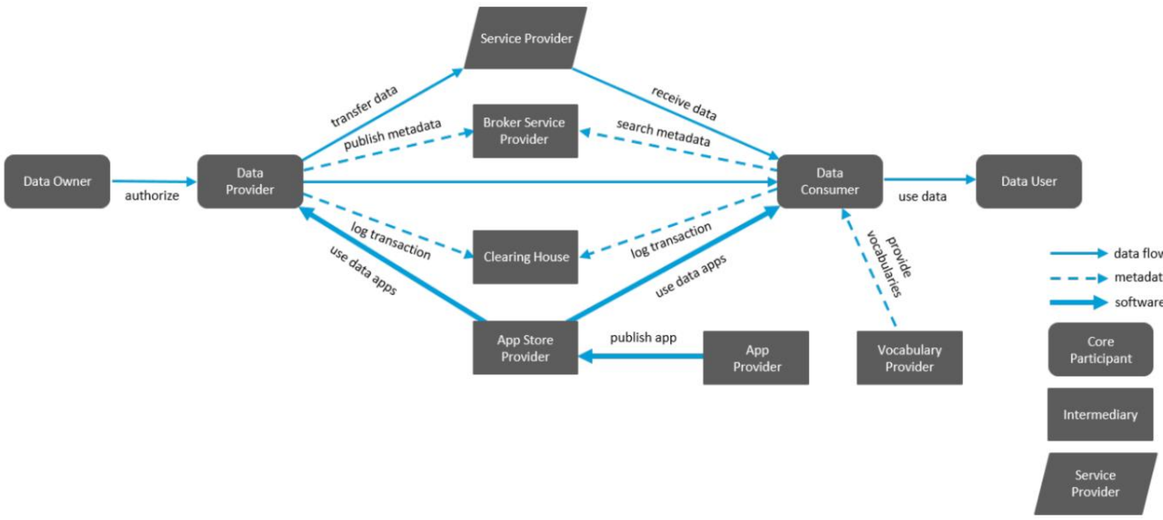


Figure 111: Data flows in data sharing ecosystem.

Organizations such as IDS consider trust, security, sovereignty, and ecosystem of data as strategic requirements, in general, of data spaces but specifically in data sharing environments [1]. In this context, identity and access management technologies, as well as monitoring and auditing techniques, are part of the general principles of data sharing environments. These aspects will be covered in Section 11.7.

IDS is an evolving ecosystem, as there are several initiatives at European level that have the goal of fostering data sharing, interoperability, and data sovereignty. GAIA-X, IDSA and FIWARE, together with Big Data Value Association (BDVA), have launched an alliance called Data Spaces Business Alliance (DSBA) to drive the adoption of data spaces across Europe. Data spaces are key to achieving sovereign, interoperable and trustworthy data-sharing across businesses and societies – a key step to the data economy of the future. The contributions for each of the organisations to the BDSA can be seen in the following figure.

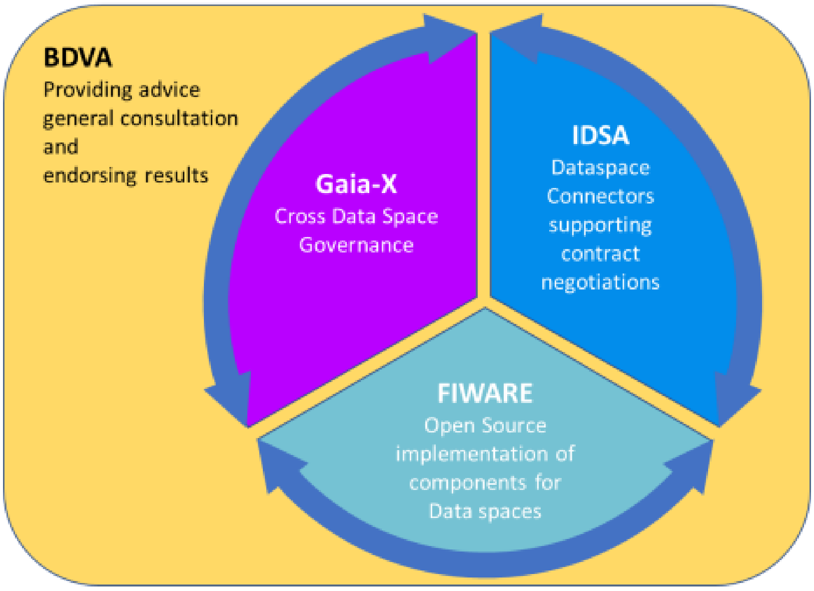


Figure 112: Core contributions of the DSBA organizations to the common framework

There are already some data-spaces already deployed in Europe, as it can be seen in https://internationaldataspaces.org/adopt/data-space-radar/, but none is specifically oriented to Railway sector. In FP1-MOTIONAL, it is foreseen to deploy an IDS-compliant Rail Federated Data Space (WP31) by the end of the project as a transversal enabler that would be available for the use cases to exchange data in a secure and trustworthy way. In practice, entities need first to register in the data space following the governance rules and mechanisms provided by the particular data space, so that their identity can be established. For the data-exchange itself, data connectors need to be implemented, for both providing data and also consuming data, together with contract negotiations if necessary. The process and key components are more in detail described in section 11.5. Finally, it is also relevant to highlight that the data-sharing enablers do not specify data-formats. Related to how data should be structured in railway domain, more insight should be obtained in section 11.6, related to Conceptual Data Model.

While the Rail Federated Data Space is being deployed in FP1-MOTIONAL, the technologies related to the data connectors, with requirements related to the use cases can also be worked within already IDS-compliant running data spaces, such as those identified in the radar. CEIT for example has recently joined to the Mobility Data Space (MDS) (https://mobility-dataspace.eu/), but other options will also be analyzed.

A brief description of the main contributors to this alliance is introduced next, and more detailed research on identity and access management and auditing and monitoring technologies will be carried out in 11.3.7.

10.4.1.1 GAIA-X

GAIA-X is a European initiative aimed at creating a secure and sovereign data infrastructure for Europe. It is a federated data infrastructure that will enable the sharing and processing of data across borders and sectors. The project is a collaboration between government, business, and academic institutions across Europe.

GAIA-X aims to create a trusted and secure ecosystem for data exchange that is based on European values, such as data protection, privacy, and transparency. The project will provide a framework for secure data sharing that will enable European businesses and organizations to benefit from the opportunities offered by digitalization and the data economy.

The GAIA-X project is based on several key principles, including open standards, interoperability, and transparency. It will provide a common framework for data sharing that is based on secure and transparent protocols and will enable the development of innovative services and solutions.

The project will create a decentralized infrastructure that will enable the secure sharing of data across a network of trusted providers. This will enable European organizations to benefit from the opportunities offered by digitalization and the data economy, while also maintaining control over their data and ensuring that it is protected and used in accordance with European values and regulations.

Overall, GAIA-X is an ambitious initiative that aims to create a trusted and secure data infrastructure for Europe, based on open standards and transparency, that will enable the development of innovative services and solutions for businesses and organizations across the continent.

10.4.1.2 IDSA – International Data Spaces Association

International Data Spaces (IDS) is a concept and framework for secure and sovereign data exchange between organizations across different industries and countries. It is an open architecture that enables the secure and trusted exchange of data, while ensuring data protection and sovereignty.

The IDS concept is based on the idea of creating a network of interconnected data spaces that enable organizations to exchange data in a secure and controlled manner. This network is designed to be interoperable, meaning that data can be exchanged between different data spaces without compromising security or data protection.

The IDS framework is built on four key pillars:

- Architecture: The IDS architecture is based on open standards and aims to create a decentralized network of interconnected data spaces.
- Governance: The IDS governance model ensures that data is exchanged in a secure and controlled manner, while maintaining data protection and sovereignty.
- Trust: The IDS trust model is based on a federated approach, where each organization has control over its own data and determines who can access it.
- Security: The IDS security model is designed to ensure that data is exchanged in a secure and encrypted manner, with data protection and privacy as top priorities.

Overall, IDS is a framework that enables secure and trusted data exchange between organizations across different industries and countries. It provides a common architecture and governance model that ensures data protection and sovereignty, while also enabling organizations to benefit from the opportunities offered by digitalization and the data economy.

10.4.1.3 FIWARE

FIWARE is an open-source platform that aims to simplify the development of smart solutions and applications for various domains such as smart cities and industries. It offers a standardized set of APIs (Application Programming Interfaces) and components that enable seamless interoperability between diverse technologies and systems. This interoperability fosters the creation and deployment of innovative services related to the Internet of Things (IoT), smart urban planning, and digital transformation. FIWARE promotes collaboration among developers, businesses, and public entities, with the ultimate goal of creating more efficient and interconnected urban and industrial ecosystems.

Data standards and data governance

Data standards are a set of rules that standardize the manner in which the data is formatted and its content is structured. To achieve a seamless and interoperable exchange of data for the various applications, developments and use cases, it is crucial that all involved parties follow these data standards.

The following items should be defined as part of the data standards:

- Structural standards: They define guidelines that form the framework for the organisation and formatting of data elements and their relationships within a data set or database. These standards define the structure, syntax and semantics of data and ensure a standardised and consistent presentation and storage of data. They specify the arrangement of data fields, data records and files as well as the rules for the validation and integrity of data. The definition of structural standards is crucial for ensuring data consistency, interoperability and quality in different systems and applications. By defining a standardised structure for data organisation, these standards enable the seamless integration, sharing and exchange of data between different stakeholders and systems.
- Content standards: They define the meaning of the data elements, allowable values, mandatory vs. optional parameters and how they relate to each other.
- Metadata standards: Metadata standards outline how data about data should be organized, stored, and accessed, facilitating effective data management, integration, and sharing within an organization or across multiple entities. The distinction to structural standards is as follows: Structural standards define how data is organised and stored, while metadata standards define how information about the data is described and managed.
- Interface standards: This defines the way in which the data is accesses or sent from one system to another. It includes the type of transmission (push vs. pull) and the frequency of exchange (regular intervals vs. real-time updates). This could mean for example the definition on when a yard management system receives data (updates) from a TMS and how this data is accessed (does the TMS send regular updates, does the YMS send a request for an update and receive information in response etc.)

Data governance encompasses the policies, procedures, and rules that govern how data is collected, stored, processed, and utilized. The primary goal of data governance is to maximize the value of data while minimizing risks and ensuring compliance with the relevant standards.

The following concepts must be defined as part of the data governance.

- Data Ownership: Designating who is responsible for each set of data. They are accountable for the quality and accuracy of their assigned data. Here we need to clarify the general data ownership for groups of information, such as during the strategic planning process. We also should distinguish between owning the data and being able to access it. For example, an RU may have data ownership over train composition and wagon performance data. They might share this information with the IM, who in turn could provide it to other systems. In this case, the IM has access rights but would not be the data owner.

- Data Quality: Maintaining accurate, complete, and consistent data. While every system will attempt to achieve high data quality, we should define a harmonised standard (KPIs) with which we can measure and ascertain that the data quality is acceptable.
- Data Lifecycle Management: This includes protocols for managing data from its creation or acquisition to its archival or disposal, ensuring its relevance, accuracy, and security throughout the entire lifecycle, e.g. how data is collected, stored, processed, and deleted.
- Data Classification and Sensitivity: Classifying data based on its sensitivity and importance.
- Data Security and Privacy: Implementing security measures, to safeguard data.
- Data Access and Sharing: Establishing who has access to what data and under what circumstances. For example: When is the terminal operator allowed to access train-related information (path planning, current position, events/conflicts etc.)
- Data Governance Policies and Procedures: Documents that indicate how data should be handled.

Data standards and data governance must be developed in FP5-TRANS4M-R in alignment with the FP1-MOTIONAL project. Specifically, FP1-WP30 Task 30.3 – Implementation of governance process shall be considered in the alignment process. The alignment must assess what has already been developed, what is going to be developed during the FP1-MOTIONAL project and what aspects are outside of its scope.

Within FP5-WP32 Task32.4, the alignment of this activity is monitored and management together with FP1- WP30 Task30.3. Both tasks began in December 2022 and both end in March 2026. It is necessary to define how the alignment in this activity will be planned during of development of both projects.

10.5 Administrative barriers

The efficient sharing of data is crucial for fostering collaboration, innovation, and informed decision-making in various domains. However, numerous administrative barriers often impede the seamless exchange of data among organizations and entities. These barriers encompass challenges such as complex regulatory frameworks, data privacy concerns, inadequate standardization, resource constraints, and organizational resistance, hindering the establishment of effective data sharing practices. Understanding and addressing these administrative hurdles are pivotal in promoting a culture of data sharing that prioritizes transparency, efficiency, and responsible data governance.

Some common administrative barriers include:

- Lack of Clear Data Sharing Policies: Absence of well-defined guidelines and policies for data sharing can create confusion and hinder the process.
- Data Privacy and Security Concerns: Fear of data breaches, unauthorized access, and misuse of sensitive information can deter organizations from sharing data.
- Legal and Regulatory Constraints: Compliance with complex and evolving legal regulations such as data protection laws, intellectual property rights, and contractual obligations can present significant hurdles.
- Lack of Standardization and Interoperability: Incompatible data formats, standards, and systems across organizations can pose challenges in integrating and sharing data seamlessly.
- Resource Constraints: Insufficient budget, technology, and skilled personnel may limit an organization's capacity to establish and maintain effective data sharing mechanisms.
- Data Ownership Issues: Disputes over data ownership and control can create reluctance to share data, especially when there is a lack of clarity on ownership rights and responsibilities.
- Risk Aversion: Organizations may be hesitant to share data due to concerns about competitive advantage, market positioning, or the potential risks associated with sharing proprietary information.
- Lack of Awareness and Understanding: Insufficient knowledge about the benefits of data sharing, as well as the methods and tools available for secure and effective sharing, can contribute to resistance or apathy towards data sharing efforts.
- Cultural and Organizational Resistance: Resistance to change, lack of trust among stakeholders, and cultural norms that prioritize data silos over collaboration can hinder the adoption of data sharing practices.

Overcoming these administrative barriers often requires a concerted effort involving stakeholders from various sectors, including policymakers, legal experts, IT professionals, and data management specialists, to develop comprehensive strategies that promote responsible and secure data sharing practices.

10.6 Investigation of data sharing, auditing and monitoring techniques

First of all, as finally IDS-based data spaces are foreseen to be used as main enablers for data sharing, this process is described in detailed as stated in the IDS Reference Architecture Model (IDS-RAM4). The description includes the process layer (which processes are involved within the data sharing) and also the system layer (related to the main technical components that enable the processes).

Then, as part of the investigation carried out related to Identity and Access Management (IAM) technologies, the three main contributors within BDSV described in section 11.3 (GAIA-X, IDS and FIWARE) have been analysed, related to how they use IAM technologies.

Similarly, as part of the investigation carried out related to Audit and monitoring techniques, again GAIA-X, IDS and FIWARE have been analysed regarding their approaches for providing these features.

10.6.1 Data sharing mechanism

Here, the process of data sharing is described as it is defined in the IDS Reference Architecture Model (IDS-RAM4). First of all, the processes involved are described, such as: onboarding, data offering, contract negotiation, exchanging data, publishing and using Data Apps, and Policy Enforcement. Then, the main technical components of IDS systems are described (system layer): Identity Provider, IDS connector, IDS apps, Metadata broker, Clearing House and Vocabulary Hub.

10.6.1.1 Process Layer

The Process Layer of the International Data Spaces (IDS) orchestrates key processes such as Onboarding, Data Offering, Contract Negotiation, Exchanging Data, and Policy Enforcement. These processes are pivotal in ensuring secure, structured, and interoperable data exchange within the IDS ecosystem.

The following processes and their sub-processes are described:

Onboarding, i.e. what to do to be granted access to the International Data Spaces as a Data Provider or Data Consumer. The Onboarding process, crucial for gaining access to the International Data Spaces as either a Data Provider or Data Consumer, involves several steps:

1. Preparation: Registration and Certification of the Organization:
   - Any organization wishing to operate an IDS Connector for data exchange must pass the Operational Environment Certification.
   - The organization is registered in the Participant Information Service (ParIS) and their initial Participant entry is populated after certification.
   - The Support Organization is informed and provided with metadata about the new IDS entity.
   - It is recommended that each Participant hosts a Self-Description on a publicly accessible endpoint, simplifying discovery. However, ParIS data takes precedence if there are discrepancies.
2. Preparation: Acquiring a Certified IDS Connector:

- Organizations can obtain an IDS Connector from a Software Provider or develop their own.
- The IDS Connector must pass IDS Component Certification to ensure security and interoperability.

3. Connector Configuration and Provisioning:
   - Each IDS Connector must have a unique identity issued or confirmed by the IDS Identity Provider.
   - Trust anchors for the Identity Provider are provisioned onto the connector for verification of identity information.
   - The connector should provide a Self-Description and, for higher Trust Levels, signed metadata to prove certification levels.
4. Configuration of Existing Systems:
   - Organizations must configure and connect their existing systems to the IDS Connector.
   - Appropriate IDS metadata, including Usage Policies, must be created, and data exchange enabled, potentially using IDS Apps.
5. Availability Setup:
   - IDS Connectors must be made available for other IDS Participants in the data ecosystem.
   - Data Providers and Consumers can decide whether to publicly announce their IDS Connector and data resources within the ecosystem.

These steps ensure a structured approach to joining the International Data Spaces, focusing on certification, configuration, and availability while adhering to security and interoperability standards.

Data Offering, i.e. offering data or searching for a suitable data. The Data Offering process involves making data available in the International Data Spaces (IDS) or searching for suitable data. Here's a summary of the key points:

1. Data Offering Process:
   - Participants in IDS may offer data artifacts to potential Data Consumers.
   - Data Providers can either directly provide data information to known Data Consumers or use a more typical approach where they describe and advertise their data offerings for potential consumers.
   - IDS provides a technology-agnostic language for data Self-Descriptions and infrastructure components for hosting and searching these Self-Descriptions.
2. Data Self-Descriptions:
   - Data Providers create accurate and comprehensive Self-Descriptions of their data assets, adhering to IDS Information Model schema and standards.
   - These Self-Descriptions are deployed on the Data Provider's IDS Connector and can be accessed by other IDS Connectors.

3. IDS Metadata Broker:
    - Data Providers may choose to announce their Self-Descriptions to a central component, the IDS Metadata Broker, which stores and makes them available for search requests.
    - Data Consumers can search through stored Self-Descriptions, negotiate with Data Providers, and request data assets through the hosting IDS Connector.
4. Data Provider Control:
    - Data Providers have full control over their data asset's Self-Descriptions and can update them at any time.
    - Data Consumers may request the latest Self-Description version from the original IDS Connector for reassurance.
5. Maintaining Self-Descriptions:
    - Data Providers can maintain Self-Descriptions at IDS Metadata Brokers to avoid misunderstandings and protect their reputation.
    - Updates to Self-Descriptions are sent to IDS Metadata Brokers, which can store previous versions for documentation.
6. Interaction Patterns:
    - Data Providers can register Self-Descriptions with IDS Metadata Brokers, which do not actively search for Self-Descriptions but rely on notifications from Data Providers.
7. Data Consumer Search:
    - Data Consumers can search for data providers in IDS Metadata Broker catalogs, selecting suitable brokers and query capabilities.
    - The IDS Metadata Broker returns query results, including information about IDS Connectors capable of providing the desired data.
8. Crawling Self-Descriptions:
    - An alternative approach involves federated caching and crawling of data offerings, allowing Data Consumers to search through cached data offers.
    - Multiple IDS Connectors can participate in crawling, and this approach can be part of a hybrid setup that combines various crawling methods.

These processes and components ensure efficient data offering and searching within the IDS ecosystem while maintaining control and accuracy of data information.

Contract Negotiation, i.e., accepting data offers by negotiating the usage policies. The Contract Negotiation process in the International Data Spaces (IDS) involves the acceptance of data offers through negotiations of usage policies. Here's a summary of the key points:

1. Contract Offer:
    - Connector Self-Descriptions contain Usage Control information in the form of a Contract Offer.

- A Contract Offer specifies the conditions under which a Data Provider is willing to make its data available to a Data Consumer, ranging from access restrictions to more complex duties.

2. Negotiation Process:
   - In a semi-automated negotiation process facilitated by the Usage Control frameworks of IDS Connectors, the Data Consumer and Data Provider must agree on a Data Usage Contract or Contract Agreement.
   - The negotiation process can involve simple or complex flows, including counteroffers and external input.
3. Basic Flow:
   - The Data Provider attaches a Contract Offer to a data offer, which is part of the IDS Connector's Self-Description.
   - The Data Consumer can submit a Contract Request at any time, even if no Contract Offer exists initially.
   - The negotiation process can occur synchronously or asynchronously and can be canceled at any point.
4. Counter Offers:
   - In a more complex negotiation flow, when the Data Provider's IDS Connector receives a valid Contract Request, it may notify interested users or systems and provide an interface for input.
   - The IDS Connector can be extended to negotiate contracts or allow user interaction automatically.
   - Users or services can reject, agree to, or propose Contract Offers or Requests, affecting the negotiation.
   - Once a Contract Agreement is reached, it is persisted and enforced by both IDS Connectors.

This process ensures that data sharing within the IDS ecosystem adheres to specified usage policies and can be adapted to different negotiation scenarios, whether simple or complex.

Exchanging Data, i.e. transfer data between IDS Participants. Exchanging Data involves the transfer of data between IDS Participants after a successful Onboarding process. This operation is divided into the Control Phase and the Transfer Phase.

1. Control Phase:
   - In the Control Phase, Participants pass through processes like Data Offering and Contract Negotiation to prepare for data transfer, using IDS-specific communication protocols defined in IDS-G.
   - A Data Operation request requires information for technical automation, such as authentication details and protocol specifics.
2. Communication Pattern:

- Communication between Connectors can be synchronous or asynchronous.
- Data Consumers can request updates for subscribed data, either event-based or within specified time intervals.
- The specifics of communication patterns are covered by existing standards and best practices in the industry.

3. Communication Protocol:
   - The Transfer Process is not restricted to a specific protocol, allowing flexibility based on system requirements.
   - Data Transfer can occur directly between Connectors using an IDS protocol or involve other infrastructure and protocols.
4. Out-of-band Data Exchange:
   - Out-of-band data exchange allows Connectors to establish connections directly between data source and data sink systems.
   - This approach offers flexibility in managing connections and data transfer methods.
5. Semantic Interoperability:
   - Semantic interoperability is crucial and involves querying vocabularies from the Vocabulary Hub.
   - Steps for achieving semantic interoperability include publishing and referencing vocabularies, schema validation, and data validation against vocabularies.
6. Usage Control:
   - Usage control ensures that the contents of negotiated Contract Agreements are enforced during data transfer.
   - Connectors must comply with usage control requirements, including event-based notifications.

Publishing and using Data Apps, i.e. interacting with an IDS App Store or using IDS Data Apps. Publishing and using IDS Data Apps involves interactions with an IDS App Store and utilizing IDS Data Apps for various data processing tasks. Here's a summary:

1. IDS Data Apps:
   - IDS Apps are used by IDS Connectors for specific data processing or transformation tasks, ranging from simple data parsing to complex analytics.
   - App Providers create IDS Apps, which are then published at an IDS App Store.
2. Publishing IDS Apps:
   - The "IDS App Publication Process" includes certification by the Certification Body for some IDS Apps.
   - App Providers push app images to the App Store's App Container Registry and publish app metadata.
   - Published IDS Apps and metadata are stored in the IDS App Store and can be accessed by IDS Participants via a search interface.

3. Using IDS Apps:
    - IDS Participants, referred to as "App Users," can search for IDS Apps in the IDS App Store through their IDS Connectors using the "Find IDS App" process.
    - App Users may need to make payments for selected IDS Apps, similar to Contract Negotiation.
    - If a suitable IDS App is found, it can be requested through the "Retrieve IDS App" process, which involves retrieving metadata and pulling the app image for deployment in the App User's IDS Connector.

This process allows IDS Participants to discover, acquire, and use IDS Data Apps from the IDS App Store for various data-related tasks, enhancing the functionality of IDS Connectors.

Policy Enforcement in the context of IDS (International Data Spaces) involves the implementation of data usage restrictions through technical means. Here's a summary of the key components and processes:

1. Policy Enforcement Overview:
    - Policy Enforcement can be both technical and organizational, but IDS focuses on technical enforcement to enhance security.
    - Technical enforcement involves monitoring and intercepting system actions by Policy Enforcement Points (PEPs).
    - A decision engine, known as the Policy Decision Point (PDP), evaluates actions based on policies, conditions, and obligations.
    - PEPs enforce decisions made by the PDP, potentially modifying or locking data.
2. Policy Enforcement Components:
    - Policy Enforcement Point (PEP):
        - Serves as the entry point for enforcing policies.
        - Stops and transfers data or metadata to the PDP for decision-making.
        - Manipulates or locks data based on decisions.
    - Policy Decision Point (PDP):
        - Makes decisions based on data from PEPs and defined policies.
        - Policies specify conditions, obligations, and context information.
        - Results of the evaluation are sent back to the PEP for enforcement.
    - Policy Information Point (PIP):
        - Determines context information during policy evaluation.
        - Provides additional information used by the PDP for decision-making.
    - Policy Execution Point (PXP):
        - Implements instructions or requirements.
        - Execution can occur before or after a decision.
        - Successful execution may be included as a condition.
    - Policy Management Point (PMP) and Policy Administration Point (PAP):

- Not directly involved in enforcement.
- PMP manages policies, making them available to the PDP.
- PAP supports the creation and specification of policies via a user-friendly interface.

3. Interaction in the IDS Connector:
   - Example process within an IDS Connector for Usage Control.
   - The IDS Connector Core is central, knowing data routes and destinations.
   - PEPs can be integrated at appropriate points in data flows.
   - PEPs send data and required information to the PDP.
   - PDP analyzes policies and may depend on external systems for context information.
   - Decisions trigger actions, such as logging data usage in a Clearing House using a Policy Execution Point (PXP).

This process ensures that data usage restrictions are enforced technically, enhancing security and control within the IDS ecosystem.

10.6.1.2 System Layer

The System Layer in the International Data Spaces (IDS) serves as the essential bridge between the conceptual framework defined in the Business Layer and the technical realization detailed in the Process Layer. It is the foundational core of the IDS, translating abstract concepts into a tangible data and service architecture, facilitating secure and trusted data exchange among IDS participants. Key components of the IDS ecosystem include the Identity Provider, responsible for identity and access control, the IDS Connector, the cornerstone of data exchange, the App Store and IDS Apps for extending functionality, the Metadata Broker for managing Connector metadata, the Clearing House for clearing and billing services, and the Vocabulary Hub, ensuring standardized and machine-readable terms. Together, these components form a robust technical foundation for the IDS, enabling seamless and secure data interactions in the digital ecosystem. The IDS consists of the following core components:

- **Identity Provider**: The Identity Provider (consisting of CA, DAPS, and ParIS) is a crucial component in the International Data Spaces (IDS) responsible for managing identity and access control. It comprises three main components:

1. Certificate Authorities (CAs): CAs issue identity certificates for connector instances by signing Certificate Signing Requests (CSRs). They also handle certificate revocation and ensure the proper storage of private keys, enhancing trust and security in the IDS.
2. Dynamic Attribute Provisioning Service (DAPS): DAPS enriches connector identities by providing up-to-date information in the form of signed claims, which are embedded into Dynamic Attribute Tokens (DATs). This service verifies the status and validity of various metadata, such as Software Manifests and Company

Descriptions, providing dynamic attributes like device location and supported transport certificates. DAPS aids in dynamic attribute handling, reducing the need for certificate revocation and enabling flexible attribute assignment.

3. Participant Information Service (ParIS): ParIS offers business-related information about IDS Participants that have been verified by the Support Organization. It manages Participant Self-Descriptions, which are similar to IDS Metadata Broker Self-Descriptions but focus on Participants. ParIS components include servers to host IDS Endpoints, databases for storing RDF Self-Descriptions, IAM for identity verification and authorization, optional indexing for faster read requests, and a website for human interactions. ParIS interactions can be categorized into two main types: internal provisioning of Participant information during onboarding, ensuring the accuracy of metadata, and external communications with IDS Connectors. ParIS provides IDS-compliant functions for dereferencing Participant identifiers, allowing for various search and querying capabilities, including full-text search, attribute-based search, and SPARQL queries. The lifecycle of Participant Self-Descriptions involves initial creation, updates, and potential deactivation or reactivation, with operators and Participants having the ability to adjust these descriptions. Regarding data synchronization between ParIS instances, there is a focus on maintaining core attributes of IDS Participants, but no strict enforcement of synchronization between different ParIS instances.

- **IDS Connector**: The IDS Connector is a fundamental component of the International Data Spaces (IDS) network. Here is a summary of its key features and architecture:

1. IDS Connector Overview:
    - The IDS network is composed of IDS Connectors, and each IDS Connector allows data exchange via the Data Endpoints it exposes.
    - There is no central data storage instance in IDS; data is exchanged directly between IDS Connectors.
    - IDS Connectors must be reachable by IDS Connectors from other organizations, possibly requiring changes in firewall policies or the establishment of a demilitarized zone (DMZ).
    - IDS Connectors should be accessible via standard Internet Protocol (IP) and can operate in various environments, including on-premises or in the cloud.
    - A Participant may operate multiple IDS Connectors, which can be used for load balancing or data partitioning.
2. IDS Connector Architecture:
    - IDS Connector Architecture employs application container management technology to create an isolated and secure environment for individual IDS Apps and IDS Connector functionalities.

- IDS Apps are services that implement business logic within the IDS Connector, such as data processing, integration with external systems, or controlling the IDS Connector itself.
- IDS Apps can be downloaded from the IDS App Store and deployed within the IDS Connector.
- The IDS App Store, Metadata Broker, and Clearing House are built based on the IDS Connector architecture to support secure and trusted data exchange with these services.

3. Connector Architecture Elements:
    - Application Container Management: Manages the deployment of IDS Core Services and IDS Apps within containers to ensure isolation and prevent unintended interdependencies.
    - Certified Core Container: Contains one Connector Core Service, providing components like Data Management, Metadata Management, Contract and Policy Management, and more.
    - Certified App Container: A certified container downloaded from the App Store, providing a specific IDS App to the IDS Connector.
    - Custom Container: Contains a self-developed Custom App, typically requiring no certification.
    - IDS App: Defines a public API invoked from the IDS Connector, with a formally specified meta-description imported during deployment
4. IDS Connector Functionalities:
    - IDS Connector must include essential functionality within its Connector Core Service(s), which can be implemented as individual microservices or a single comprehensive software block.
    - Functionalities include Authentication Service, Data Exchange, IDS Protocol(s), Remote Attestation, Logging Service, Monitoring Service, Data App Management, Policy Engine, Contract Management, Metadata Management, Data Management, Configuration Management, and User Management.
    - These functionalities work together to ensure secure and trusted data exchange within the IDS network.
5. Special Connectors:
    - IDS Connectors can be customized based on specific needs and deployment environments.
    - Developer Connector: Used during development and debugging phases, may not require application container management for faster development cycles.
    - Mobile Connector: Designed for mobile operating systems or resource-constrained environments, may run IDS Apps and Connector Core Services directly on the host system.

- Embedded Connector: Miniaturized version of IDS Connector, may use a common runtime or simplified components for specific use cases.

These aspects collectively define the IDS Connector and its role within the IDS network, enabling secure and trusted data exchange among participants.

- **App Store and App Ecosystem:** The IDS App Store and the concept of IDS Apps are essential components within the International Data Spaces (IDS) ecosystem. Here's a summary of their key features:

1. IDS App Overview:
    - An IDS App is a self-contained, functional, and reusable software asset that can be deployed, executed, and managed within an IDS Connector.
    - IDS Apps are versatile and serve different purposes within the IDS ecosystem.
    - Three main types of IDS Apps are distinguished: Data App, Adapter App, and Control App.
2. Types of IDS Apps:
    - Data App: These are reusable, interchangeable, and connector-independent applications that perform data processing tasks such as data transformation, cleaning, or analysis. Data Apps manipulate available data in some way, and they can be chained together to perform multiple processing steps on the same data.
    - Adapter App: Adapter Apps are also reusable, interchangeable, and connector-independent. They provide access to enterprise information systems, making them accessible to the underlying Connector. These apps are used when the routing framework cannot inherently support endpoints or protocols provided by external services.
    - Control App: Control Apps allow for the external control of the Connector and are used to connect backend systems to the IDS ecosystem. They work on administrative control flows and are connector-specific, requiring programming against the specific Connector's API.
3. Integration and Endpoints:
    - IDS Apps can be equipped with various endpoints for exchanging data within the IDS ecosystem. These endpoints include those for consuming data, providing data, and communicating with external components.
    - Endpoints are categorized as INPUT, INPUT EXTERNAL, OUTPUT, and OUTPUT EXTERNAL, depending on their role and whether they communicate internally or with external components.
    - There are also optional endpoints like the config endpoint for changing configuration parameters during runtime and the status endpoint for retrieving status information from an IDS App during runtime.
4. IDS App Store:

- The IDS App Store is a secure platform for distributing IDS Apps, including a registry of available IDS Apps and search functionality.
- It supports operations like App registration, publication, maintenance, and querying.
- Users can search for IDS Apps using various criteria, including functional properties, certification status, community ratings, and more.
- The IDS App Store also allows for billing and support services.
- The App Store communicates with Connectors of App Providers and App Users within the IDS Data Space.

5. App Store Architecture:
    - An IDS App Store consists of a registry for IDS Apps and supports various operations related to IDS Apps.
    - It includes an IDS Connector to communicate with Connectors of App Providers and App Users.
    - Each instance of an App Store must meet Connector Certification criteria and provide standard Connector functionalities and endpoints, along with specific App Store operations.

- **Metadata Broker:** The IDS Metadata Broker is a core component in the International Data Spaces (IDS) ecosystem, functioning as an IDS Connector. Its primary role is to manage Self-Descriptions, which provide metadata about IDS Connectors, their capabilities, and the data they offer. Key points about the IDS Metadata Broker:

1. Self-Descriptions: These contain information about IDS Connectors, including interfaces, owners, and offered data. Self-Descriptions are provided by Connector operators.
2. Phone Book Functionality: The Metadata Broker acts like a phone book, allowing IDS Connectors to register their Self-Descriptions for discovery. Multiple Metadata Brokers may exist within a Data Space.
3. Interaction: Participants interact with the Metadata Broker using defined processes and message types. It may offer additional services based on the IDS Information Model.
4. Not a Message Broker: Unlike a message broker, it doesn't actively distribute data assets but serves as a registry and discovery service.
5. Connector Certification: It must meet Connector Certification criteria, providing standard Connector functionalities and endpoints.
6. Database Requirements: It requires a scalable internal database, often in a graph-oriented format, for storing Self-Descriptions.
7. Flexible Architecture: The architecture must support extensions to the IDS Information Model and domain-specific attributes.

8. Human Interface: Metadata Brokers typically provide a user-friendly interface for accessing Self-Descriptions.
9. Endpoints: It offers endpoints for reading and, in the case of hosting Connectors, writing Self-Descriptions.
10. Search and Querying: Its main purpose is to provide search functionality, supporting various types of queries based on the IDS Information Model.
11. Self-Description Life Cycle: Self-Descriptions can transition between active and unavailable states, allowing updates but not complete deletions.
12. Data Synchronization: In cases of multiple Metadata Broker instances, data synchronization mechanisms are not specified by IDS, and operators may implement their own approaches.

In essence, the IDS Metadata Broker acts as a crucial information hub, enabling efficient discovery and access to data assets within the IDS Data Space without actively distributing data like a message broker.

- **Clearing House:** The IDS Clearing House is a key component within the International Data Spaces (IDS) ecosystem, and it operates as an IDS Connector. Its primary function is to facilitate clearing, billing, and usage control processes based on logged information. Key points about the IDS Clearing House:
  1. Architecture: The Clearing House consists of an IDS Connector, which is based on a logging service. This service records specific information defined in the Process Layer.
  2. Clearing and Settlement: The Clearing House uses the recorded information to offer a Clearing and Settlement Service. This service automates payment processes between Data Providers and Data Consumers based on usage contracts.
  3. Billing Service: Additionally, the Clearing House provides a Billing Service that enables the Data Space Operator to bill participants effectively.
  4. Usage Control Validation: The UC (Usage Control) Claim Validation service utilizes the logged usage control data to validate usage claims on resources.

In essence, the IDS Clearing House plays a crucial role in ensuring fair and transparent transactions within the IDS ecosystem by automating clearing, settlement, billing, and usage control processes.

- **Vocabulary Hub:** The IDS Vocabulary Hub is a vital component of the International Data Spaces (IDS) ecosystem, designed to support standardized and machine-readable vocabularies for describing data, services, contracts, and more. Here's a summary of its key functions and role:
  1. Standardized Vocabularies: The IDS relies on standardized terms to describe various aspects within its ecosystem. These terms form controlled vocabularies. In the IDS, these vocabularies must be machine-readable.

2. Machine-Readable Terms: To ensure interoperability, the terms in these vocabularies must be machine-readable. This means that both the terms and their descriptions should be structured in a way that software systems can understand.
3. Expanding Vocabulary: While the core IDS Information Model provides fundamental terms for all IDS components, specific use cases may require more expressive terms. Additional vocabularies are created to address these domain-specific needs.
4. Vocabulary Hub: The IDS Vocabulary Hub is a service that hosts, maintains, publishes, and documents these additional vocabularies. It serves as a management platform for data schemes used in IDS use cases.
5. Maintenance and Collaboration: Experts can use the Vocabulary Hub to collaboratively work on vocabulary definitions, document them, and improve them over time. This collaborative approach ensures that the vocabularies remain up-to-date and accurate.
6. Runtime Lookups: When Connectors encounter unknown terms in asset Self-Descriptions, they can perform runtime lookups at the Vocabulary Hub. The Vocabulary Hub responds with RDF documents that explain the attributes, including their type, label in different languages, and descriptions.
7. Namespace Organization: Vocabularies are often organized into namespaces, each containing terms for specific purposes. Connectors can request complete vocabularies defined by previously unknown namespaces, reducing the need for repeated interactions with the Vocabulary Hub.

In essence, the IDS Vocabulary Hub supports the growth and management of controlled vocabularies, ensuring that Connectors and other IDS components can communicate effectively by understanding the meaning of terms used in Self-Descriptions and other data representations.

10.6.2 Identity and Access Management (IAM) Technologies

Digital identity systems are a fundamental part of the chain of trust of a data sharing environment. This chain of trust can be mainly divided into two schemes, a static one related to the certification process, including, for example, the provisioning of X509 certificates to the different components. The dynamic scheme, on the other hand, deals with the management of dynamic attributes such as identity tokens exchanged between the parties. In addition to the establishment of needs related to digital identity, the grouping of entities, systems and individuals participating in the chain of trust involves the definition of roles with a set of rights and duties. For instance, the Identity Provider is responsible for offering services to create, maintain, manage, monitor, and validate identity information of and for participants in the data sharing ecosystem.

The use of blockchain technology can ensure data consistency and transparency in combination with the general data sharing approach for the trust chain, data sovereignty and data security. For instance, blockchain can be used to verify that some user information needed to initiate a transaction is valid without having to act as a custodian and store user profile and identity data themselves. A key implication of reduced data custody is that it can lower costs (e.g., for infrastructure, security, and regulatory compliance), privacy and security burdens, and barriers to bootstrapping new business activities.

As it can be seen, there is not a unique technology for dealing with identity and access management. An analysis of the technologies used within the three main data-sharing enabler initiatives has been carried out.

10.6.2.1.1 GAIA-X

How identity and access management (IAM) technologies work in GAIA-X: The IAM system in GAIA-X is decentralized, meaning there is no central authority controlling user identities and access. Instead, each organization operates its own IAM system and acts as an identity provider to its users.

GAIA-X IAM is based on the following core concepts [1]:

Self-sovereign identity (SSI): SSI is a new approach to identity management that gives users full control over their own digital identities. With SSI, users can create and manage their own identities without having to rely on a third-party identity provider. SSI is also known as sovereign identity in some GAIA-X documents, but the term SSI is preferred as it emphasizes the user's autonomy and agency over their identity data.

Decentralized identity (DID): A DID is a unique identifier that is not controlled by any single entity. DIDs are used to link different pieces of information about a user's identity, such as their name, email address, and public key. DIDs are also known as distributed identities in some GAIA-X documents, but the term DID is preferred as it emphasizes the user's independence and mobility across different domains.

Verifiable credentials (VCs): VCs are digital credentials that can be used to prove a user's identity or claims about their identity. VCs are signed by the user and can be verified by any provider that trusts the user's signature. VCs can be used to demonstrate various attributes of a user's identity, such as their education, skills, or preferences.

GAIA-X IAM is implemented using a variety of technologies, including [1][3][4]:

Self-sovereign identity (SSI)

Distributed ledger technology (DLT): DLT is a technology that uses a network of nodes to store and share data in a secure and tamper-proof way. DLT is used to store and share

DIDs and VCs in GAIA-X, ensuring that the user's identity data is always available and consistent.

Blockchain technology: Blockchain technology is a type of DLT that uses a chain of blocks to store and verify transactions. Blockchain technology can be used to implement DLTs for IAM in GAIA-X, providing a high level of trust and transparency for the user's identity data.

OpenID Connect (OIDC): OIDC is an open standard for authentication that allows users to sign in with their existing identities from different providers. OIDC can be used to integrate IAM in GAIA-X with existing identity systems, such as social media accounts or enterprise directories.

OAuth 2.0: OAuth 2.0 is an open standard for authorization that allows users to grant or revoke permissions to access their resources from different providers. OAuth 2.0 can be used to control access to resources in GAIA-X based on a user's identity, such as data or services.

SAML is used to authenticate and authorize users to access GAIA-X services and resources.

X.509 certificates are used to secure communication between GAIA-X participants and services.

Benefits of GAIA-X IAM: IAM in GAIA-X offers a number of benefits, including:

Increased security and privacy: Self-sovereignty and decentralization make IAM in GAIA-X more resistant to attack and give users more control over their privacy. Users can decide who can access their identity data and how they can use it, without having to share it with third parties or intermediaries. For example, users can use VCs to prove their age without revealing their date of birth.

Improved efficiency and agility: IAM in GAIA-X can help organizations to improve efficiency and agility by simplifying and streamlining the process of managing user identities and access. Users can use their existing identities to access resources from different providers, without having to create multiple accounts or passwords. For example, users can use OIDC to sign in with their Google account to access a service offered by another provider.

Reduced costs: IAM in GAIA-X can help organizations to reduce costs by eliminating the need for expensive and complex identity management systems. Users can manage their own identities using their own devices or applications, without having to rely on centralized servers or databases. For example, users can use DLTs to store and share their DIDs and VCs, without having to pay for storage or network fees.

Federated identity: IAM in GAIA-X supports identity federation, which allows users to use their existing identities to access resources from different providers. Users can choose which providers they trust and which ones they want to interact with, without having to compromise their security or privacy. For example, users can use OAuth 2.0 to grant or revoke permissions to access their data or services from different providers.

Identity governance: IAM in GAIA-X supports identity governance, which allows organizations to define and enforce policies for managing user identities and access. Organizations can specify the rules and requirements for creating and verifying user identities, as well as the roles and permissions for accessing resources. For example, organizations can use VCs to issue and validate certificates for their employees or customers.

Identity compliance: IAM in GAIA-X supports identity compliance, which helps organizations to meet regulatory requirements for managing user identities and access. Organizations can demonstrate the provenance and validity of their user identities, as well as the consent and accountability of their user actions. For example, organizations can use DLTs to provide an immutable and auditable record of their user transactions.

GAIA-X IAM is still under development, but it has the potential to revolutionize the way that we manage our digital identities. By giving users full control over their own identities and enabling decentralized identity management, GAIA-X IAM can help to create a more secure, private, and efficient digital world.

10.6.3 IDSA – International Data Spaces Association

Identity and access management (IAM) technologies in International Data Spaces (IDS) are designed to enable secure and trustworthy data exchange among different participants. IAM technologies consist of three main components: Certificate Authorities (CAs), Dynamic Attribute Provisioning Service (DAPS), and Participant Information Service (ParIS) [8].

- Certificate Authorities (CAs) are responsible for issuing and managing identity certificates for connectors, which are the technical components that enable data sharing in IDS. Identity certificates are digital documents that prove the identity and authenticity of a connector and its owner. CAs follow a set of rules and standards to ensure that only legitimate and trustworthy organizations can obtain identity certificates and operate connectors in IDS.CAs also provide mechanisms for revoking or renewing identity certificates in case of changes or incidents. CAs are the backbone of the trust infrastructure in IDS, as they enable participants to verify each other's identity and credentials before engaging in data transactions.
- Dynamic Attribute Provisioning Service (DAPS) provides up-to-date information about connectors and participants in the form of Dynamic Attribute Tokens (DATs),

which are signed claims that contain attributes such as certification status, location, or vulnerabilities. DATs are issued by DAPS upon request from connectors, and they have a limited validity period. DAPS allows dynamic assignment and revocation of attributes based on the current situation and needs of the data ecosystem. DAPS enhances the flexibility and adaptability of IDS, as it enables participants to adjust their data sharing behavior according to the changing conditions and requirements.

- Participant Information Service (ParIS) provides business-related information about participants in IDS, such as their name, contact details, or description. ParIS helps participants to discover and evaluate potential data providers or consumers in IDS. ParIS also supports the creation and maintenance of business relationships among participants, by facilitating communication and negotiation processes. ParIS fosters the collaboration and innovation in IDS, as it enables participants to find and connect with suitable data partners for their data projects.

Together, these IAM technologies form the basis for data sovereignty and trust in IDS, as they allow participants to identify, authenticate, and authorize each other before engaging in data transactions. IAM technologies also support the enforcement of usage policies that specify the conditions and restrictions for data access and usage in IDS.

Here is a more detailed overview of how identity and access management technologies work in the International Data Spaces (IDS) architecture:

IDS relies on IAM technologies to ensure the trustworthiness and interoperability of the data exchange. Each IDS connector has a private key with a corresponding X509v3 certificate (device certificate) that is used for authentication. The certificates are issued by an identity provider (IDP) that is trusted by all IDS participants. The IDP also administers self-descriptions and attested (certified) attributes of the connectors, such as their roles, capabilities, policies, and certifications.

The connectors can obtain dynamic tokens from an attribute server called Dynamic Attribute Provisioning Service (DAPS), which implements the OAuth2 protocol. The tokens contain the required attributes of a connector for accessing the services and data of other connectors. The decision about permitted access is always made by the requested connector itself, based on its own policies and preferences.

Some of the properties of IAM technologies in IDS are [9]:

- They enable federated identity management across companies and industries, without requiring a centralized authority or intermediary.
- They support data sovereignty by allowing data owners to define and enforce their own policies and preferences for data sharing.

- They facilitate secure and efficient data exchange by using cryptographic mechanisms and standards-based protocols.
- They enable dynamic trust management by allowing connectors to verify the identity and attributes of other connectors in real-time.
- They support interoperability and scalability by following a reference architecture and a formal standard defined by the International Data Spaces Association (IDSA).

10.6.3.1.1 FIWARE

FIWARE is a framework that consists of a set of components that can be used to build smart solutions for different domains. FIWARE uses Keyrock [11], Wilma[12], Steelskin[13] and AuthZforce[14] as its IAM component, which provides the following features:

- User management: Users can sign up, log in, and manage their profiles using Keyrock. Users can also belong to one or more organizations, which are groups of users that share some common attributes and roles.
- Application management: Applications are securable FIWARE components that consist of a series of microservices. Applications can register with Keyrock and obtain credentials to access other FIWARE components or external services.
- Role-based access control (RBAC): Keyrock and AuthZforce allow defining roles and permissions for users and applications, and assigning them to organizations. Roles and permissions determine what actions can be performed on which resources within the system.
- OAuth 2.0 support: Keyrock and Wilma implement the OAuth 2.0 protocol, which is a standard for authorization. OAuth 2.0 allows applications to request and obtain access tokens from Keyrock, which can be used to access protected resources without sharing credentials.
- SAML and OpenID Connect support: Keyrock also supports SAML and OpenID Connect, which are standards for authentication. These protocols allow users to log in to Keyrock or other applications using their existing identities from other providers, such as Google or Facebook.

Table 32 summarizes the key aspects of identity and access management (IAM) in GAIA-X, IDS, and FIWARE:

IAM		GAIA-X	IDS	FIWARE
Architecture		Decentralized, federated	Decentralized, federated	Centralize
Technologies used		Self-sovereign identity (SSI), blockchain, distributed ledgers (DLT), OAuth 2.0, OpenID Connect (OIDC), Security Assertion Markup	SSI, DLT, X.509 certificates, OAuth 2.0	Self-sovereign identity (SSI), OAuth 2.0, SAML, OpenID Connect

		Language (SAML) and X.509 certificates		
Key components		Identity providers, wallets, credential issuers	IDS Identity Provider (IDIP), Certificate authorities, attribute providers	Keyrock identity manager
Benefits		User control, privacy, security	Data sovereignty, dynamic trust	Role-based access control, single sign-on

Table 32: Comparison table summarizing the key aspects of identity and access management (IAM) in GAIA-X, IDS, and FIWARE

10.6.3.1.2 FEDERATED

FEDeRATED established a data exchange model using semantic web technology with an overarching ontology to enable mapping between existing ontologies from different transport domains. This to avoid the obsoletion problems posed by tranditional development and establishment of technical standards for exchange of data.

10.6.4 C. Audit and Monitoring:

Monitoring data sharing and usage activities across ecosystems using tools and techniques can help detect and respond to any data anomalies, breaches, or incidents, such as unauthorized access, excessive access, data leakage, data manipulation or data theft. Data sharing and data usage monitoring can also help measure and improve the performance, efficiency, and quality of data operations. Some of the tools and techniques for monitoring data usage and sharing include logs, audits, alerts, dashboards, reports, or analytics.

Auditing data sharing and usage compliance across ecosystems, using various methods and standards can help to verify and validate that data access policies and controls are effective and compliant with data privacy and security policies, as well as the legal and ethical requirements of use case industry and jurisdiction. Data sharing and usage auditing can also help to identify and address any data risks, gaps, or issues, and recommend corrective or preventive actions. Some of the methods and standards for data access and usage auditing include internal or external audits, self-assessments, reviews, or certifications.

Again, an analysis of the technologies related to auditing and monitoring used within the three main data-sharing enabler technologies has been carried out. For the case of FIWARE, no specific tools have been found for audit and monitoring.

10.6.4.1 GAIA-X

Auditing and monitoring [5][2][6] are essential aspects of Gaia-X, the federated open data infrastructure based on European values regarding data and cloud sovereignty. Gaia-X relies on the Data Exchange services, which are part of the Federation Services, to enable auditing and monitoring among participants in the Gaia-X ecosystem. The Data Exchange services consist of four main components: Data Exchange Protocol, Data Usage Control, Data Sovereignty Services, and Auditing and Monitoring Services.

The Auditing and Monitoring Services are responsible for collecting, storing, and analyzing data about the activities and events that occur within the Gaia-X federation. They provide transparency and accountability for data providers and consumers, as well as regulators and auditors. They also support the enforcement of policies and rules defined by the Gaia-X Trust Framework.

The Auditing and Monitoring Services are designed to be decentralized, interoperable, and scalable. They rely on common standards and protocols for data collection, storage, and analysis. They also respect the privacy and security of the data subjects and the data owners. The Auditing and Monitoring Services provide various functionalities, such as:

- Logging: recording relevant information about data transactions, such as who accessed what data, when, where, how, and why.
- Reporting: generating summaries and statistics about data transactions, such as how much data was exchanged, by whom, for what purpose, and with what outcome.
- Alerting: notifying relevant stakeholders about anomalies or violations of policies or rules, such as unauthorized access, data leakage, or non-compliance.
- Auditing: verifying the correctness and completeness of data transactions, such as whether they followed the agreed terms and conditions, respected the data sovereignty principles, and complied with the applicable regulations.
- Monitoring: measuring and evaluating the performance and quality of data transactions, such as whether they met the expected service level agreements, satisfied the user requirements, and achieved the intended goals.

Auditing and monitoring in Gaia-X offer a number of benefits for organizations that participate in the platform, such as:

- Improved security: Auditing and monitoring can help organizations to identify and respond to security threats more quickly and effectively. This can help to reduce the risk of data breaches and other security incidents.
- Enhanced compliance: Auditing and monitoring can help organizations to meet their regulatory compliance obligations. For example, many regulations require organizations to audit and monitor their systems to ensure that they are protecting sensitive data and meeting other security requirements.
- Increased operational efficiency: Auditing and monitoring can help organizations to identify and address operational inefficiencies. For example, audit logs can be used to identify users who are accessing resources that they do not need or to identify applications that are using more resources than they should be. This information can be used to improve the efficiency of the system and reduce costs.

10.6.4.1.1 IDSA – International Data Spaces Association

Audit and monitoring [7][10] in International Data Spaces (IDS) are important aspects of ensuring data sovereignty, security, and trust among data providers and consumers. According to the IDS Knowledge Base, IDS aims to facilitate secure and standardized data exchange and data linkage in a trusted business ecosystem, while guaranteeing data sovereignty for data owners. To achieve this goal, IDS relies on several components and mechanisms, such as:

- IDS Connector: The central technical component of IDS that enables data transfer between participants in a data space. The IDS Connector implements the IDS communication protocol and the IDS information model, and enforces the usage policies agreed upon by the data providers and consumers.
- IDS Communication Protocol: The protocol that defines the messages and interactions between IDS Connectors, such as contract negotiation, data transfer, and policy enforcement.
- IDS Information Model: The model that defines the common vocabulary and semantics for describing data, participants, contracts, policies, and other relevant concepts in a data space.
- IDS Certification: The process that verifies the compliance of IDS components with the IDS standard and ensures their interoperability and trustworthiness. IDS Certification is based on a set of criteria and requirements defined by the IDSA.
- Observability, Traceability and Audit Logging: The features that enable monitoring and auditing of transactions and events in a data space, such as contract negotiation, data transfer, and policy enforcement. These features can be implemented by using trusted technology systems that record and verify domain events, or by using cloud-aware policy engines that can be embedded in other processes.

Table 33 summarizes the key aspects of auditing & monitoring in GAIA-X, IDS:

Auditing & Monitoring	GAIA-X	IDS
Architecture	Decentralized data logs and reports	Built into connectors and protocols
Key components	Logging, reporting, alerting, auditing, monitoring, Gaia-X Audit Agent (GAA)	Audit logs, traceability mechanisms
Focus areas	Security, compliance, efficiency	Data sovereignty, security, trust
Benefits	Threat detection, regulatory compliance, optimization	Policy enforcement, provenance

Table 33: comparison table summarizing the key aspects of auditing & monitoring in GAIA-X, IDS

10.7 Common and Conceptual Data Model for a structured data exchange (FA1)

Within the FP1 project are working on the CDM and will continue based on the results of the previous LINX4Rail project. In the project LINX4Rail "System architecture and Conceptual Data Model for railway, common data dictionary and global system modelling specifications" deliverable 3.3 we can find a clear definition between Common Data Model and Conceptual Data Model

- - The Conceptual Data Model represents business entities and determines what kinds of relationships exist between them. It supresses details to provide the big picture.
- The Common Data Model provides an additional level of indirection between application's individual data formats. If a new application is added to the integration solution only transformation between the Common Data Model must be created, independent from the number of applications that already participate.

In this sense the Common Data Model represents a contract between data producer and data consumer about content of exchanged information

10.8 CDM overview Data

According to Deliverable 3.3 from LINX4Rail two consequences can be drawn:

- For a high-performance application interoperability, a Common Data Model must be standardized (message schemata),

- For a data-management-consistency a higher-level model is required, which defines the data semantic and can build the ground for any physical model. In the context of Linx4Rail this high-level-model is called Conceptual Data Model. To allow automatic consistency validation any physical model should be linked to the conceptual data model.

We can therefore expect the CDM specification to be composite and include both conceptual and common data models with well-defined and verifiable relationships.

10.9 Data entities and their attributes

The methodology remains close to OPTIMA project where it practiced many CDM extensions. It however sticks to requirements and does not consider (semi) automated model extensions at present in FP1. From FP5 perspective, we will be aligned to these already concepts, see table 1 in next chapter as example.

10.10 Input from demonstration workshop.

Maintenance workshops must make the most of their capabilities to reduce the time the trains spend in them, reduce the total maintenance cost and increase the safety of the revised rolling stock.

In order to carry out this ambitious objective, one of the solutions is to use an innovative solution that consists of mounting gantries for measuring train parameters at the entrance to the workshops.

These gantries will be able to record different parameters of the rolling stock using different external equipment. The data will be stored in a data cloud that will later, through the appropriate processing of a CBM (Condition Base Maintenance), allow the objectives set at the beginning of this paragraph to be achieved.

The most important challenges in this section are found in the development of software based on CBM, as well as the standardization of data so that standard frames in the industry can be created at low cost.

In Table 34 (Template according to Use Case for Collection Workshop Data), we have a proposal table to collect input from demonstration workshop, this table is a specific example for other demonstrators.

Table 34 plots the information or data that must be collected from the Checkpoints that are installed in the railway infrastructure. These Checkpoints will automatically dump the data into this table.

Table 34 aims to automatically identify the owner of this data, who has access to it and whether it can be shared with other infrastructure managers in the case of international freight transport. It also tries to identify the position and location of this data within the train to make it easier to locate.

In successive updates of this table, the type of variable (number, word) must be incorporated, in the case that its unit is a numerical value (m, cm, kg, Cº, etc.).

Last but not least, it will be necessary to define in successive refinements of this table, a section with the limit value of the variables to be recorded and the alarm level that should appear as a consequence of the appearance of this alarm, for example: stop of the rolling stock or send the rolling stock for inspection within 24 hours.

Collection of requirements of the use cases check-list definition is going to be developed in the WP32 according to FP1 alignment.

10.11 Interaction with FA1-CDM alignment for Common Data model specification and enablement of data-format translators.

Data format translators are tools designed to transform data from one format to another. These translators are essential when data needs to be exchanged between different systems, applications, or platforms that use different data formats to achieve data interoperability.

Data-format translators and specifications for Common Data Model must be developed in FP5-TRANS4M-R in alignment with the FP1-MOTIONAL project.

Within FP5-WP32 Task32.4, the alignment of this activity is monitored and management together with FP1- WP30. It is necessary to define how the alignment in this activity will be planned during of development of both projects.

The alignment to be carried out should focus on determining the following information:

- What has already been done
- What is going to be developed within the FP1-MOTIONAL project
- What is out of the scope of the FP1-MOTIONAL project

10.12 Application of data sharing principles to Use Cases

This chapter will address the data sharing aspect in the work packages involved in the project. The goal is to formulate use cases based on various work packages and demonstrate them in a showcase in work package 33 and 34.

Data exchange has a major role in standardised European checkpoints in TRANS4M-R project.

Data exchange at checkpoint in Spain (ADIF, RENFE, INDRA, CEIT)

The objective of this section is to define the IVG automatic measurements gantry based, mainly, on image recognition (OCR) as well as the entry and exit times of the wagons that make up the train, which allows us to know which train is circulating through the freight terminal, entering or leaving, as well as some variables of the wagons or ILUs.

This image recognition system must be able to operate both during the day and at night, and must also have sufficiently precise image quality with a very high resolution in the cameras so that it allows us to detect the parameters of interest, such as are detailed later, of the locomotive, the wagons or the ILUs.

It is well known that the identification of wagons, along with that of ILUs, is a task that is currently carried out by hand, under very difficult conditions, since it is often done on foot, walking among the ballast, with rain, snow, at night or in very high heat. To reduce this hardship, and increase automation and digitalization, this proposed system will allow us to identify:

1. The EVN (European vehicle number) of the locomotive and wagons that make up the train, as well as the codes of their ILUs.
2. Identify the track on which the train runs as a whole.
3. The spatial dimensions of the wagons, to detect if there is any excess gauge due to the fact that there has been a displacement of the load. (optional)
4. Type of goods through the identification of dangerous goods labels thanks to image recognition on the wagons.
5. Graffiti on the locomotive or wagons that prevents their EVNs from being read (optional)
6. Train length
7. Number of wagons
8. The date and time of entry or exit from the terminal
9. Order of wagons and containers in the train composition

The information extracted from this system must be published in the data space, so that it is available, after materializing the corresponding access agreements between publishers and consumers, for the following entities:

1. Terminal Operator System (TOS): System used for the management of the operations in the terminal.

2. RU/IM (terminal manager): through the access provided by the TOS you will have access to the information.

3. Traffic Management System (TMS): The TOS should send information to the TMS of the train's exit or entry. (out of the scope in this call)

Likewise, the use case is complemented by on-board monitoring, where some train car incorporates a series of sensors that can provide information about the status of the car and the load through the data space. In particular, in the onboard part it is planned to incorporate sensor nodes integrated into the bogies that can measure the following parameters:

- Triaxial and gyro accelerations for bogie and suspension performance data
- Multi-constellation GNSS position to synchronize and position the cars in relative
- Humidity and pressure sensor to monitor load
- Distance sensor for determination of load placement

This gateway will send this information to the cloud which will be processed to provide punctuality data to the other systems, as well as the rest of the processed information that is of interest.

Requirements for data transmission:

The messages related to the **real time information** of the terminal activities.

Service providers (could include IMs, terminal managers, shunting operators, road transport operators) have the information that can be the inputs for the TOS platform.

Checkpoints will produce the information that can be the inputs for the TOS platform.

Data standards:

The inputs for TOS and for TMS will be studied as standard information prepared for future tasks of integrations of the systems.

Data owners/providers:

TMS: owner

TOS: owner

Hauliers: provider

Maneuvers: provider

Data consumers:

TMS: owner

TOS: owner

Hauliers: provider

Maneuvers: provider

Summary

The Seamless Data Exchange deliverable addresses the challenges in transport data exchange, targeting to create an integrated and efficient system considering the already existing technologies. The specifications framework was developed to enhance data exchange and quality based on the partners experiences and creating a repository of existing standards and solutions. The primary objective is to provide an overall framework to allow a seamless and harmonised exchange of data.

11 Conclusions

Seamless Planning: The current processes for the planning of train paths with various infrastructure managers involved such as international cross-border paths or paths with a section in a terminal or yard have been described. Shortcomings regarding the long-term planning as well as the short-term and real-time planning were identified and requirements for seamless path planning were deviated from this. Interfaces between the different systems involved such as capacity planning and train management systems have been specified to enable an exchange of relevant data between all partners involved in the supply chain. This data is required to optimize planning processes which emphasizes the high relevance of reliable data availability. Data security and privacy requirements of the partners must be considered to accomplish wide acceptance and dissemination. In the next steps, the specified systems will be developed and tested. In parallel, a transformation path that shows organizational changes in the railway sector which are relevant to enable the usage of the systems and interfaces must be designed. This transformation path will also be used to analyse the future impact of the developed systems.

Dynamic Dispatching: For Terminals and Yards existing pain points were identified resulting in requirements. Those requirements formed the basis for the envisaged use cases. The use cases will demand in the next period development activities and testing in the field as described in the use cases. All next steps will have the aim to demonstrate that improvements can be achieved thanks to the joint efforts of the partners and the intermodal ecosystem, processes can be simplified and the use of existing infrastructure can be maximized thanks to dynamic information reception and active exchange of information.

Intermodal Prediction: Two kinds of prediction systems were specified – one system for an ETA and one system for an ETD. Both use existing standards: TAF TSI for main line train information and EDIGES for terminal information. Additional data about infrastructure and network information has to be obtained from other sources, most notably the TMS. The quality evaluation of the predictions follows the TAF TSI KPIs (ETA qualifier and CTO qualifier) and is adapted to also include the terminal processes. One of the main applications of these predictions is the Asset Warehouse, where the assignment of rolling stock can be optimised based on the incoming prediction values. Utilising prediction values and the thereby enhanced reliability as well as the possibility for optimisation, there are various other possible applications for Seamless Freight. For example, yard and terminal operations (Dynamic Dispatching) can be optimised in various ways. Different short-term path planning options can be evaluated based on ETD (Seamless Planning).

Finally, the transparency achieved through the monitoring of live trains can be used as an additional user feature for tracking a booked train/loading unit (Multimodal Integration).

Standardised European Railway Checkpoints: The concept of Standardised European Railway Checkpoints is a further development of the previous work carried out in Shift2Rail and the concept of "Intelligent Video Gates" (IVG). The main objective was thus further development of the previous work. Moreover, in FP3 the checkpoints are also developed but at main lines for both freight and passenger trains. Hence, one main aim was to give a clear and through background description in chapter 8.1, including existing similar systems that the IMs in T25.4 currently possess. Process descriptions were carried out for three types of operational stops for freight trains; intermodal terminals, marshalling yards and borders. Opportunities for improving these processes though the use of Checkpoints as well as a vast set of use cases were identified. Functional and non-requirements were developed based on the MoSCoW method (Must, Should, Could or Will not have) in a physical workshop with all partners. Based on the process analysis and the defined requirements, technical specifications for detection technologies were outlined in chapter 8.4 and the data sharing aspects in chapter 8.5. Albeit technical standardisation has been addressed both regarding detection technologies and data sharing, further work is needed to be carried jointly between the System Pillar sub-project Harmonized European Railway Diagnostics (Herd), FP5 T25.4/WP29 and FP3 WP7. The main regulations identified thus far in T25.4 that the concept needs to relate to concern inspections for cross border traffic and handling of dangerous goods. Regarding cross border traffic, the implementation of Automated Freight Train Transfer Inspections (ATTI) at borders has already been harmonised all over Europe. The integration of Checkpoints or other wayside monitoring systems (WMS) seems logical as the ATTI does not yet provide the integration of WMS data. Therefore, it is recommended that actions are taken here. It should be noted that when stakeholders are not bounded by ATTI, GCU Appendix 9 is applied. Thus, the specifications outlined in this report will be the basis for a standardised development and installation of Checkpoints within WP29.

Multimodal Integration: It is the common objective of all partners in FP5 to increase the ratio of freight on rail. One important element to achieve this objective is to decrease the associated complexity in order to lower the entry barrier. Booking freight on rail should not be a task, that can only be performed and executed by specialists with decades of experience. Therefor major constraints and pain points have been identified and different use cases have been identified to prove that the envisaged digitalization will make the booking process ideally more user friendly and more efficient. The upcoming developments, user tests and use case demonstrations shall overcome as many existing constraints as possible. The use cases focus around the optimized and simplified search of possible connections and available services to cover the market demand, the simplified booking even if more than one service provider is involved and the simplified creation of new services if the market demand is not matching the actual market offering. An important outcome of the next phase is on top of this to identify additional or remaining constraints that still hinder a simplified access of freight on rail.

Seamless Data Exchange: The aim of the data exchange is to facilitate the function of rail freight transportation within a segment of entire supply chain ecosystem, from the origin to the final destination. Administrative barriers are a major obstacle in data sharing. This difficulty arises from a lack of knowledge about the importance of data exchange, uncertainty about the appropriate methodologies and systems, concerns about security, and the ease of opting for non-cooperation due to potential risks. To overcome these barriers, it is essential to enhance knowledge and competence in data exchange and establish a trustworthy approach with clear processes and relationships, showcasing the benefits for all stakeholders. This aligns with the concept of a 'platform of platforms' approach. The project identified that the issue isn't a shortage of systems or methodologies, but a lack of standardization and ontologies, as well as knowledge gaps. Often, different systems and organizations interpret the same data differently. Thus, this work package, following this understanding, should not develop new technologies but instead align with ongoing advancements. For instance, the FP1-MOTIONAL project's efforts to deploy an IDS-compliant Rail Federated Data Space (WP31) and a conceptual data model. The federated approach is emerging as an effective strategy for enabling data exchange between various actors. For seamless data exchange across Europe, such as in achieving Standardised European checkpoints, a conceptual data model is promising. This would ensure that gates operate and communicate uniformly across European countries. Achieving seamless and interoperable data exchange for various applications is important, and the project's focus on these aspects marks a significant step towards more efficient and seamless freight sector. This project will undergo further development in work package 32. The use cases gathered from different work packages within Seamless operations will be integrated in WP32.

12 References

Agile Business Consortium (2023), *Chapter 10: MoSCoW Prioritisation*, Retrieved 2023-11-22, https://www.agilebusiness.org/dsdm-project-framework/moscow-prioririsation.html

ALICE (2023), *ALICE Alliance for Logistics Innovation through Collaboration in Europe – ALICE supporting logistics innovation through collaboration in Europe*, Retrieved 2023-11-12, https://www.etp-logistics.eu/

ARCC (2018). Real-time yard management: Description of business processes of a network management system and the interactions/interfaces with a Real-time Yard Management System. Deliverable D2.2 from the ARCC project.

Authzforce CE (2023), *Official Documentation Authzforce*, Retrieved 2023-07-29 from https://authzforce-ce-fiware.readthedocs.io/en/latest/

[Bane NOR, 2023] https://www.banenor.no/siteassets/bane-nor-sf/godstransport/sporbruksplaner/sporbruksplan-oslo-godsterminal-alnabru.pdf, last access 08.12.2023.

(C4R D2.3, 2017)), Capacity4Rail WP2.3.1 Conceptual terminals' design methodology for different markets , Retrieved 2023-10-27, https://kth.diva-portal.org/smash/get/diva2:1651025/FULLTEXT01.pdf

Crozet, Y. (2014). Development of rail freight in Europe : What regulation can and cannot do United Kingdom Case Study. *CERRE: Center on Regulation in Europe*, *December*, 1–43.http://www.cerre.eu/sites/cerre/files/141211_CERRE_RailFreight_UK_Case_Study_Final.pdf

Directive 2008/68. *Directive 2008/68/EC of the European Parliament and of the Council of 24 September 2008 on the inland transport of dangerous goods* http://data.europa.eu/eli/dir/2008/68/oj

FEDeRATED (2023), *Home,* Retrieved 2023-11-12, https://www.federatedplatforms.eu/

Fiware Pep Proxy (2023), *Pep Proxy - Wilma*, Retrieved 2023-07-21 from https://fiware-pep-proxy.readthedocs.io/en/latest/

fr8hub (2020). Deliverable 3.3 Results of traffic simulation of defined scenarios and evaluation. FR8HUB (shift2rail.org)

FR8RAIL II (2020), WP5 Freight Automation Deliverable 5.1

FR8RAILIII (2022). DELIVERABLE D 2.2 *Method development for enhanced and integrated line- and yard planning*. FR8RAIL III (shift2rail.org)

FR8RAIL III (2022b), *D1.4 Wayside vehicle monitoring for Condition-Based Maintenance*, 2022-10-17, Retrieved 2023-11-21 https://projects.shift2rail.org/s2r_ip5_n.aspx?p=FR8RAIL%20iii

Fr8Rail III (2023). Demonstration of enhanced and integrated line- and yard planning and possibilities for implementation. Deliverable D2.3 form project Fr8Rail III.

Gaia-X (2022), *New GXFS Whitepaper sheds light on envolving Self Sovereign Identities (SSI) landscape, Retrieved 2023–07-06 from* New GXFS Whitepaper sheds light on evolving Self Sovereign Identities (SSI) landscape - GXFS.eu

Gaia-X (2022), *Gaia-X Architecture Document*, Retrieved 2023-07-05 from https://gaia-x.eu/wp-content/uploads/2022/06/Gaia-x-Architecture-Document-22.04-Release.pdf https://link.springer.com/chapter/10.1007/978-3-030-93975-5_4

Gaia-X (2022), *White Paper Design Final EN*, Retrieved 2023-07-06 from https://gaia-x.eu/wp-content/uploads/2022/06/SSI_White_Paper_Design_Final_EN.pdf

Gaia-X (2022), *Gaia-X Trust Framework*, Retrieved 2023-07-06 from https://gaia-x.eu/wp-content/uploads/2022/05/Gaia-X-Trust-Framework-22.04.pdf

Gaia-X (2021), *X Federation Services White Paper 1*, Retrieved 2023-07-06 from https://gaia-x.eu/wp-content/uploads/files/2022-01/Gaia X_Federation_Services_White_Paper_1_December_2021.pdf

Github (2023), *fiware-pep-steelskin*, Retrieved 2023-07-25 from https://github.com/telefonicaid/fiware-pep-steelskin#readme

Green Cargo (2023), *Green Cargo – your sustainable logistics partner*, Retrieved 2023-07-03 from: https://www.greencargo.com/

GCU (2023), *Appendix 9 to the General Contract of Use (GCU) for Wagons -Technical Conditions for Wagon Transfers between Railway Undertakings*, GCU Bureau, 2023-01-01 https://gcubureau.org/wp-content/uploads/Contract/2023/20230101_A09_EN.pdf

GS1 (2013), RFID in RAIL - European Guideline for the Identification of Railway Assets using GS1 Standards, 2013-01-08, Retrieved 2023-10-27 https://bransch.trafikverket.se/contentassets/c38f728aa7a0486699cc61b068019be0/rfid_in_rail_gs1_in_eu.pdf

[HUPAC; 2023] HUPAC website https://www.hupac.com/DE/Verkehrstechniken-1b38a100 last access 02-11-2023.

Industrial Data Spaces (2023), *Ram 4,* Retrieved 2023-07-03 from: https://docs.internationaldataspaces.org/ids-knowledgebase/v/ids-ram-4/

International Data Spaces (2022), *IDS Reference Architecture Model*, Retrieved 2023-07-18 from https://docs.internationaldataspaces.org/ids-knowledgebase/v/ids-ram-4/

Kordnejad, B., Åkerfeldt, M., Aronsson, M., Barbi, C. E., Diotallevi, C., Gotelli, G., Garcés Mencía, H., Irala Briones, A., Ivansson, G., Karl, J., Kjellin, M., Merle Carrera, L., Lengu, R., Posseger, E., Treiber, A. (2018), *D4.1 Description of functional and technical requirements and selection of components*, WP4: Intelligent Video Gate, FR8HUB, Shift2Rail

Kordnejad, B., Åkerfeldt, M., Aronsson, M., Barbi, C. E., Diotallevi, C., Garcés Mencía, H., Gotelli, G., Irala Briones, A., Ivansson, G., Karl, J., Kjellin, M., Lengu, R., Merle Carrera, L., Mitrovic, B., Nordmark, I. (2019), *D4.2 Technical Proof of Concept and Roll-out and Implementation Plan,* WP4: Intelligent Video Gate, FR8HUB, Shift2Rail

Kordnejad, B., Åkerfeldt, M., Aronsson, M., Gotelli, G., Irala Briones, A., Ivansson, G., Kjellin, M., Lengu, R., Merle Carrera, L., Müllerschön, J., Naranjo, A., Nordmark, I., Römer, H., Wießner, S., Wohlrath, R. (2020), *Deliverable D 3.1, Requirements definition and IVG preliminary installation report*, WP3: Intelligent Video Gate, FR8RAIL III, Shift2Rail

Kordnejad, B., Åkerfeldt, M., Aronsson, M., Irala Briones, A., Ivansson, G., Kjellin, M., Lengu, R., Merle Carrera, L., Nordmark, I., Olsson, E., Wohlrath, R. (2021), *Deliverable D 3.2, Description of demonstrator – Intelligent Video Gate*, WP3: Intelligent Video Gate, FR8RAIL III, Shift2Rail

Kordnejad, B., Åkerfeldt, M., Aronsson, M., Ivansson, G., Kjellin, M., Lengu, R., Nordmark, I., Rius García, G., Salvitti, G., Vilabella, S., Wohlrath, R. (2022), *Deliverable D 3.3, Demonstration and Evaluation including Best Usage of the Data Capture*, WP3: Intelligent Video Gate, FR8RAIL III, Shift2Rail

Lesavre Loïc, Varin Priam et al., (2020) *A Taxonomic Approach to Understanding Emerging Blockchain Identity Management Systems*, NIST, Retrieved 2023-07-25: https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.01142020.pdf

Minbashi, N., Sipilä, H., Palmqvist, C. W., Bohlin, M., & Kordnejad, B. (2023). *Machine learning-assisted macro simulation for yard arrival prediction*. Journal of Rail Transport Planning & Management, 25, 100368.

Minbashi, N., Bohlin, M., Palmqvist, C. W., & Kordnejad, B. (2021). *The application of tree-based algorithms on classifying shunting yard departure status*. Journal of Advanced Transportation, 2021, 1-10.

Nelldal, B.-L., & Wajsman, J. (2015). *Godstransporter 2014-2030-2050 : Analys av godsflöden, järnvägens produkter och rangerbangårdar.* KTH Royal Institute of Technology. Retrieved from: http://urn.kb.se/resolve?urn=urn:nbn:se:kth:diva-310967

OTIF (2023a), *Regulations concerning the International Carriage of Dangerous Goods by Rail (RID)*, OTIF – Intergovernmental Organisation for International Carriage by Rail, Retrieved 2023-12-21, https://otif.org/en/?page_id=1105

OTIF (2023b), *COTIF 1999*, OTIF – Intergovernmental Organisation for International Carriage by Rail, Retrieved 2023-11-12, https://otif.org/en/?page_id=172

Pineda-Jaramillo, J., & Viti, F. (2023). *Identifying the rail operating features associated to intermodal freight rail operation delays*. Transportation Research Part C: Emerging Technologies, 147, 103993.

Prinz, W., Rose, T., Urbach, N. (2022). Blockchain Technology and International Data Spaces. In: Otto, B., ten Hompel, M., Wrobel, S. (eds) Designing Data Spaces . Springer, Cham. https://doi.org/10.1007/978-3-030-93975-5_10

[Trafikverket; 2023] https://www.researchgate.net/figure/Layout-of-Hallsberg-marshalling-yard-own-creation-upon-plans-provided-by-Trafikverket-to_fig5_291126373, last access 02-11-2023.

[TRANS4M-R, D2.1; 2023] TRANS4M-R Deliverable D2.1 'Preliminary Operational Procedures', V01, 30-06-2023.

[TRANS4M-R D25.2, 2023] TRANS4M-R Deliverable D25.2 'High-level specification of requirements, challenges and a future target state for freight cross-border planning and operations from an operator perspective as input for FP1', V01, 30-06-2023.

UIC (2017), *ATTI Special Group -Agreement on freight Train Transfer Inspections*, International union of railways, 2017-08-29, https://uic.org/IMG/pdf/atti_special_group_2017-08-29_en.pdf

UIC (2023), *ATTI_Members_Public_List_20230501*, International union of railways, 2023-05-01, https://uic.org/IMG/pdf/atti_members_public_list_20230501.pdf

[RNE; 2023] Rail Net Europe, official website *Customer Information Platform*, https://rne.eu/it/rne-applications/cip/ last access 02-11-2023.

[RNE PCS; 2023] Rail Net Europe, *Introduction to PCS Processes and Phases*, https://cms.rne.eu/pcs/pcs-documentation/introduction-pcs-processes-and-phases, last access 27-11-2023

Xrail (2023), *Singel Wagonload – Intro,* Retrieved 2023-07-03 from: https://www.xrail.eu/wagonload-intro

13 Appendices

13.1 Seamless freight requirements

ID	WP	SYSTEM/FUNCTION	FR/NFR	DESC	CATEGORY
111	26	Track Assignment Optimizer (TAO)	NFR	The TAO must provide an interface to the planners and operators which visulizes the plan, conflicts and allows interaction, changes and overwrites	Mandatory
112	26	Track Assignment Optimizer (TAO)	FR	The TAO must be able to read in the data that is generated from the operator's application for tracks	Mandatory
113	26	Track Assignment Optimizer (TAO)	FR	The TAO must be able to compute track assignment plans that fullfill the requirements for such a plan	Mandatory
117	26	Track Assignment Optimizer (TAO)	FR	The TAO should be able to provide suggestions or constraints to the time-table generating software (FA1) to facilitate a process where the generation of both track assignment plans and time-tables take each others feasiblity into account.	Optional
126	26	short-term departure planning module	FR	The module must receive yard/terminal predictions as an input.	Mandatory
127	26	short-term departure planning module	FR	The module must receive planned departure and arrival (timetable data) as input.	Mandatory
128	26	short-term departure planning module	FR	The module must receive information about the planned track occupancy of the yard/terminal	Mandatory
129	26	short-term departure planning module	FR	The module must plan the departure time of trains	Mandatory

130	26	short-term departure planning module	FR	The module must plan the arrival time to the next yard/terminal	Mandatory
114	26/27	Track Assignment Optimizer (TAO)	FR	The computation time for plans must allow for at least semi-interactive adjustments of the plan	Mandatory
66	26/27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard-CMS must allow to inform the CMS about a new planned departure track allocated to a train in the handover area of a yard.	Mandatory
67	26/27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard-CMS must allow to inform the CMS about a changed planned train consist in the yard (pre being moved to the departure track) without hitting overload/oversize route restrictions.	Mandatory
68	26/27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard-CMS must allow to inform the CMS about a changed planned train consist in the yard (pre being moved to the departure track) with hitting overload/oversize route restrictions (leading to choosing a different route in the CMS).	Mandatory
69	26/27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard-CMS must allow to inform the CMS about an earlier planned availability time of a train in a departure track of the handover area of a yard.	Mandatory
70	26/27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard-CMS must allow to inform the CMS about a later planned availability time of a train in a departure track of the handover area of a yard.	Mandatory
71	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about a new planned arrival track allocated to a train in the handover area of a yard.	Mandatory

72	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about a changed planned train consist in the yard (pre being moved to the arrival track).	Mandatory
73	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about an earlier planned arrival time of a train in a arrival track of the handover area of a yard.	Mandatory
74	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about a later planned arrival time of a train in a arrival track of the handover area of a yard.	Mandatory
75	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about an earlier planned departure time of a train in a departure track of the handover area of a yard (relevant only in specific cases).	Mandatory
76	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the Yard-CMS about a later planned departure time of a train in a departure track of the handover area of a yard.	Mandatory
77	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to send and receive freight path requests via PCS (or successor application at RNE) using TSI TAF.	Mandatory
78	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to receive Temporary Capacity Restrictions (TCR) from RNE TCR tool using TSI TAF on a relevant line section behind the border and to identify conflicts with cross-border freight paths.	Mandatory
79	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to receive Temporary Capacity Restrictions (TCR) from RNE TCR tool using TSI TAF on a	Mandatory

				relevant line section behind the border and to indicate re-planning options on the local network.	
80	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to receive Temporary Capacity Restrictions (TCR) from RNE TCR tool using TSI TAF on a relevant line section behind the border and to update an allocated freight path for resolving a conflict.	Mandatory
81	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to show the impact of two non-coordinated TCRs behind and towards the border.	Mandatory
82	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	A CMS must allow to exchange a new planned/changed/cancelled cross-border freight path on defined line sections towards the border, and to receive it in the CMS of the neighbouring network triggering path validation and conflict detection.	Mandatory
83	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	A CMS must allow to exchange a new planned/changed/cancelled TCR on defined line sections towards the border, and to receive it in the CMS of the neighbouring network triggering TCR validation and conflict detection.	Mandatory
84	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a new planned/changed/cancelled train path (including cross-border freight paths); included in FP1 WP11/12 requirements.	Mandatory
85	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a new planned/changed/cancelled	Mandatory

				TCR; included in FP1 WP11/12 requirements.	
86	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a new planned departure track allocated to a train in the handover area of a yard.	Mandatory
87	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a changed planned train consist in the yard (pre being moved to the departure track).	Mandatory
88	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about an earlier planned availability time of a train in a departure track of the handover area of a yard.	Mandatory
89	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a later planned availability time of a train in a departure track of the handover area of a yard.	Mandatory
90	26/27/FA1	(Main-line) Capacity Management System (CMS)	FR	The CMS must allow to inform the TMS about a new planned departure track allocated to a train in the handover area of a yard.	Mandatory
91	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a cancelled train (including cross-border freight trains) due to TC decisions; included in FP1 WP11/12 requirements.	Mandatory
92	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a new planned/changed/cancelled operational TCR; included in FP1 WP11/12 requirements.	Mandatory
93	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a change of a train's arrival track in the yard.	Mandatory
94	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a different train	Mandatory

				consist than planned (pre arrival at yard track).	
95	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about an earlier arrival time at yard track.	Mandatory
96	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a later arrival time at yard track.	Mandatory
97	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about an earlier departure time at yard track (not typical but may happen).	Mandatory
98	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to inform the CMS about a later departure time at yard track.	Mandatory
99	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to receive estimated times of arrival at handover locations (ETH) of the borders from RNE TIS using TSI TAF messages for communicating Train Running Forecasts.	Mandatory
100	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to use the ETH information as a starting time for the forecast calculation on the local network.	Mandatory
101	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to use information about Temporary Capacity Restrictions (TCRs) behind the border originating from RNE TCR tool using TSI TAF messages. The messages are received by the local CMS and forwarded to the TMS, see requirement 3.2 above.	Mandatory
102	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to exchange Train Running Forecast of a cross-border freight train on defined line sections towards the border, and to receive it in the TMS of	Mandatory

				the neighbouring network triggering conflict detection.	
103	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to exchange operational TCR status information on defined line sections towards the border, and to receive it in the CMS of the neighbouring network triggering conflict detection.	Mandatory
104	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to identify and manage the impact of TCRs behind the border by identifying related conflicts with cross-border freight paths.	Mandatory
105	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to identify and manage the impact of TCRs behind the border by indicating decision options on the local network.	Mandatory
106	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to identify and manage the impact of TCRs behind the border by implementing required decisions for handling the conflicts.	Mandatory
107	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to show the impact of two non-coordinated TCRs behind and towards the border on the local network.	Mandatory
108	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to consider knock-on delays in the forecast in context with planned exchanges of rolling stock (e.g., traction units) at the handling locations and late inbound trains.	Mandatory
109	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to consider and implement train sequence changes because of conflict resolution at a handover location.	Mandatory

110	26/27/FA1	Traffic Management System (TMS)	FR	The TMS must allow to identify and solve conflicts of an international train impacted by TCRs on both sides of the border and featuring connected shunt-moves to the yard.	Mandatory
195	26/28	ETD prediction model	FR	The model must predict the departure deviation per train.	Mandatory
196	26/28	ETD prediction model	FR	The model must calculate the Estimated Time of Departure per train.	Mandatory
8	26/31	Asset Warehouse	FR	The system must provide data about (un)successful resource reservation and its attributes to RU's planning system.	Mandatory
11	26/31	Asset Warehouse	FR	The system must receive planed trains data of request for resources assignment to train from RU's planning system.	Mandatory
15	26/31	Asset Warehouse	FR	The system must plan resources (loco, driver, staff, service facilities) to services.	Mandatory
115	27	Track Assignment Optimizer (TAO)	FR	The TAO should be able to receive real time train running information and display that in relation to the plan visualize deviations	Optional
116	27	Track Assignment Optimizer (TAO)	FR	The TAO should be able to automatically adjust the plan according to real time information, or suggest those adjustments if automatic changes are not desired	Optional
118	27	Yard Dispatching System (YDS)	FR	The YDS must know the yard and terminal topology and information about safety regulations (minimum timelags, maximum speed etc.)	Mandatory

119	27	Yard Dispatching System (YDS)	FR	The YDS must know the trains' arriving and departing times form the train time table	Mandatory
120	27	Yard Dispatching System (YDS)	FR	The YDS must know the assigned arrival and departure tracks from the track assignment plans	Mandatory
121	27	Yard Dispatching System (YDS)	FR	The YDS must get information about train information (length, number of wagons etc)	Mandatory
122	27	Yard Dispatching System (YDS)	FR	The YDS should return either a feasible shunting plan or an infeasibility notification	Mandatory
123	27	Yard Dispatching System (YDS)	FR	The YDS should recieve information about updated ETAs	Mandatory
124	27	Yard Dispatching System (YDS)	NFR	The YDS could have information about preferred sequence of routes for shunting operations, or about tracks not preferred either at a general or area specific level.	Optional
125	27	Yard Dispatching System (YDS)	NFR	The YDS should include an algorithm for finding not only feasible, but optimal shunting plans	Optional
137	27	Terminal Operating System (TOS)	FR	The Terminal Operating System (TOS) must need to be able to adapt task planning dynamically due to live data	Mandatory
138	27	Terminal Operating System (TOS)	FR	The Terminal Operating System (TOS) must need to be able to receive and process data from different sources in order to fill in necessary check in data for containers automatically	Mandatory
139	27	Terminal Operating System (TOS)	SA	The Terminal Operating System (TOS) must need to be able to record movements and distinguish between	Mandatory

				productive and non-productive movements	
140	27	Terminal Operating System (TOS)	SO	The Terminal Operating System (TOS) must need to be able to receive also Truck ETA data if available	Mandatory
141	27	Terminal Operating System (TOS)	MO	The Terminal Operating System (TOS) must need to be able to treat a sophisticated multi tenancy, so several stakeholder from different legal entities able to access but with own restricted access	Mandatory
142	27	Shunting dispatcher	FR	The computation time for plans must allow for at least semi-interactive adjustments of the plan	Mandatory
143	27	Shunting dispatcher	FR	The system shall be able to receive real time train running information and display that in relation to the plan / visualize deviations	Optional
144	27	Shunting dispatcher	FR	The system shall be able to automatically adjust the plan according to real time information, or suggest those adjustments if automatic changes are not desired	Optional
145	27	Terminal Operating System (TOS)	FR	The System will be able to know Waggon numbers, and container numbers in the exact order in wich they are loaded in the train, by interacting with a CheckPoint. This inofrmation needs to be integrated in the Terminal Operating System and make it visible to the staff in order to facilitate unloading operations	Mandatory
146	27	Terminal Operating System (TOS)	FR	THe terminal Operating System is able to control the status of each cargo in the terminal, and is requred to	Mandatory

				have an integration with Customs	
147	27	Terminal Appointmen System (TAS) (Or Booking system)	FR	Truck drivesrs need to be able to select a slot of time in which they want to access the terminal, and indicate the ieration that they are planning to do	Mandatory
148	27	Terminal Appointmen System (TAS) (Or Booking system)	FR	The Terminal is aable to indicate the number of trucks that are accepted in the terminal by slots of time, deppending on the capacity	Mandatory
149	27	Terminal Appointmen System (TAS) (Or Booking system)	FR	The System has to control how many drivers want to acces the terminal by slot of time, and is requied that it doenst allow to request access for a slot in which the number of appointmes equals the capacity stated	Mandatory
150	27	Terminal Appointmen System (TAS) (Or Booking system)	FR	The system is requierd to get the status of trhe cargoes that are announced to acess the terminal by train, and of all the cargoes that are in stock waitng for been collected. This status need to be shared with drivers that want to access the terminal	Mandatory
151	27	Yard Dispatching System (YDS)	FR	The YDS must know the yard and terminal topology and information about safety regulations (minimum timelags, maximum speed etc.)	Mandatory
152	27	Yard Dispatching System (YDS)	FR	The YDS must know the trains' arriving and departing times form the train time table	Mandatory
153	27	Yard Dispatching System (YDS)	FR	The YDS must know the assigned arrival and departure tracks from the track assignment plans	Mandatory

154	27	Yard Dispatching System (YDS)	FR	The YDS must get information about train information (length, number of wagons etc)	Mandatory
155	27	Yard Dispatching System (YDS)	FR	The YDS should return to the *(what system?)* either a feasible shunting plan or an infeasibility notification	Mandatory
156	27	Yard Dispatching System (YDS)	FR	The YDS should recieve information about updated ETAs from *(what system?)*	Mandatory
157	27	Yard Dispatching System (YDS)	NFR	The YDS could have information about preferred sequence of routes for shunting operations, or about tracks not preferred either at a general or area specific level.	Optional
158	27	Yard Dispatching System (YDS)	NFR	The YDS should include an algorithm for finding not only feasible, but optimal shunting plans	Optional
180	27	ETA prediction system	FR	The Terminal Operating System must be able to measure the turn around time of container in a terminal.	Mandatory
9	27/31	Asset Warehouse	FR	The system must provide data about (un)succesful resource reservation and its attributes to RU's dispatching management system.	Mandatory
12	27/31	Asset Warehouse	FR	The system must recive data of request for resources assignment to train from RU's dispatching management system.	Mandatory
16	27/31	Asset Warehouse	FR	The system must allocate resources (loco, driver, staff, service facilities) to services.	Mandatory
18	27/31	Asset Warehouse	NFR	The system operational rate (Service Level Agreement SLA) reaches 98% on a benchmark basis.	Mandatory

19	27/31	Asset Warehouse	NFR	The system needs to put the information into a common well-known format (for example REST API, WSDL).	Mandatory
20	27/31	Asset Warehouse	FR	The system works for defined resources (loco, driver, staff, path, service facilities).	Mandatory
21	27/31	Asset Warehouse	NFR	The system works 24/7.	Mandatory
22	27/31	Asset Warehouse	NFR	The system has a maximum unplanned downtime of 60 minutes per year.	Optional
23	27/31	Asset Warehouse	NFR	The system shall require minimum maintenance to work.	Optional
131	27/FA1	Terminal Operating System (TOS)	FR	The Terminal Operating System (TOS) must need to know in advance the waggon number and the waggon consist from the Traffic Management System	Mandatory
132	27/FA1	Terminal Operating System (TOS)	FR	The Terminal Operating System (TOS) must to send the final waggon numbers and the waggon consist to the Traffic Management System once train "is ready to depart"	Mandatory
133	27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard Capacity Management System (Yard-CMS) must need to know in advance the waggon number and the waggon consist from the Traffic Management System	Mandatory
134	27/FA1	Yard Capacity Management System (Yard-CMS)	FR	The Yard Capacity Management System (Yard-CMS) must to send the final waggon numbers and the waggon consist to the Traffic Management System once train "is ready to depart"	Mandatory
135	28	Terminal Operating System (TOS)	FR	The Terminal Operating System (TOS) must need to know in advance the	Mandatory

				estimated time of arrival of approaching trains	
136	28	Yard Capacity Management System (Yard-CMS)	FR	The Yard Capacity Management System (Yard-CMS) must need to know in advance the estimated time of arrival of approaching trains	Mandatory
159	28	ETA prediction system	NFR	The system must have an uptime of 99%.	Mandatory
160	28	ETA prediction system	FR	The system must send out the predictions as a Train Running Forecast message in the TAF TSI format	Mandatory
161	28	ETA prediction system	FR	The system must calculate a prediction of arrival times for every relevant location for the main line.	Mandatory
162	28	ETA prediction system	FR	The system must calculate a prediction of arrival times for every pre-defined process/timestamp/milestones for terminals for which there is data.	Mandatory
163	28	ETA prediction system	FR	The machine learning algorithm should take into account weather information.	Optional
164	28	ETA prediction system	NFR	The system must receive real-time train running information messages from the IMs/RUs (via RNE TIS)	Mandatory
166	28	ETA prediction system	NFR	The algorithm must have access to historical data for the main line.	Mandatory
167	28	ETA prediction system	NFR	The algorithm should have access to historical data for terminal data.	Optional
168	28	ETA prediction system	FR	The system must calculate an ETA for every relevant location 2 hours before train departure from the first location/timestamp.	Mandatory

169	28	ETA prediction system	NFR	The system must receive timetable data for the main line in TAF TSI format.	Mandatory
170	28	ETA prediction system	NFR	The system should receive timetable data for the relevant timestamps in the EDIGES format.	Optional
172	28	ETA prediction system	NFR	The system mush be able to push the ETA information to another connected system.	Mandatory
173	28	ETA prediction system	NFR	Other connected systems should be able to pull the ETA information from the system.	Optional
174	28	ETA prediction system	NFR	The system must receive relevant timetable data at least 2 hours before planned departure from the first location.	Mandatory
175	28	ETA prediction system	FR	When receiving any non-train related data, the system must be able to map it to train-related information (such as GPS coordinates)	Mandatory
176	28	ETA prediction system	NFR	When receiving terminal-related data in any format other than EDIGES, this data must have all the relevant data to fill the mandatory parameters from the EDIGES status codes	Mandatory
177	28	ETA prediction system	FR	The system must be able to connect/map terminal data to main line train data.	Mandatory
178	28	ETA prediction system	FR	The system must be able to display/send the information on train and on loading unit level.	Mandatory
179	28	ETA prediction system	NFR	The system must receive information such as the wagon composition, which allowes the mapping of LUs to a train.	Mandatory
181	28	ETA prediction system	SA	The Terminal Operating System must be able to	Mandatory

				measure the unproductive craning tasks.	
182	28	ETA prediction system (TMI)	NFR	The terminal must receive the ETA messages from the time of cross-border of the train.	Mandatory
183	28	ETA prediction system (TMI)	NFR	The terminal must receive ETA messages compliant with the TAF TSI standards.	Mandatory
184	28	ETD prediction model	FR	The model must receive historical data related to trains (for example; train composition, wagon connections, wagon compositions, and ILUs)	Mandatory
185	28	ETD prediction model	FR	The model must receive train timetables and actual train running data.	Mandatory
186	28	ETD prediction model	FR	The model must receive terminal operational schedules.	Mandatory
187	28	ETD prediction model	FR	The model must receive historical data on terminal actual operations.	Optional
188	28	ETD prediction model	NFR	The model should receive data on terminal staff and train drivers (for example; the availability, shortage, etc...).	Optional
189	28	ETD prediction model	NFR	The model should receive data on terminal resources.	Optional
190	28	ETD prediction model	NFR	The model should receive data on locomotives.	Optional
191	28	ETD prediction model	FR	The model should receive data from main line status (any disturbances or disrucptions).	Optional
192	28	ETD prediction model	NFR	The model should receive data from the destination terminal (any disturbances or disruptions).	Optional
193	28	ETD prediction model	FR	The input data received by the model must be secured.	Mandatory
194	28	ETD prediction model	NFR	The model should receive rea-time data on arriving trains	Optional

				including ETAs to predict real-time ETDs.	
165	28/29	ETA prediction system	NFR	The system should receive real-time information from the video gates regarding train position and damages	Optional
10	28/31	Asset Warehouse	FR	The system must provide data about actual staus and changes of resource based on AWH functions to RU's resources management system.	Mandatory
13	28/31	Asset Warehouse	FR	The system must recive data of free/disposable resources from RU's resources management system.	Mandatory
14	28/31	Asset Warehouse	FR	The system must recive data of ETA recalculation from ETA prediction system.	Mandatory
17	28/31	Asset Warehouse	FR	The system must reallocate resources (loco, driver, staff, path, service facilities) to services.	Mandatory
171	28/FP1	ETA prediction system	FR	The algorithm should take into account real-time data received from the TMS.	Optional
197	28/FP1	ETD prediction model	NFR	The model must send ETDs to other connected systems.	Optional
43	30	European Railway Checkpoints	FR	The camera resolution is high enough to enable OCR reading of the smallest character on the wagon/container passing the camera on the track.	Mandatory
44	30	European Railway Checkpoints	FR	The system shall identify for each wagon the following: UIC code of passing vehicle, ILU/ISO codes of containers/UN-numbers or other cargo information of the wagons passing the camera on the track.	Mandatory
45	30	European Railway Checkpoints	FR	The system must identify dangerous goods signs on	Mandatory

				containers on wagons passing the camera on the track.	
46	30	European Railway Checkpoints	NFR	The system detection rate reaches 95% on a benchmark basis.	Mandatory
47	30	European Railway Checkpoints	FR	The system needs to identify itself so that downstream systems know the origin of the data.	Mandatory
48	30	European Railway Checkpoints	NFR	The system needs to put the information into a common well-known format.	Mandatory
49	30	European Railway Checkpoints	NFR	The system works 24/7 in all weather conditions and for trains/wagons that pass by until 140km/h, that break, stand still or accelerate in front of the camera.	Mandatory
50	30	European Railway Checkpoints	NFR	The system is installed at relevant sites for capturing rolling stock traffic.	Mandatory
51	30	European Railway Checkpoints	NFR	The system shall not interfere with the normal train operation.	Mandatory
52	30	European Railway Checkpoints	NFR	The system follows existing regulations (for example GDPR).	Mandatory
53	30	European Railway Checkpoints	FR	The system is expandable with other sensors/measurement systems (RFID, Hotbox, wheel profile measurements).	Mandatory
54	30	European Railway Checkpoints	FR	The system should identify: The position of each wagon. The direction in which the train is moving. The total count of wagons.	Mandatory
55	30	European Railway Checkpoints	FR	The system must capture high-quality images of wagon and container sides and tops for detailed visual inspection.	Optional
56	30	European Railway Checkpoints	FR	The system is able to share the data / result with other systems.	Optional

57	30	European Railway Checkpoints	FR	The user must have access to the data captured by the IVG.	Optional
58	30	European Railway Checkpoints	NFR	The data is secured.	Optional
59	30	European Railway Checkpoints	FR	The data can be accessed transnationally.	Optional
60	30	European Railway Checkpoints	FR	The system detects defective wagons.	Optional
61	30	European Railway Checkpoints	FR	The system measures the wagon weight and detects if there is an axle unbalance.	Optional
62	30	European Railway Checkpoints	NFR	The system has a maximum unplanned downtime of 30 minutes per year.	Optional
63	30	European Railway Checkpoints	NFR	The system shall require minimum maintenance to work.	Optional
64	30	European Railway Checkpoints	NFR	The system has an operational life of 30 years.	Optional
65	30	European Railway Checkpoints	FR	The system should identify: - Close-coupled wagons - Intermodal wagons and wagons with integrated goods compartments - Train speed	Optional
1	31	Booking System (BS)	FR	The Booking System (BS) must need to be able to receive and process data from different sources in order to fill in necessary data for the various booking processes	
2	31	Booking System (BS)	FR	The Booking System (BS) must need to be able to treat a sophisticated multi tenancy, so several stakeholder from different legal entities able to access but with own restricted access	
3	31	Booking System (BS)	FR	Booking System shall enable Train Operating Companies to understand where additional train run services will be required or where they can still offer train run services.	

4	31	Booking System (BS)	FR	Booking System shall enable Terminal Operating Companies to understand on which routes additional change over stops can be offered or additional Terminal services can be offered such as intermediate storage place or repairs of Containers.	
5	31	Booking System (BS)	FR	Booking System shall enable Trucking Companies to understand where last mile could be offered. The platform will explicitly not help to understand where railway legs can be substituted by truck services.	
6	31	Booking System (BS)	FR	Booking System shall enable Freight Oeprators to offer their services, such as taking over commercial risks, taking care of the invoicing, prepayments, customs declarations, booking of other needed services to execute a journey or a leg of a journey.	
7	31	Booking System (BS)	FR	Booking System shall enable Freight Operators to understand where additional capacity is required or where they can purchase additional capacity in order to offer complete journeys.	
24	31	Trip planning system	FR	The system must be able to use EDIGES messages as a basis for timetable information.	Mandatory
25	31	Trip planning system	FR	The system should be able to additionally incorporate UNL files as a backup solution should EDIGES not be fully available.	Optional

26	31	Trip planning system	NFR	The system must receive timetable information from >1 source/operator.	Mandatory
27	31	Trip planning system	NFR	There must be an API-driven integration for seamless navigation/connection between different (interconnected) modules.	Mandatory
28	31	Trip planning system	FR	The system should be built up from a scalable architecture for the system to have the possibility to scale with growing data volumes and user requirements	Optional
29	31	Trip planning system	NFR	The timetable information should be regularly updated, to allow for the display of up-to-date schedules instead of the commercial timetable.	Optional
30	31	Trip planning system	NFR	The system should receive information related to the capacity utilisation of the intermodal trains (for example with booking confirmation).	Optional
31	31	Trip planning system	FR	The system must be able to process data that contain information about capacities (in terms of content for additional information)	Mandatory
32	31	Trip planning system	FR	The system must display information on available routes based on dynamic user input (for example addresses)	Mandatory
33	31	Trip planning system	FR	The system should display and enable direct bookability for each train based on the capacity information	Optional
34	31	Trip planning system	FR	The system should display "fully booked" when connections for which there is no capacity or not the individually required capacity	Optional

35	31	Trip planning system	FR	The system must be able to sort the results of the routing requests by price per route (sorted in ascending or descending order)	Mandatory
36	31	Trip planning system	FR	The system must be able to sort the results of the routing requests by fastest route (sorted in ascending or descending order)	Mandatory
37	31	Trip planning system	FR	The system must be able to sort the results of the routing requests by shortest route (sorted in ascending or descending order)	Mandatory
38	31	Trip planning system	FR	The system must be able to sort the results of the routing requests by most environmentally friendly route (sorted in ascending or descending order)	Mandatory
39	31	Trip planning system	FR	The system must be able to show several variants of routing (incl. comparison with truck transportation) of a possible connection ("best route") based on various selectable criteria, such as time, frequency, CO2, price	Mandatory
40	31	Trip planning system	FR	The system must contain an improved and extended CO2 calculator that calculates the CO2 emissions of a connection based on load weight, transhipments and exact route and must enable follow-up analysis about the CO2 savings made and to "verify" them using a supplementary calculator, i.e. to indicate how much CO2 was actually saved (incl. export option)	Mandatory

41	31	Trip planning system	FR	The system should be able to exclude possible results based on user input.	Optional
42	31	Trip planning system	FR	The system should be able to select the most suitable terminals for the best connection/largest selection of suitable connections (route optimisation on GIS-based routing systems)	Optional

13.2 List of milestones for Seamless Freight

Milestone ID	Description of the milestone	Status	Level
Departing train			
D01	the time that the booking of a loading unit is made (including booking details + updates)	Actual	ILU
D02	the time that a loading unit is cancelled	Actual	ILU
D03	the estimated time that a Loading unit starts its journey towards the departure terminal (via truck)	Estimate	ILU
D04	the actual time that a Loading unit starts its journey towards the departure terminal (via truck)	Actual	ILU
D05	the time of verification of physical status of the loading unit prior to the check-in	Actual	ILU
D06	the time that a truck enters the terminal	Actual	ILU
D07	the time the terminal reverses the truck entry (cancellation)	Actual	ILU
D08	the time that a loading unit is unloaded from the truck	Actual	ILU
D09	the time that a loading unit is refused for unloading from the truck	Actual	ILU
D10	Planned time for the wagonset being ready for loading	Plan	Wagonset
D11	The time the loading track is available for the wagonset	Plan	Track
D12	the time that the wagonset is ready for being loaded	Actual	Wagonset
D13	the time that an ILU at the latest must have been received by the terminal for being loaded on a specific train or wagonset (cut-off time)	Plan	ILU
D14	the time when the ILU is loaded on the wagon	Actual	ILU
D15	the time when the train or wagon set must be fully loaded at the latest	Plan	Wagonset
D16	The time when the wagonset must have cleared the loading track	Plan	Track
D17	the time when the train or wagon set is fully loaded according to the planned loading list	Actual	Wagonset
D18	the time that the Consignment note has been generated	Actual	Wagonset
D19	the time that the wagonset must at the latest be handed over to the RU with documents given by the consignor (CTO or its representative/terminal) to the RU	Actual	Wagonset
D20	The time that shunting must at the latest be ended to enable departure of train on time	Plan	Wagonset
D21	Coupling loco and join driver to train	Actual	Wagonset
D22	Planned departure of train terminal/yard time slot	Plan	Wagonset

	(schedule)		
D23	the train is ready to depart from the terminal/yard	Actual	Wagonset
D24	the time that the Consignment note and train list have been generated and exchanged	Actual	Wagonset
D25	the time that the brake test and inspection of a loaded train or wagonset by the RU or its representative is completed	Actual	Wagonset
D26	the time that a train is declared not ready for departure after it was previously considered ready	Actual	Wagonset
D27	the time that the train has been inspected by the RU, is under responsibility of the RU and is ready to start its journey	Actual	Wagonset
D28	the actual time-the train leaves the terminal/yard and starts its journey	Actual	Wagonset
D29	the time that the train leaves the connecting line, enters the handover station and arrives at the (public) network entry point	Actual	Wagonset
D30	the time that the train starts its journey on the public network	Actual	Wagonset

Milestone ID	Description of the milestone	Status	Level
Arriving train			
A01	the time that a train arrives at the network exit point (handover station)	Actual	Wagonset
A02	the time that a train departs from the network exit point (handover station) identified by its Primary Location Code (PLC) towards the terminal/yard of destination identified by its Subsidiary Location Code (SLC)	Actual	Wagonset
A03	the time that the train is planned to arrive at the terminal/yard (regular timetable)	Plan	Wagonset
A04	the time that the train is estimated to arrive at the terminal/yard	Estimate	Wagonset
A05	The time of resource release from train (loco, driver)	Actual	Wagonset
A06	the planned time for pick up of a Loading Unit at arrival terminal (regular timetable)	Plan	ILU
A07	the estimated time that a Loading Unit can be picked up at the arrival terminal (ETP)	Estimate	ILU
A08	the time that a train enters the terminal/yard of destination identified by its Subsidiary Location Code (SLC)	Actual	Wagonset
A09	the time that the train or wagonset is available and ready for handling by the terminal/yard operator	Actual	Wagonset
A10	Start of shunting with wagonset (tractor, driver, staff)	Actual	Wagonset

A11	End of shunting with wagonset (tractor, driver, staff)	Actual	Wagonset
A12	The time that must start at the latest shunting to enable hand over wagonset on time	Plan	Wagonset
A13	The time the wagonset is ready for unloading	Plan	Wagonset
A14	The time the unloading track is ready for the wagonset	Plan	Track
A15	the time that loading units, which have arrived by train, are available for pick-up by a Logistic Service Provider/road haulier	Actual	ILU
A16	the time at which the LSP will estimate to pick up the loading unit	Estimate	ILU
A17	the time that a loading unit is picked up at the destination terminal (actual time of pick-up)	Actual	ILU
A18	The time the unloading of the wagonset needs to be finished at latest	Plan	Wagonset
A19	The time the wagonset has to have cleared the unloading track at latest	Plan	Track

13.1 Template according to Use Case for Collection Workshop Data

Position of the data to be analyzed	*Data*	*Assembly*	*Part*	*Subpart*	*Data to be recorded in the cloud*	*Traceability of property*			*Data owner*	*Data manager*	*TMS access*	*International trafic. TMS data to international trafic*	*SMS access*	*Internationanl trafic. SMS data to international trafic*
						Predictions	*History*	*Last value*						
Low	Wheels status	Wheel	Bogie	Wheelset	Qr				RU	ECM	No	No	Yes	Yes
					Sh									
					Sd									
					Distance between wheels									
					Wheel diameter									
Low	Wheels defects	Wheel	Bogie	Wheelset	Analysis of impact or cracks in the wheel				RU	ECM	Yes	Yes	Yes	Yes
					flats on the wheels									
					Cracks or loosening of material on the tread of the wheel									
Low	Wheel bearings	Wheel	Bogie	Wheelset	Left bearings (IVG side)				RU	ECM	No	No	Yes	Yes
					Right bearings (IVG side)				RU	ECM	No	No	Yes	Yes
Low	Gearbox bearings	Wheelset	Bogie	Wheelset	Gearbox				RU	ECM	No	No	Yes	Yes
Low	Traction Motor bearings	Wheelset	Bogie	Wheelset	Traction motor									
Low	Brake	Bogie	Bogie	Bogie	Brake shoes status				RU	ECM	No	No	Yes	Yes
					Condition of the brake discs									
					brake lining pin									

Position of the data to be analyzed	*Data*	*Assembly*	*Part*	*Subpart*	*Data to be recorded in the cloud*	*Traceability of property*			*Data owner*	*Data manager*	*TMS access*	*International trafic. TMS data to international trafic*	*SMS access*	*Internationanl trafic. SMS data to international trafic*
						Predictions	*History*	*Last value*						
Low	Bogie	Bogie	Bogie	Bogie	Screw condition				RU	ECM	No	No	Yes	No
					knocks or impacts									
Low	Damping	Bogie	Bogie	Bogie	condition of the shock absorbers				RU	ECM	No	No	Yes	No
					Condition of the shock springs									
Medium	Visual condition	Coach	Coach	Coach	Graffiti				RU	ECM	No	No	Yes	No
					Windows									
					Fairing									
					Couplers (Schafenberg)									
					dragging objects									
					Doors									
					Windshield									
Low or High	heat exchangers	Coach	Coach		Dirty or clean				RU	ECM	No	No	Yes	No
Low or high	Air conditioning filters	Coach	Coach		Dirty or clean				RU	ECM	No	No	Yes	No
High	Pantograph	Coach	Coach		Condition carbon strip				RU	ECM	No	No	Yes	Yes
					Pantograph height									

Medium	General data	Coach	Coach		European vehicle number and UIC number				RU	ECM	Yes	Yes	Yes	Yes
					Train lenght									
					Car o wagon weight									
					Axle weight									

Table 34: Template by use case for collection workshop data

*Scope

ECM = Entity in Charge of Maintenance (ECM)

SMS = Safety Managment System

TMS = Train Managment System