Ref. Ares(2024)9271843 - 30/12/2024

Deliverable D11.1
Specification of selected Processes and Communication between applications

Project acronym:	MOTIONAL
Starting date:	01/12/2022
Duration (in months):	46
Call (part) identifier:	HORIZON-ER-JU-2022-01
Grant agreement no:	101101973
Due date of Deliverable:	30/11/2024 (Month 24)
Actual submission date:	30/12/2024
Code:	FP1-WP11-D-HAC-001-01
Responsible/Author:	Rolf Gooßmann (HACON)
Dissemination level:	PU
Status:	Issued

Reviewed: Yes
Reviewers: Martin Vaclavik (AZD)
Martin Joborn (TRV/RISE)

This project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement No 101101973.

Document history		
Revision	*Date*	*Description*
1	10-07-2023	First issue
2	18-07-2024	Version for internal review
3	15-11-2024	Version for official review
4	27-12-2024	Final version

Report contributors		
Name	*Beneficiary Short Name*	*Details of contribution*
Rolf Gooßmann	HACON	Lead author of the document. Main author of chapters 1, 2, 6, 9 and 10. Contributions to all chapters in all versions.
Blanca Delgado	INECO/ADIF	Main author of chapter 7. Contributor to chapter 8. Internal reviewer of the full document.
Zbigniew Dyksy	ATSA	Main author of chapter 5. Contributions to all chapters.
Carmen Ramos	INDRA	Main author of chapter 8. Contributions to all chapters.
Martin Joborn	RISE/TRV	Main author of chapters 3 and 4. Contributions to chapters 8 and 9.
Henrik Teinelund	RISE	Contributions to chapter 9.
Angelo Naselli	MERMEC	Contributions to chapters 7 and 8.
Mirko Ghersi	MERMEC	Contributions to chapters 7 and 8 and minor reviews.

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1. Executive Summary

This report constitutes the deliverable D11.1 *Specification of selected Processes and Communication between applications* of the work package WP 11 *Development - Integration of TMS and processes including cross-border traffic management*. It is based on input from the activities performed in the tasks of WP 11 providing the specification of Use Cases, requirements and interfaces to support and improve the traffic management process facilitated by Traffic Management Systems (TMS) used by the Railway Infrastructure Managers (IM) in Europe. The specifications are used for development and set-up of the demonstrations 12.1 to 12.9 of Workstream 1.2. In this context, it will serve as an input document required for the activities performed in the future WP 12 of the MOTIONAL project and the future activities in the next EU-Rail calls to strive for higher TRL and large-scale demonstrations regarding the Technical Enablers:

- TE 8 Real-time connection of rail networks as managed by TMS and involved actors;
- TE 9 Modelling and decision support for cross-border traffic management; and
- TE 10 Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching.

Within the context of the WP 11, each partner contributed to the writing of deliverable D10.1 by describing a set of high-level Use Cases and high-level requirements for integration of planning systems with other systems including planning systems of neighbouring rail networks. The D10.1 has been used as the starting point for further analysis, and the resulting Use Case description work in WP 11 is documented in this D11.1. Interaction meetings and exchange of material with the System Pillar Task 3 and RNE experts as well as with the Flagship Projects of Destinations 3, 5 and 6 helped to achieve the required alignment level. As a result, one or more Use Cases referring to each high-level Use Case of D3.1 were specified based on further analysis. Similarly functional and non-functional requirements were identified and specified which were mapped against the high-level requirements associated with the Technical Enablers 8, 9 and 10.

Hence, this document represents a detailed study in addition to D2.3 and D10.1 including the basis for the development of the WS 1.2 demonstrations:

- Demo 12.1 (ATSA) - *Interfaces TRL 5 from the communication Platform to the Timetable Management Applications and to the Traffic Control (RBC, Interlocking).*
- Demo 12.2 (PKP) - *Integration solution for the data exchange and storage system (Data Lake) allowing the exchange through interfaces, data quality assessment, and metadata generation. This solution will be used for integrating disparate decision support systems.*
- Demo 12.3 (STS) - *Interface from TMS Planning system to ATO-TS control module to maximise the energy efficiency of the train operation in a short-term action.*
- Demo 12.4 (INDRA) - *Interfaces from the communication Platform to wayside C-DAS operation system, focusing on speed profiles functionalities.*
- Demo 12.5 (MERMEC) - *Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between neighbouring TMS and IM) to provide a TMS and IM real-time connection of rail networks focused on cross border traffic management.*

- Demo 12.6 (HACON) - *TRL 6 interfaces and TRL 5 decision support module for integration and traffic management of two neighbouring TMS and IM including cross-border operations (supporting Destination 5 activities).*
- Demo 12.7 (HACON) - *Interfaces for integration of TMS with other services such as station and yard management systems (supporting Destination 5 activities), digital maintenance systems (supporting Destination 3 activities), Passenger Information Services (supporting Destination 6) as well as electric traction systems and crew/ rolling stock management systems.*
- Demo 12.8 (TRV) - *Interface of TMS to Yard Coordination System 2.0 in Malmö node. Work connects to WP 4.*
- Demo 12.9 (CEIT) - *Interface in view of the future autonomous inspection vehicle for the infrastructure (Destination 3) and its integration with the Intelligent Asset Management System (IAMS). To receive information about asset status and planned interventions and deliver allocated paths to execute inspections and interventions.*

2. Abbreviations and acronyms

Abbreviation / Acronym	*Description*
AIV	Autonomous Inspection Vehicle
API	Application programming interface
ARS	Automatic Route Setting
ATO	Automatic Train Operation
ATO-TS	Automatic Train Operation – Trackside
ATO-OBU	Automatic Train Operation – On-Board Unit
B2B	Business-to-Business
BI	Business Intelligence
CCS	Command and Control System
C-DAS	Connected Driver Assistance System
C-DAS TS	Connected Driver Assistance System – Trackside
C-DAS OB	Connected Driver Assistance System – On-Board
CDM	Common/Canonical Data Model (TMS platform specific)
CI	Common Interface (Telematics TSI)
COM-P	Communication Platform
CSV	Comma-separated values (file format)
CTC	Centralised Train Control
DL	Data Lake
DMPS	Digital Maintenance Planning System
DSS	Decision Support System
DTO	Data Transfer Object
ERJU	Europe's Rail Joint Undertaking
ETA	Expected Time of Arrival
ETD	Expected Time of Departure
ETL	Extracting, Transforming and Loading (Data Lake)
ETS	Electric Traction System (trackside)
FA	Flagship Area (Destination) of Europe's Rail Programme
FP	Flagship Project of Europe's Rail Programme
FRQ	Functional Requirement
GA	Grant Agreement
GDPR	General Data Protection Regulation
GUI	Graphical User Interface
HLR	High-Level Requirement
IAMS	Integrated Asset Management System (ERJU Destination 3)
IL	Integration Layer (developed in Technical Demonstrator TD 2.9 of Shift2Rail)
IM	Infrastructure Manager (Rail)
IP	Innovation Programme (Shift2Rail)
JP-SP	Journey Profile - Segment Profile (ATO-TS, C-DAS TS)
JSON	JavaScript Object Notation
MAWP	Multi Annual Work Programme

MP	Mission Profile
MSD	Message Sequence Diagram
NFRQ	Non-functional Requirement
OBU	On-Board Unit
OMA	Open Mobile Alliance (*https://www.openmobilealliance.org/*)
RBC	Radio Block Centre
RCA	Reference CCS Architecture
REST	Representational State Transfer
RNE	RailNetEurope
RTTP	Real-Time Traffic Plan
RU	Railway Undertaking
S2R	Shift2Rail
S-DAS	Stand-alone Driver Advisory System
SG	Sub-Group
SP	System Pillar
SR	Status Report (C-DAS)
SW	Software
TAF/TAP TSI	Technical Specification for Interoperability, Application Freight/Passenger (Renamed in 2024 to *Telematics TSI*)
TC	Train Characteristics (C-DAS)
TCCS	TMS/TCS data model specified by the System Pillar.
TCR	Temporary Capacity Restriction
TD	Technical Demonstrator (Shift2Rail)
TE	Technical Enabler
TIS	Train Information System (RNE)
TM	Traffic Management
TMS	Traffic Management System
TRL	Technical Readiness Level
TSI	Technical Specification for Interoperability
TTR	Timetable Re-design (RNE)
UC	Use Case
UML	Unified Modelling Language
UI	User Interface
WP	Work Package
WS	Work Stream
YCS	Yard Coordination System
XML	Extensible Markup Language

3. Background

The present document constitutes the Deliverable *D11.1 "Specification of selected Processes and Communication between applications"* in the framework of the Flagship Project 1 – [MOTIONAL], part of the EU-RAIL programme described in the EU-RAIL MAWP[1]. This deliverable is based on the outcome of tasks T11.1, T11.2 and T11.3 from Work Package (WP) 11 "Integration of TMS and processes including cross-border traffic management". It is setting up specifications and requirements for innovations in the integration of TMS with other systems and with neighbouring TMS systems. The development work made in WP 11 is followed by work package WP 12 in which the developments in WP 11 will be demonstrated.

Within the framework of the Innovation Pillar FP 1: "Network management planning and control & Mobility Management in a multimodal environment and digital enablers" (MOTIONAL) of Europe's Rail Joint Undertaking (ERJU), WP 11 focuses on the integration of TMS systems with other TMS-systems, particular in cross-border settings, and also with other systems. The TMS-system is the heart and brain of railway operations. The improved integration of TMS with surrounding systems is expected to increase the smoothness and efficiency of railway operations in several different ways, like better handover at borders, better connections to train drivers via C-DAS, improved yard operations, and several other aspects.

This deliverable document includes Use Cases that are related to the topic, i.e., the integration of TMS with other systems. Further, it includes a specification of processes and communication requirements related to the overall topic.

[1] https://rail-research.europa.eu/wp-content/uploads/2022/03/EURAIL_MAWP_final.pdf

4. Objective/Aim

The aim of this document is to report the results from Work Package 11 (WP 11) of the Europe's Rail project FP1-MOTIONAL. In short, the scope of the document includes reporting and documenting the Use Cases, interfaces, and process requirements that are related to the WP's development work for Technical Enablers (TE) 8, 9 and 10. These are dedicated to deliver future railway processes and solutions supporting seamless cross-border traffic management and an improved basis for decision support through integrated systems/modules.
The main input to the document is the output from Task 11.2, and its main objective is to present the specification of processes and communication requirements with regards to data elements needed for an interoperable data exchange addressed within the work package. The documented specifications are paving the way for related development of prototypes and demonstrations in the succeeding work package WP 12.

As stated in the GA, the overall objectives of WP 11 are linked to Technical Enablers 8, 9 and 10 covering specification, and development of use-cases, processes and interfaces needed to achieve a much higher integration level of functions and decision processes including increase of the precision of the traffic prediction. In focus are also the alignment between different TMS areas including cross-border and integration of TMS with yard/station and trackside energy management systems as well as crew and rolling stock planning and management systems. The specification and development of appropriate interfaces between the different clients and stakeholders and applications will help to support an aligned re-planning and management of platform track/parking/facility track allocation of trains including graphical visualisation, conflict detection and resolution. The new possibilities will increase the interests and the level of engagement of RUs in traffic operation.

The developments regarding Technical Enablers 8, 9 and 10 as part of WP 11 should achieve TRL 4.

The WP 11 activities aim to address and contribute to a harmonised cross-border traffic management supported by the future European TMS by specifying and integrating/developing interoperable processes and interfaces between TMS and other resource management systems including other TMS, containing all necessary information to execute efficient cross-border traffic. This includes:

- Cross borders within and between IMs
- Coherence with short term planning activities
- Incidents and disruption management for cross-border traffic
- Integration of TMS with train control
- Integration of TMS with yard and station management systems
- Integration of TMS with trackside Electric Traction Systems (ETS)
- Integration of TMS with rolling stock and crew scheduling

5. Introduction

Within the framework of the Innovation Pillar FP 1: "Network management planning and control & Mobility Management in a multimodal environment and digital enablers" (MOTIONAL) of the Europe's Rail Joint Undertaking (ERJU), Work Package (WP) 11 focuses on the specification and development of appropriate interfaces between the different clients and stakeholders and applications supporting aligned re-planning and management of platform track/parking/facility track allocation of trains including graphical visualisation, conflict detection and resolution. The new possibilities will increase the interests and the level of engagement of RUs in traffic operation.

The goal of an overarching System Pillar is to deliver a safe and secure standardised European railway architecture – towards this goal the System Pillar steers the Innovation Pillar by providing architectural and operational concepts in terms of high-level requirement specifications. Under the guidance of the System Pillar, the Innovation Pillar develops desired new technologies and, when appropriate, also delivers more refined requirement specifications. The results of the Innovation Pillar feed back into the System Pillar, thereby informing, and possibly adapt, the work of the System Pillar.

Within this context, in WP 11 new requirements were developed for integration of TMS systems with other systems and related processes taking existing TSI as e.g., Telematics TSI, or European railway harmonisation documents such as RNE Handbooks into account.

WP 11 covers the following technical enablers (TE) from the Multi-Annual Work Programme (MAWP) of the ERJU:

- Technical Enabler 8 (TE 8): Real-time connection of rail networks as managed by TMS and involved actors [TRL4].
- Technical Enabler 9 (TE 9): Modelling and decision support for cross-border traffic management [TRL 4].
- Technical Enabler 10 (TE 10): Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching [TRL4].

WP 11 consists of the three tasks T11.1, T11.2 and T11.3. Formally, the Tasks of WP 11 are described as[2]:

Task 11.1: Alignment of development

This task focusses on the alignment of the technical specifications and the development of the prototypes to secure interoperability. In addition, all activities related to dissemination, overall reporting of the status of the Work Package and the alignment with other projects and work packages are part of the activities of this WP.

Task 11.2: Specifications

This task comprises all activities required to generate detailed specifications for the prototype applications/systems/interfaces needed for the demonstrators developed in this work package. The specification is based on the related high-level requirements and Use Cases delivered by WP 10, and the alignment activities of Task 11.1. Inputs from the related activities of Shift2Rail are considered.

[2] As formulated in the Grant Agreement.

Task 11.3: Development of prototypes TRL 4

This task comprises all activities to develop and test prototypes TRL 4. (Task 11.3 consists of nine subtasks, in which each partner's development work is performed).

The following chapters are based on the input of Tasks 11.1, 11.2 and 11.3 of WP 11, in which new requirements including Use Cases for TE 8, 9 and 10 were developed. The development of the requirements was guided by a set of high-level requirements and related descriptions previously obtained in WP 10 (Task 10.1) in which high-level specifications for TE of WP 11-WP 18 were developed for Workstream 1.2: "Operations" of MOTIONAL. The high-level Use Cases from WP 10 are also used as starting point.

6. Methodology

The aim of this chapter is to give confidence to the reader that the requirements and Use Cases presented in chapter 7 and chapter 8 are aligned with the MOTIONAL GA and in line with the work in the rest of the MOTIONAL project. A detailed overview of how the requirements and Use Cases delivered in this report were developed, is presented.

The chapter starts with a description of the mapping of high-level requirements and their links to WP 12 demonstrations, a work mainly performed within WP 10. The high-level requirements are further specified and clarified in more detailed Use Cases and requirements, which is described in chapter 6.3. The chapter ends by describing the review phase.

6.1. Mapping of High-Level Requirements

In the MOTIONAL GA, 10 Technical Enablers (TE) are linked to the Workstream 1.2 *Increased resilience of a connected 'real time' rail network* related work packages WP 11/WP 12, WP 13/WP 14, WP 15/WP 16 and WP 17/WP 18. The Technical Enablers relevant for WP 11/WP 12 are:

- TE 8: Real-time connection of rail networks as managed by TMS and involved actors.
- TE 9: Modelling and decision support for cross-border traffic management.
- TE 10: Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching.

In WP 10, the TE were further described and specified. High-level requirements (HLR) were also set up for each TE with the purpose to describe in which areas progress was to be expected for WPs 11-18. The HLR for TE 8, TE 9 and TE 10 are presented here. For other HLR and a further description of the Technical Enablers, see deliverable D10.1.

For assignment of the High-Level Requirements identified in WP10 to the required demonstrations in WP 11/12, contribution was given to WP 10 after detailed assessment and discussion of partners involved in the WP 11 demonstrations. The mapping table resulting from WP 10 and documented in D10.1 was used as a basis for organisation and scope-detailing in WP 11 which itself was fed back to WP 10 to support the specification work for High-Level Use Cases.

6.1.1. High-Level Requirements for TE 8

Regarding TE 8: Real-time connection of rail networks as managed by TMS and involved actors:

HLR 8.1: An enhanced, standardised communication between TMS and subsystems in the area of Train Control including ATO-TS and C-DAS.

HLR 8.2: An integrated forecast information for the IMs' TMS for capacity production.

HLR 8.3: The RFC management with a transparent view of capacity usage on track and signalling level.

HLR 8.4: Input to harmonised operational rules or paradigms for integration of national traffic management systems.

HLR 8.5: Visibility of TCR behind the area border to pre-align traffic management decisions.

All HLR 8.1-8.5 are addressed in WP 11/WP 12.

6.1.2. High-Level Requirements for TE 9

Regarding TE 9: Modelling and decision support for cross-border traffic management:

HLR 9.1: A TM process which is compliant with international ad-hoc path (re-)planning process in line with TTR.

HLR 9.2: The capability for harmonised/integrated cross-border alignment of traffic management decisions on track/signalling level (routing, timing, conflict detection and resolution, TCR related train regulation).

HLR 9.3: Delivering input to harmonised operational rules or paradigms for coordination process in national traffic management systems.

HLR 9.4: Capability to pre-align traffic management decisions based on TCR or disruptions visible behind the border.

All HLR 9.1-9.4 are addressed in WP 11/WP 12.

6.1.3. High-Level Requirements for TE 10

Regarding TE 10: Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching:

HLR 10.1: For interfacing with yards and stations,

- Extend data exchange with terminals, ports and freight forwarders to provide relevant data for customers
- Use, where applicable, TAF/TAP TSI compliant interfaces
- Receive from yard/station capacity planning and management
  - track reservations (stabling, parking, ...)
  - yard delays and consist/consist changes or Rolling Stock limitations
  - track assignment changes for trains
  - shunting activities with impact on lines
- Send to yard/station capacity planning and management
  - updated train running forecast
  - updated Operational Plan

HLR 10.2: For interfacing with asset/maintenance planning and management systems

- Receive from infrastructure maintenance planning system
- Updated capacity restrictions in conjunction with planned maintenance activities
- Send to infrastructure maintenance planning system
  - updated train running forecast
  - updated Operational Plan
- Receive from asset management system
  - asset status information
- Send to asset management system
  - updated train running forecast
  - updated Operational Plan

HLR 10.3: For interfacing with electric traction system components

- Receive from electric traction system real-time simulator
  - electric power restrictions
- Send to electric traction system real-time simulator
  - updated train running forecast
  - updated Operational Plan

HLR 10.4: For interfacing with real-time crew / rolling stock dispatching systems

- (If integration with crew dispatching system and crew data is available to IMs,) receive from crew dispatching systems
  - crew links indicating train crew exchanges at stations for trains in the Operational Plan
  - crew information and qualification
- Receive from rolling stock dispatching systems
  - rolling stock links indicating re-use of rolling stock material at stations for trains in the Operational Plan
  - rolling stock information and qualification
- Send to crew/rolling stock dispatching system
  - updated train running forecast
  - updated Operational Plan

All HLR 10.1-10.4 are addressed in WP 11/WP 12.

6.2. Links to Partner Demonstrations

With HLR specified and assigned to each work package, each HLR was mapped to one or several demonstrations. In WP 11/WP 12, there are 10 demonstrations planned, which together shall address all HLR for WP 11/WP 12. Some requirements are included in only one demonstration, while other requirements are addressed in several demonstrations. The reason for this is that even if a demonstration is set up for a specific HLR, it may also fulfil others just to get the demonstration working for its main purpose. Some HLR are also written relatively vague, which allows multiple demonstrations fulfilling them. One example is HLR 8.1, where the demonstration should provide a*n enhanced, standardised communication between TMS and subsystems in the area of Train Control including ATO-TS and C-DAS*, which a couple of the demonstrations in WP 11/ 12 intend to do. The HLR is fulfilled at the same time by different demonstrations in relation to different Use Cases and/or requirements of the same HLR.

Table 1 below shows an overview of which demonstrator addresses which HLR.

Demos WS 1.2		**Mapping demos-TE-HLR**		**Mapping Use Cases- TE - HLR**		
No	**Partner**	**TE**	**HLR**	**Use case ID**	**TE**	**HLR**
12.1	ATSA	8, 10	8.1, 8.2, 10.2, 10.3	FP1-DEMO-12.1-UC-01	8	8.1
				FP1-DEMO-12.1-UC-02	8	8.1
				FP1-DEMO-12.1-UC-03	8, 10	8.2, 10.2, 10.3

12.2	PKP	9	9.4	FP1-DEMO-12.2-UC-01	9	9.4
12.3	STS	8	8.1	FP1-DEMO-12.3-UC-01	8	8.1
12.4	INDRA	8	8.1	FP1-DEMO-12.4-UC-01	8	8.1
12.5	MERMEC	8, 9	8.5, 9.2, 9.4	FP1-DEMO-12.5-UC-01	8,9	8.5, 9.2, 9.4
				FP1-DEMO-12.5-UC-02	8,9	8.5, 9.2, 9.4
12.6	HACON	8, 9	8.2, 8.3, 8.4, 8.5, 9.1, 9.2, 9.3, 9.4	FP1-DEMO-12.6-UC-01 (ADIF)	8,9	8.5, 9.2, 9.4
				FP1-DEMO-12.6-UC-02	8	8.2, 8.3, 8.4,
				FP1-DEMO-12.6-UC-03	8,9	8.4, 8.5, 9.1, 9.2, 9.3, 9.4
12.7	HACON	10	10.1, 10.2, 10.3, 10.4	FP1-DEMO-12.7-UC-01	10	10.2
				FP1-DEMO-12.7-UC-02	10	10.1
				FP1-DEMO-12.7-UC-03	10	10.1
				FP1-DEMO-12.7-UC-04 (ADIF)	10	10.1
				FP1-DEMO-12.7-UC-05 (ADIF)	10	10.1
				FP1-DEMO-12.7-UC-06	10	10.1
				FP1-DEMO-12.7-UC-07	10	10.1
				FP1-DEMO-12.7-UC-08	10	10.3
				FP1-DEMO-12.7-UC-09	10	10.3
				FP1-DEMO-12.7-UC-10	10	10.4
				FP1-DEMO-12.7-UC-11	10	10.4
				FP1-DEMO-12.7-UC-12	10	10.4
				FP1-DEMO-12.7-UC-13	10	10.4
12.8	TRV	10	10.1	FP1-DEMO-12.8-UC-01	10	10.1
				FP1-DEMO-12.8-UC-02	10	10.1
12.9	CEIT	10	10.2	FP1-DEMO-12.9-UC-01	10	10.2
				FP1-DEMO-12.9-UC-02	10	10.2
				FP1-DEMO-12.9-UC-03	10	10.2

Table 1: Mapping of the demonstrations and assigned Use Cases and HLR

For each partner demonstration in WP 11/12, the assigned high-level requirements and Use Cases have been analysed to feed the process of creating initial demonstrator descriptions as provided to WP 10 for the preparation of the D10.1.

6.3. Specification Process

The activities in WP 11 were based on the work of WP 10 where sources in previous international projects dealing with TMS development and integration and the trends of the market for such type of projects have been identified and initially assessed. As a result, high-level Use Cases and high-level designs for future TMS enhancements to be demonstrated in WP 11/12 have been described and documented in the deliverable D10.1. The D10.1 has been used as the starting point for further analysis and the resulting specification work in WP 11 being documented in this report.

6.3.1. Use Case specification

With mapped HLR and TE, the next step in WP 10 was to formulate high-level Use Cases for each demonstration to exemplify which problem the demonstration is meant to solve and to explain the demonstration in more detail. The high-level Use Cases were provided for each demonstration in D10.1. In WP 11, these have been further specified in D11.1, chapter 7 to gain one or multiple, more detailed Use Cases. Each Use Case describes inter alia, which partner(s) is/are performing the demonstration, relationships to other tasks/flagships, affected actors and involved components. It also describes technical implementation aspects as e.g., Use Case trigger, pre-conditions, input, sequence steps, result and final state.

In WP 11/12, there are 29Use Cases in total.

6.3.2. Requirement specification

Each HLR was detailed in D11.1 into one or several requirements, which are shown in chapter 8. Each requirement describes a specific capability that is crucial for meeting an aspect of a HLR of each demonstration supporting its associated Use Cases. The requirements can be either functional or non-functional, however, most of them are functional requirements with respect to targeted TRL 4 in WP 11.

To gain a suitable structure and overview, all requirements use the same template with pre-defined headlines. The headlines are *ID*, *Requirement*, *Type*, *Priority*, *Main goal*, *Assumptions*, *Specifications*, *Additional information and background*. The requirements are grouped by Subtask in Task 11.3 (i.e., demonstration). In each demonstration in WP 5, there will be an evaluation to check if all requirements are met and consequently also if the HLRs are met.

In total, there are 70 functional and 16 non-functional requirements specified in WP 11/12.

6.4. Alignment with other Work Packages, Flagship Projects and the System Pillar/RNE

The project partners contributing to the specification work in WP 11 have been also active in WP 10 and partially in WP 3 for high level assessment and scoping of the demonstrations which has led to an overall alignment between the Work Packages of the MOTIONAL Project's WS 1.1 and 1.2. The alignment with other MOTIONAL WS and other Flagship projects such as FP3-IAM4RAIL and FP5-TRANS4M-R of the EU-Rail program has been achieved through the interactions process managed and steered by the Work Package 2 (Technical Management).

Regular alignment meetings with System Pillar (SP) and RailNetEurope (RNE) focusing on cross-border, TMS process harmonisation and ATO/C-DAS topics supported the alignment with existing or upcoming standardised or harmonised specifications or descriptions e.g., SP Deliverables, TSI or RNE Handbooks available at that time. For relevant results, input has been provided to the TSI Input Plan via WP 2 in correlation to the System Pillar and its sector-level standardisation or harmonisation activities.

6.5. Data elements needed for an interoperable data exchange addressed within the work package

In WP 11, the data elements required by the WP 11/WP 12 demonstrations to allow an interoperable data exchange were collected and provided to Task 10.3. They are made available through the deliverable D10.2. This activity supports the interoperability between the demonstration systems or components of the partners to allow large scale demonstrations at later project waves. The interoperability is enabled via SP results with respect to the TCCS data model development process maintained in the SP, see (MOTIONAL D10.2) for more details.

7. Use Cases

The Task 11.2 comprises all activities required to generate more detailed specifications for the prototype applications/systems/interfaces needed for the demonstrators developed in WP 11. The specification is based on the related high-level requirements and Use Cases delivered by WP 10, and the alignment activities of Task 11.1.

In this chapter of the document the Use Cases associated with the WP 11 relative to integration of TMS and processes including cross-border traffic management are defined and collected, which are relevant for the definition and specification of the developments and demos linked to WP 11 and WP 12.

For the high-level Use Cases of WP 10, only the high-level fields of the WP 2 Use Case template were used (see chapter 7 of deliverable D10.1 for additional information). As part of WP 11 activities, the WP 10 high-level Use Cases are detailed, filling in all the fields proposed in the WP2 Use Case template (both high-level fields and detailed fields). To complete the information and improve the understanding of the Use Case description, a complementary field is added in all of them, named "Diagram", where it is intended to include a diagram(s) illustrating the sequence of steps (actions) which specifies the Use Case and its underlying process.

The Use Cases already covered/developed or under development by RNE are not part of the scope of the Use Cases included here.

In the Table 2 below the WP 2 template defined for providing the Use Cases in the MOTIONAL project is shown. In addition to the WP 2 template, two new fields were added: "Demo associated" and "Diagram(s)". This template is the one used to provide the description of each Use Case linked to "WP 11 - integration of TMS and processes including cross border".

Use Case ID	***FP1-DEMO-<demo number>-UC-<Use Case number>***
Name	*Descriptive Name of the Use Case*
Partner	*Abbreviation of partner (according to GA) who originated the UC*
Demo associated	*Demonstration no. according to the demonstrations table in the GA*
Description	*Short description of the Use Case*
Related to task/subtask(s)	*Precise task/subtask that this Use Case relates to (specification/implementation/demonstration)*
Impact on other task(s)	*Indicate tasks that may depend on the results of this Use Case (dependencies identification)*
Technical Enabler(s)	*Indicate TE involved "Nr-Name"*
Interactions SP/FP	*Indicate when applicable the interactions with the System Pillar or other Flagship Projects*
Actor(s)	*Involved actors (active and passive ones)*
Trigger	*Action or event that trigger the Use Case*
Pre-Condition(s)	*Preconditions of the Use Case / what is the state of the system, which allows to perform the Use Case*
Input	*Required input to execute the Use Case*

Result/Requirement	*What will be the expected result of the Use Case*
Final State	*If applicable describe the expected final state of the system after the Use Case was performed*
Sequence	*List steps of the Use Case (to be filled during specification phase)* 1. *Step x* 2. *Step y* 3. *Step z*
Diagram(s)	*One or more diagrams (preferably UML) illustrating the Use Case and its underlying process*
Expected Implementation Date	*Date when the UC is expected to be ready for tests (Month Year)*
Involved components (System)	*List the software/hardware components that will be involved to run the Use Case (to be filled during specification phase)*
Responsible partner/person	*Company and Main contact who is responsible to describe this Use Case and guarantee the system design and implementation*
Notes	*Additional notes for the Use Case*

Table 2: Template for the definition of the Use Cases

This chapter is subdivided into different subchapters linked to each of the subtasks that constitute task 11.3 "Development of prototypes". These subtasks in turn are associated with each of the developments covered in WP 11.

At the beginning of each sub-chapter, a brief description of the development to be covered is included to put into context the Use Cases.

In Table 3 the Use Cases covered by WP 11 are listed, tracing them with the specific subtask of task 11.3 associated and the link to the location in the document where the Use Case can be found.

Subtask of task 11.3	Partner	Use Case ID	Title
Subtask 11.3.1	ATSA	bookmark:// UC-FP1-WP10-01 – Information/FP1-DEMO-12.1-UC-01	Information exchange for Automatic Route Setting (ARS)
		bookmark:// UC-FP1-WP10-02 – Information/FP1-DEMO-12.1-UC-02	Information exchange for Monitor & Control Train
		bookmark:// UC-FP1-WP10-03 – Monitor/FP1-DEMO-12.1-UC-03	Monitor & control the field elements
Subtask 11.3.2	PKP	bookmark:// Use Case 2.1/FP1-DEMO-	Support for trans-border travel related decisions for station operator

		12.2-UC-01	
Subtask 11.3.3	STS	bookmark:// UC-FP1-WP10-05 – Detail/FP1-DEMO-12.3-UC-01	Detail train timetable for energy saving, ATO-TS
Subtask 11.3.4	INDRA	bookmark:// UC-FP1-WP10-06 – Information/FP1-DEMO-12.4-UC-01	Information exchange between TMS and C-DAS TS
Subtask 11.3.5	MERMEC	bookmark:// UC-FP1-WP10-07 – Cooperative/FP1-DEMO-12.5-UC-01	Cooperative conflict resolution (Two TMS)
		bookmark:// UC-FP1-WP10-08 – Exchanging/FP1-DEMO-12.5-UC-02	Exchanging real time train data regarding the border stations
Subtask 11.3.6	ADIF	bookmark:// UC-FP1-WP10-09 – Short-term/FP1-DEMO-12.6-UC-01	Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts
	HACON	bookmark:// UC-FP1-WP10-10 – Sending/FP1-DEMO-12.6-UC-02	Sending and Receiving train running forecast information
	HACON	bookmark:// UC-FP1-WP10-11 – Pre-aligned/FP1-DEMO-12.6-UC-03	Pre-aligned decisions cross-border
Subtask 11.3.7	HACON	bookmark:// UC-FP1-WP10-12 – Consider/FP1-DEMO-12.7-UC-01	Import and handling of a TCR
	HACON	bookmark:// UC-FP1-WP10-13 – Train/FP1-DEMO-12.7-UC-02	Provision and handling of TMS Operational Plan changes in the Yard Management System
	HACON	bookmark:// UC-FP1-WP10-14 – Planning/FP1-DEMO-12.7-UC-03	Receipt and handling of Yard Capacity Plan changes in the TMS
	ADIF	bookmark:// UC-FP1-WP10-14 – Planning/FP1-DEMO-12.7-UC-04	Train running forecast of the TMS improved by integration of TMS with systems and processes related to yard or station management
	ADIF	bookmark:// UC-FP1-WP10-14 –	Planning and/or management of systems and processes using information received from the TMS

		_Planning/FP1-DEMO-12.7-UC-05	
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-06	Provision and handling of TMS Operational Plan changes in the Station (Depot) Management System
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-07	Receipt and handling of Station (Depot) Capacity Plan changes in the TMS
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-08	Provision and handling of TMS Operational Plan changes in the Electric Traction System (ETS) performing the trackside Energy Management
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-09	Receipt and handling of train related energy restrictions in the TMS
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-10	Consideration of crew links reflecting train crew exchanges between trains at stations
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-11	Consideration of crew information
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-12	Consideration of rolling stock links reflecting train rolling stock exchanges between trains at stations
	HACON	bookmark:// UC-FP1-WP10-14 – _Planning/FP1-DEMO-12.7-UC-13	Consideration of rolling stock information
Subtask 11.3.8	TRV	bookmark:// UC-FP1-WP10-15 – _Sending/FP1-DEMO-12.8-UC-01	Sending and Receiving track allocation information between TMS and YCS
		bookmark:// UC-FP1-WP10-16 – _Notifying/FP1-DEMO-12.8-UC-02	Notifying TMS and YCS operators about disruptions and requests
Subtask 11.3.9	CEIT	bookmark:// UC-FP1-WP10-17 – _IAMS/FP1-DEMO-12.9-UC-01	IAMS-AIV interface
		bookmark:// UC-	TMS-IAMS, IAMS-AIV interface

		FP1-WP10-17_–_IAMS/FP1-DEMO-12.9-UC-02	
		bookmark://_UC-FP1-WP10-17_–_IAMS/FP1-DEMO-12.9-UC-03	TMS-IAMS, IAMS-AIV, TMS-AIV interface

Table 3: WP 11 Use Cases list

7.1. Use Cases for Subtask 11.3.1 (ATSA)

The demonstration no. 12.1 in WS 1.2 “Operations” is focused on designing the integration between Timetable Management Application (TMS system) and Traffic Control (CTC system) over Communication Platform.

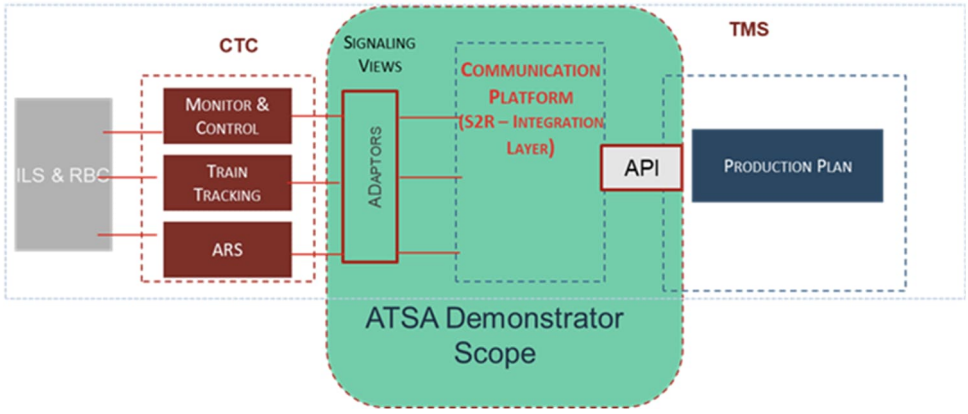


Figure 1: ATSA Demonstrator Scope

Figure 1 shows the systems involved in the integration:

- TMS class system with the Timetable Production Plan function
- CTC class system with functions
  - Monitor & Control
  - Train Tracking
  - Automatic Route Setting (ARS) providing information from Interlocking & RBC systems
- Communication Platform – being ATSA implementation of S2R Integration Layer concept developed mainly in X2Rail-2 and X2Rail-4 projects, see (X2Rail-2 D6.1) and (X2Rail-4 D9.1).

The demonstrator focuses on delivery the Communication Platform API and proper adaptors to communicate mentioned above systems.

The integration involves two scenarios:

- TMS Production Plan delivery as the input for CTC class system operations to perform ARS operations.
- Sending real-time information from CTC (including interlocking & RBC info) to TMS influencing planning and decision support.

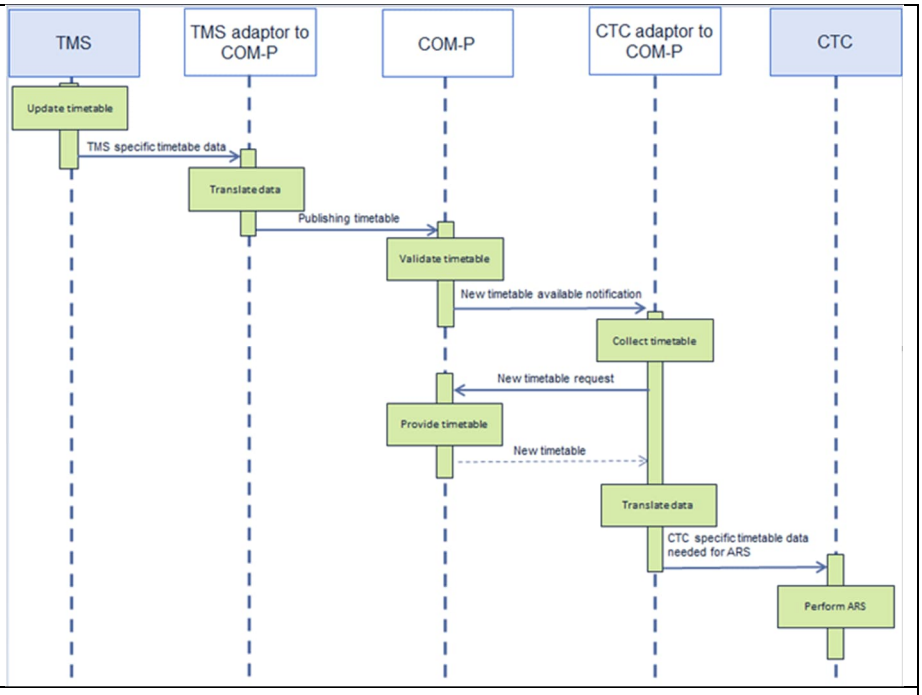
Within this subtask, COM-P interfaces are provided to allow:

- Publishing TMS the operational timetable on COM-P and receiving it in the CTC system.
- Publishing by the CTC system the train status information on COM-P and receiving it in the TMS.
- Publishing the restrictions information (in a form of unavailability info) by the CTC system to COM-P and receiving it in the TMS.

The details of the proposed scenarios are presented in the following chapter.

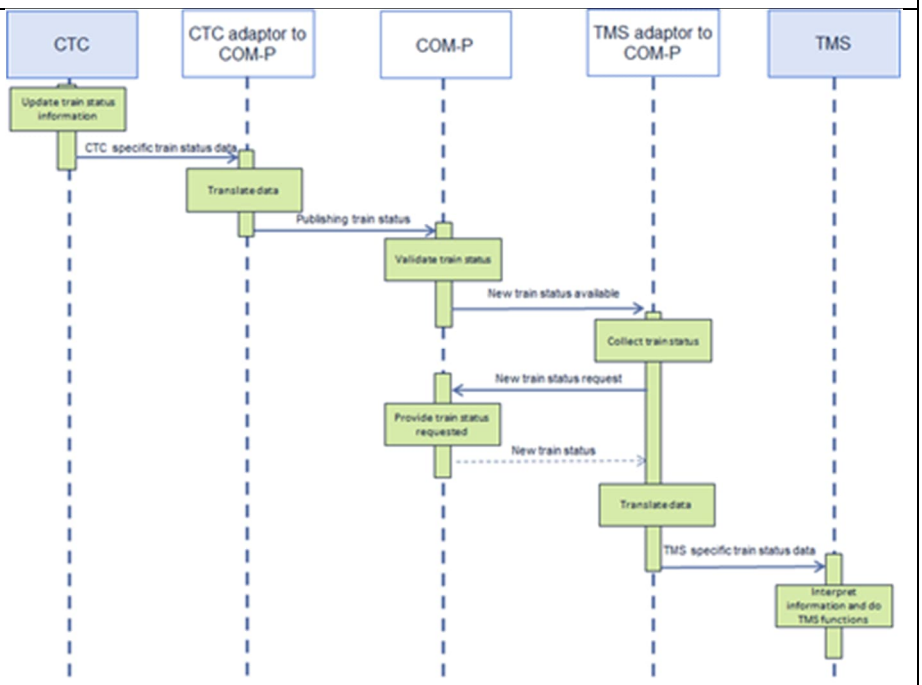
7.1.1. FP1-DEMO-12.1-UC-01 – Information exchange for Automatic Route Setting (ARS)

Use Case ID	**FP1-DEMO-12.1-UC-01**
Name	Information exchange for Automatic Route Setting (ARS)
Partner	ATSA
Demo associated	Demo 12.1 (task 12.2.1)
Description	Communication between TMS providing the trip info via Communication Platform (COM-P) and the CTC System to set the route in the automatic way (ARS). The TMS constantly updates the operational Timetable (TT) on the COM-P adopting it to the changing traffic situation. CTC System uses it to set routes for individual trains in the automatic way based on the trip info out of operational TT taking it from COM-P.
Related to task/subtask(s)	Tasks 11.3.1, 12.2.1
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors".
Interactions SP/FP	SP Interaction
Actor(s)	Initiator: TMS / TMS Operator. Other systems involved: CTC System, Communication Platform (COM-P).
Trigger	TMS publishes new or updated operational Timetable on COM-P
Pre-Condition(s)	All involved systems operate on the same railway area (infrastructure / topology information aligned)
Input	Infrastructure / topology information aligned between TMS, CTC System and COM-P
Result/Requirement	• CTC System is notified by COM-P each time when new/ updated operational Timetable will be provided. • CTC can take the new/updated timetable and continue operation according to it.
Final State	CTC System operates according to new received timetable
Sequence	1. The operational timetable including trips of many trains is being published by the TMS on Communication Platform 2. All registered subscribers (including CTC System) of timetable information are notified about timetable change. 3. The CTC System takes decision if the change is important from its perspective and specify filter criteria to indicate which part of the whole timetable needs to be taken from COM-P. 4. CTC System continues operation (in particular ARS) according to new / modified timetable.

Diagram(s)	
Expected Implementation Date	04 2024
Involved components (System)	• TMS – ATSA TMS system, • CTC – ATSA CTC system, • COM-P – ATSA implementation of S2R Integration Layer concept.
Responsible partner/person	ATSA/Zbigniew Dyksy
Notes	None

7.1.2. FP1-DEMO-12.1-UC-02 – Information exchange for Monitor & Control Train

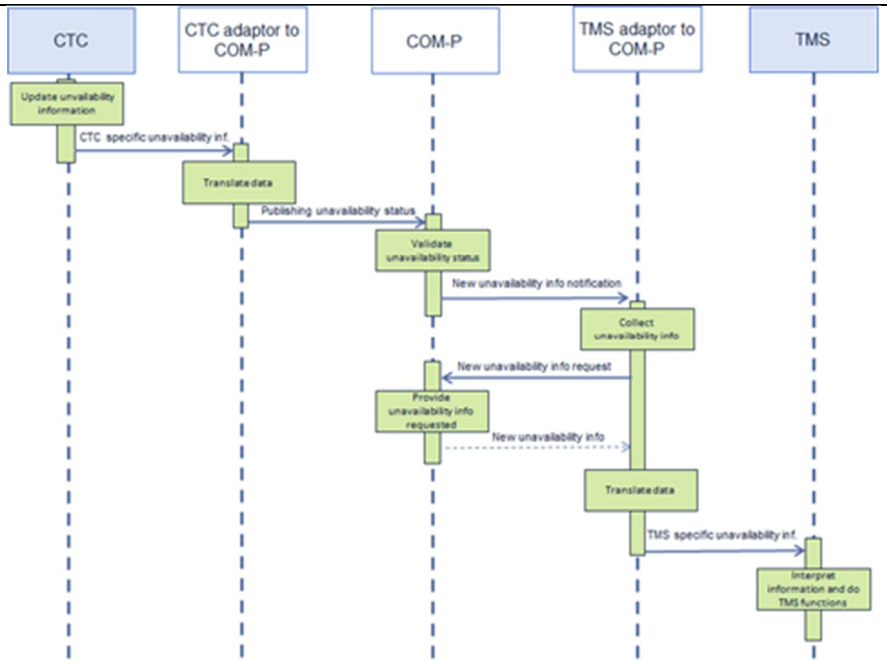
Use Case ID	**FP1-DEMO-12.1-UC-02**
Name	Information exchange for Monitor & Control Train
Partner	ATSA
Demo associated	Demo 12.1 (task 12.2.1)
Description	Communication between CTC System providing interlocking / RBC info about train to the TMS system via the Communication Platform (COM-P). CTC System publishes constantly train status information originated from Interlocking / RBC on Communication Platform. TMS accesses Communication Platform and uses this information to optimise operational timetable.
Related to task/subtask(s)	Tasks 11.3.1, 12.2.1
Impact on other task(s)	None

Technical Enabler(s)	TE 8 - “Real-time connection of rail networks as managed by TMS and involved actors”.
Interactions SP/FP	SP interaction
Actor(s)	Initiator: CTC System that receives information from Interlocking/RBC. Other systems involved: TMS, Communication Platform (COM-P).
Trigger	CTC System publishes new train status information on COM-P.
Pre-Condition(s)	All involved systems operate on the same railway area (infrastructure / topology information aligned).
Input	Infrastructure/topology information aligned between TMC, CTC System and Communication Platform (COM-P).
Result/Requirement	TMS system is notified about new train status. TMS can process this information for its internal usage (for example updating the operational timetable).
Final State	TMS operates having new train status.
Sequence	While the train moves, the CTC System publishes periodically the train status information on the Communication Platform (COM-P). Information is stored on COM-P. Registered subscribers are notified about updated train status by COM-P. The information is processed, and the Operational Plan is updated if applicable by the TMS.
Diagram(s)	
Expected Implementation Date	06 2024
Involved components (System)	• TMS – ATSA TMS system, • CTC – ATSA CTC system,

	• COM-P – ATSA implementation of S2R Integration Layer concept.
Responsible partner/person	ATSA/Zbigniew Dyksy
Notes	None

7.1.3. FP1-DEMO-12.1-UC-03 – Monitor & Control the field elements

Use Case ID	**FP1-DEMO-12.1-UC-03**
Name	Monitor & control the field elements
Partner	ATSA
Demo associated	Demo 12.1 (task 12.2.1)
Description	Information about limitations available on Communication Platform (COM-P) are provided to TMS system. The CTC System publishes unplanned unavailability information of the railway infrastructure element on COM-P. The unavailability information is delivered by COM-P to the TMS which is able to take it and perform proper actions (example: change the route of one or more trains affected by the unavailability of the infrastructure element).
Related to task/subtask(s)	Tasks 11.3.1, 12.2.1
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors". TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching".
Interactions SP/FP	SP interaction
Actor(s)	Initiator: CTC System. Other systems involved: TMS, Communication Platform (COM-P).
Trigger	CTC system publishes unplanned unavailability information.
Pre-Condition(s)	All involved systems operate on the same railway area (infrastructure / topology information aligned).
Input	Infrastructure/topology information aligned between TMC, CTC System and COM-P.
Result/Requirement	TMS is notified by COM-P each time when new/ update unavailability information will be provided. TMS can receive it and take proper actions related to the information.
Final State	TMS operates including unavailability information.
Sequence	1. The CTC System publishes on the Communication Platform information about unavailability of the infrastructure

	element. It can be a switch, track circuit, signal or other. 2. All registered subscribers are notified about the new limitation defined and take proper actions. 3. The TMS uses the information and changes the route of one or more trains affected by the unavailability of the infrastructure element.
Diagram(s)	
Expected Implementation Date	08 2024
Involved components (System)	• TMS – ATSA TMS system, • CTC – ATSA CTC system, • COM-P – ATSA implementation of S2R Integration Layer concept.
Responsible partner/person	ATSA/Zbigniew Dyksy
Notes	None

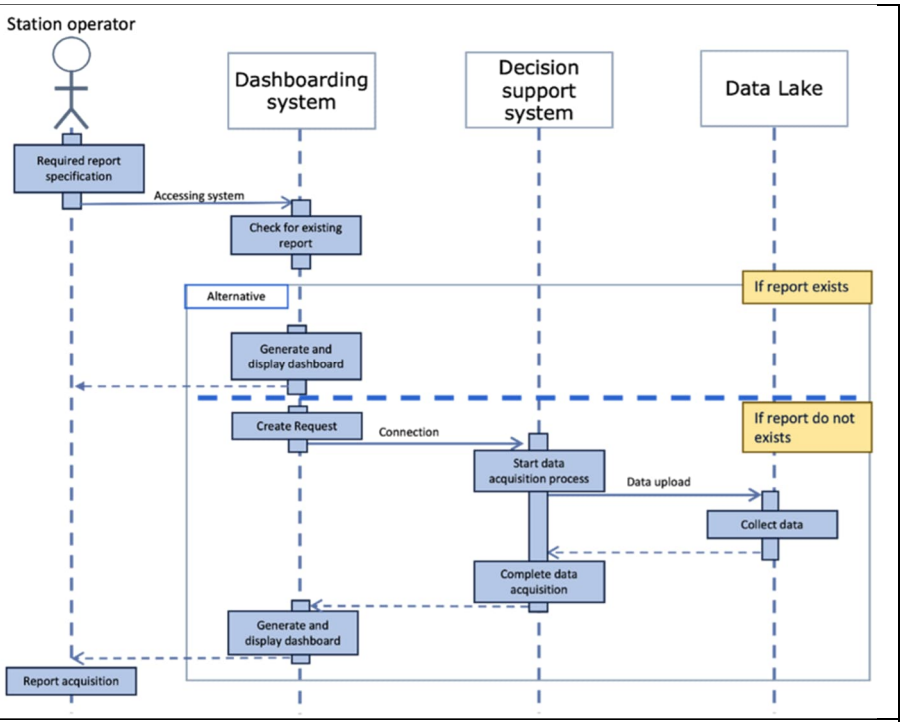
7.2. Use Cases for Subtask 11.3.2 (PKP)

The demonstration no. 12.2 in WS 1.2 “Operations” is focused on the need for an integrated data system—specifically a Data Lake—that aggregates and stores essential trans-border travel data from sources such as TrainMS (Train Management Systems) and geographical databases. The Data Lake is designed to store not only real-time but also historical data, ensuring that station operators can perform robust analyses on trans-border traffic potential based on varied parameters like Destination cities, travel times, and connectivity options. This solution aligns closely with the requirements of the Use Case, providing a foundation that feeds critical data to the Decision Support System (DSS) and the BI Dashboard, where analyses can be generated and visualised to

meet station operators' needs.

7.2.1. FP1-DEMO-12.2-UC-01 – Support for trans-border travel related decisions for station operator

Use Case ID	**FP1-DEMO-12.2-UC-01**
Name	Support for trans-border travel related decisions for station operator
Partner	PKP
Demo associated	Demo 12.2 (task 12.2.2)
Description	Trans-border transport availability is an important aspect when making decision regarding economic effectiveness of station operation. For ensuring effective decision-making process one needs to receive relevant data in accessible and well visualised form. The Use Case is based on dashboards and relevant data processing and logic for helping to make an informed decision. For example, areas are visualised (selected main cities) using geographical maps available from the stations within one or more legs of a trans-border journey.
Related to task/subtask(s)	Tasks 11.3.2, 12.2.2
Impact on other task(s)	None
Technical Enabler(s)	TE 9 - "Modelling and decision support for cross-border traffic management"
Interactions SP/FP	FP3-IAM4RAIL/ (WP 14, WP 15) where the asset management decision support systems for stations are being developed
Actor(s)	Station Operator, Data Lake service, DSS
Trigger	Station Operator requests a report.
Pre-Condition(s)	None.
Input	Search parameters (list of cities, time constraints)
Result/Requirement	Report will be generated and provided to the station operator.
Final State	Generated report is stored in the Data Lake.
Sequence	1. Accessing DSS. 2. Selection of appropriate station to analyse. 3. Setting how many target stations being analysed. 4. Setting parameters (geographical distance, maximum number of connections). 5. DSS generates dashboard with indicated accessibility network.
Diagram(s)	

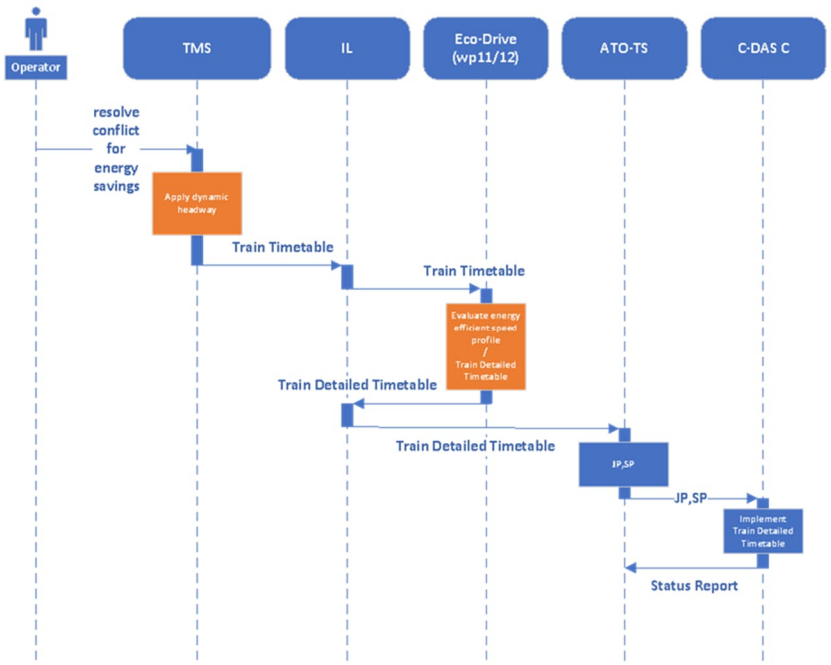
	
Expected Implementation Date	10 2024
Involved components (System)	• TMS, • Data Lake, • BI Dashboard.
Responsible partner/person	PKP/Jerzy Baranowski
Notes	The System must analyse the trans-border travel availability for selected destination stations. The System shall visualise the information in a readable way. System must communicate with the Data Lake to access necessary information on the trans-border travel.

7.3. Use Cases for Subtask 11.3.3 (STS)

The demonstration no. 12.3 in WS 1.2 “Operations” is focused on providing ATO-TS with a revision of the train timetable (as defined by CDM) that includes a time reference for intermediate timing points to optimise the train energy consumption using short-term data collected from the field status.

7.3.1. FP1-DEMO-12.3-UC-01 – Detail train timetable for energy saving ATO

Use Case ID	**FP1-DEMO-12.3-UC-01**
Name	Detail train timetable for energy saving ATO - TS

Partner	STS
Demo associated	Demo 12.3 (task 12.2.3)
Description	Provide ATO-TS with a revision of the train timetable (as defined by CDM) that includes a time reference for intermediate timing points to optimise the train energy consumption.
Related to task/subtask(s)	Tasks 11.3.3, 12.2.3
Impact on other task(s)	FP 1/ WP 15 (Task 15.4.4)
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors"
Interactions SP/FP	None
Actor(s)	ATO-TS, TMS, Integration Layer
Trigger	Acquisition of the Operational Plan.
Pre-Condition(s)	None
Input	Operational Plan
Result/Requirement	Detailed timetable with intermediate timing points to optimise the train energy consumption.
Final State	Not applicable.
Sequence	1. Acquisition of the Operational Plan. 2. Evaluation of the detailed train timetables. 3. Publishing of the detailed train timetables.
Diagram(s)	
Expected Implementation Date	12 2025
Involved components (System)	• TMS, • Integration Layer,

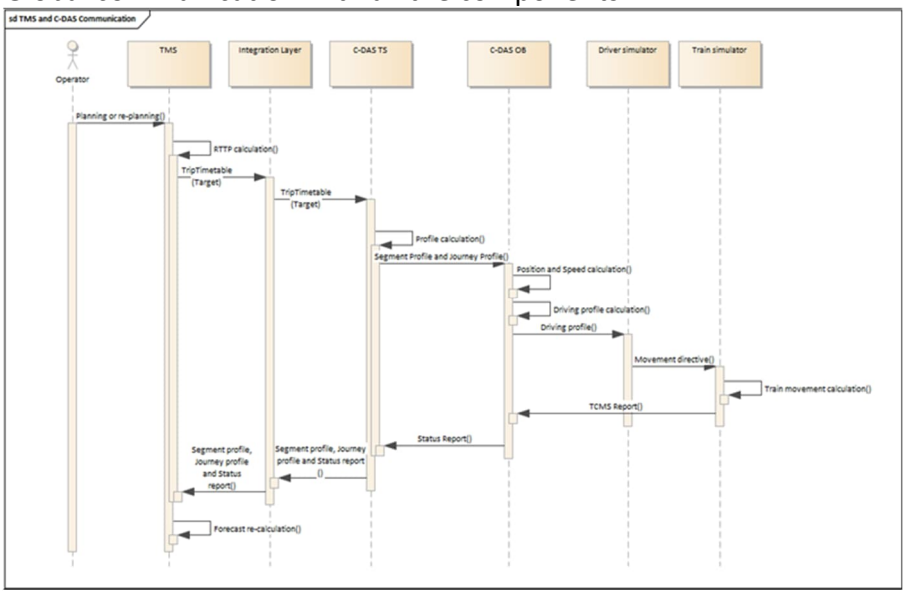
	• ATO-TS, • ATO-OBU.
Responsible partner/person	STS/Carmelo Lofiego
Notes	None

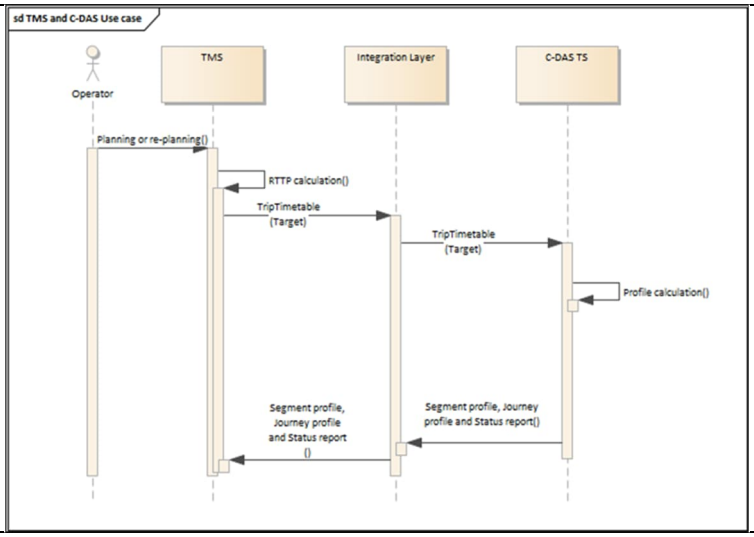
7.4. Use Cases for Subtask 11.3.4 (INDRA)

Demonstrator no. 12.4 is focused on the communication between TMS and C-DAS trackside. The communication is based on an integration layer that acts as intermediary for information management. Both systems need to exchange information about the Real-Time Traffic Plan (RTTP). The TMS sends the target RTTP, which is used by C-DAS TS to perform the profile calculation and to generate the segment and journey profiles. Through the information of the status reported by the train, the C-DAS TS returns the segment profile, journey profile and status report to the TMS by means of the integration layer.

7.4.1. FP1-DEMO-12.4-UC-01 – Information exchange between TMS and C-DAS TS

Use Case ID	**FP1-DEMO-12.4-UC-01**
Name	Information exchange between TMS and C-DAS TS
Partner	INDRA
Demo associated	Demo 12.4 (task 12.2.4)
Description	Communication between TMS providing the trip information and C-DAS TS system.
Related to task/subtask(s)	Tasks 11.3.4, 12.2.4
Impact on other task(s)	FP 1/WP 16 (Task 16.3)
Technical Enabler(s)	TE 8 - “Real-time connection of rail networks as managed by TMS and involved actors”
Interactions SP/FP	None
Actor(s)	TMS, C-DAS TS
Trigger	The creation or update of a trip plan by the TMS.
Pre-Condition(s)	The TMS must be operational with trip plans ready for sharing, the C-DAS TS must be prepared to receive and process this information, the communication network must be stable, and the communication protocols between TMS and C-DAS TS must be defined and configured.
Input	The data or information sent from TMS to C-DAS TS. Planned trip schedule with its modifications (TargetTrips from the TripTimetable class).
Result/Requirement	Accurate and timely reception of trip information by C-DAS TS, real-time update and synchronisation of trip plans between TMS and C-DAS TS, improved train operation and safety through optimised speed

	profiles, and compliance with defined communication protocols and formats.
Final State	The C-DAS TS has the updated trip information provided by the TMS, enabling the trains to operate according to the latest data received. The connection between TMS and C-DAS TS remains stable and continuous for future information exchanges. Continuous monitoring ensures data accuracy and timely updates.
Sequence	1. Requirements review to define the exchange of information between TMS and C-DAS TS. 2. Definition of the exchange communication protocol (communication system, interfaces and flow). 3. Functional testing to verify accurate and timely information exchange. 4. Definition of the messages involved in the interfaces (Messages, information included in each message, timing of the messages, messages flow). 5. Continuous monitoring.
Diagram(s)	Global communication with all the components:  Use case of interface from TMS to wayside C-DAS operation system, focusing on speed profile functionalities:

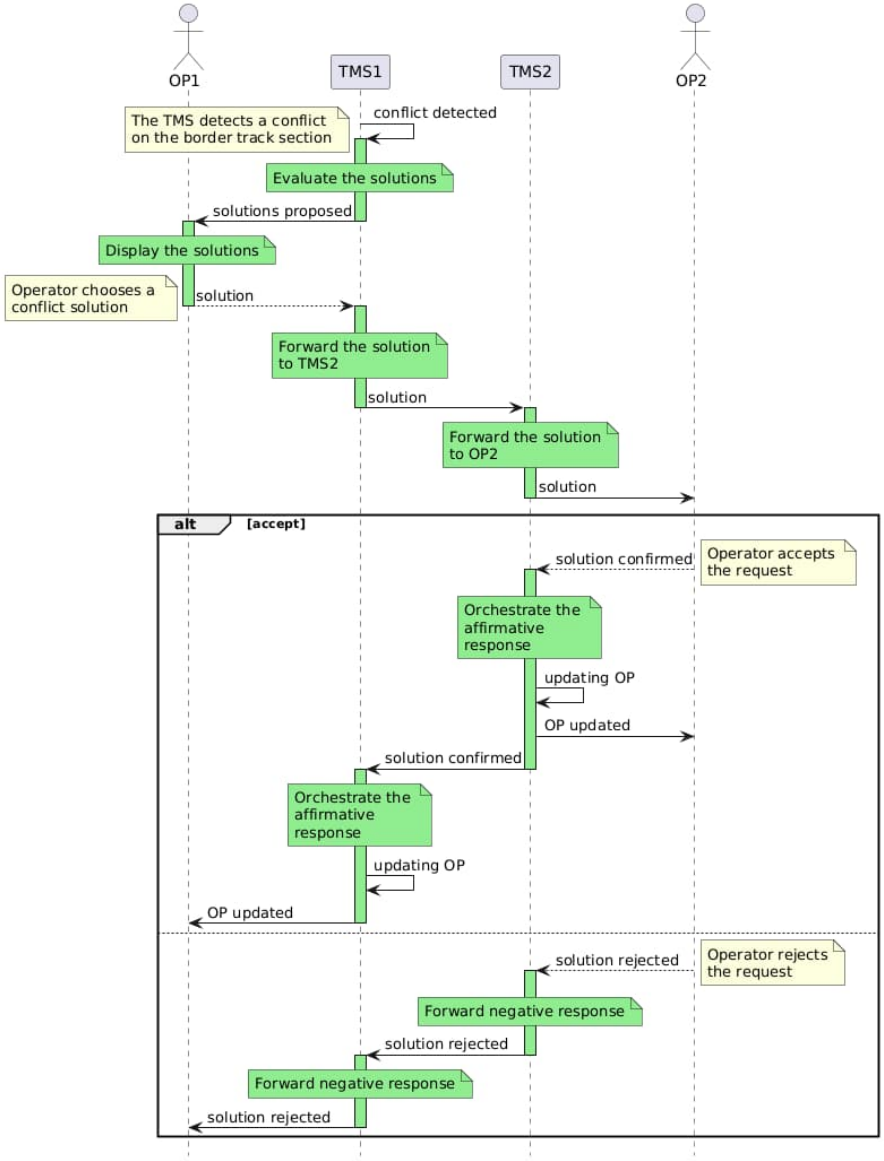
	
Expected Implementation Date	11 2025
Involved components (System)	• TMS: Manages railway traffic and generates trip plans. • Integration layer: component to exchange data between TMS and C-DAS TS. • C-DAS TS: Receives data from TMS to optimise train operations.
Responsible partner/person	INDRA/Enrique Gómez, Carmen Ramos
Notes	None

7.5. Use Cases for Subtask 11.3.5 (MERMEC)

Demonstrator no. 12.5 is focused on two TMS controlling a part of national line with a common track section. That track section is controlled by both TMS so that it could be considered as the border.
This "cross controlled area" concept could be easily extended to an international cross-border scenario.
Considering this example, the TMS need to exchange important data such as border train delays for instance, to evaluate forecasts and conflicts as soon as border trains run instead of waiting their entrance on the controlled part.
Another important information they need to exchange is the possible conflict solution for those conflicts on the common track section that have impact on the neighbouring system. A conflict solution decided behind the border can affect the neighbour TMS for the incoming train order or time for instance and that could generate problems or new critical conflicts. In such a case the solution should be shared and accepted by the neighbour TMS.

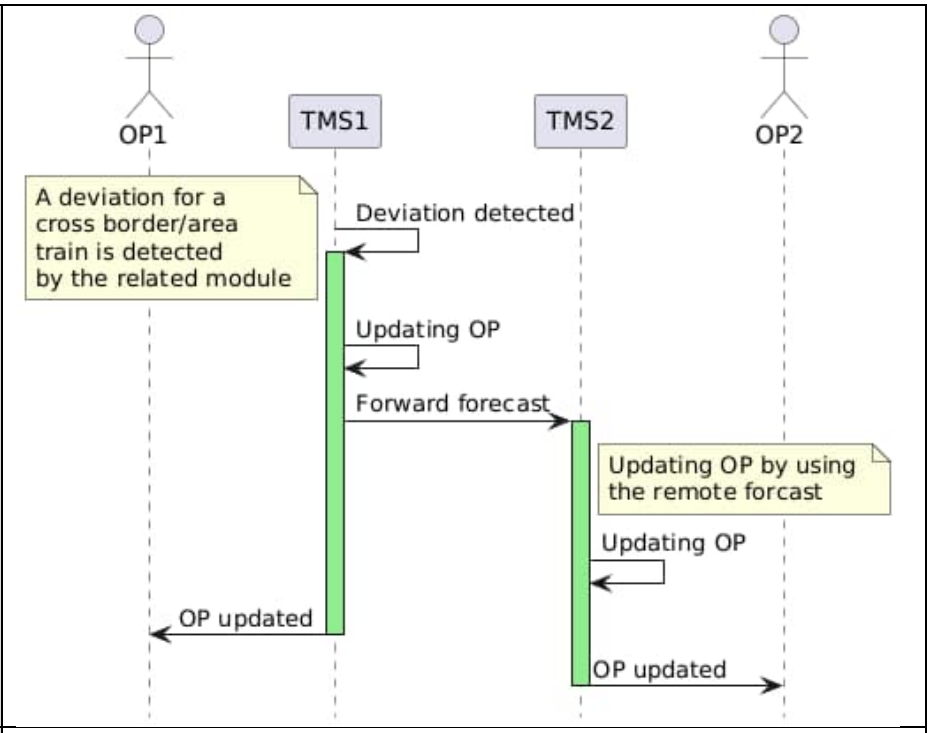
7.5.1. FP1-DEMO-12.5-UC-01 – Cooperative conflict resolution (Two TMS)

Use Case ID	**FP1-DEMO-12.5-UC-01**
Name	Cooperative conflict resolution (Two TMS)
Partner	MERMEC
Demo associated	Demo 12.5 (task 12.2.5)
Description	A train conflict solution shall consider also the possible choices taken by the TMS behind the border.
Related to task/subtask(s)	Tasks 11.3.5, 12.2.5
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors". TE 9 - "Modelling and decision support for cross-border traffic management".
Interactions SP/FP	SP/RNE: cross-border topic
Actor(s)	TMS 1, TMS 2, TMS Operator 1, TMS Operator 2
Trigger	Crossing Conflict Detection
Pre-Condition(s)	Two TMS up and running controlling their lines with at least one common track sections, i.e. the cross-border track. The current plans are loaded, and two trains need to go through the track at the same time.
Input	Infrastructure containing the common track section and a capacity plan with at least one train for each side passing through the common track section.
Result/Requirement	Both TMS have an Operational Plan containing the proposed solution, TMS 2 must approve or reject it.
Final State	If approved, an Operational Plan with conflict solved for both TMS.
Sequence	1. TMS 1 Operator chooses a conflict solution. 2. Conflict solution is sent to TMS 2. 3. TMS 2 Operator accepts or rejects the proposal solution (and eventually adds a note). 4. When accepted the conflict is solved in both TMS.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS Event Logger, • TMS Deviation Detection module, • TMS Forecast Calculation module, • TMS Conflict Detection module, • TMS Conflict Resolution module, • TMS Operational Plan, • Cooperative Interface.
Responsible partner/person	MERMEC/Angelo Naselli
Notes	None

7.5.2. FP1-DEMO-12.5-UC-02 – Exchanging real time train data regarding border stations

Use Case ID	**FP1-DEMO-12.5-UC-02**
Name	Exchanging real time train data regarding border stations.
Partner	MERMEC
Demo associated	Demo 12.5 (task 12.2.5)
Description	The TMS shall be able to exchange train characteristic, issues, and forecast information with neighbour TMS.
Related to task/subtask(s)	Tasks 11.3.5, 12.2.5
Impact on other task(s)	FP 1/WP 17/18 (Tasks 17.2.8, 18.2.8)
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors" TE 9 - "Modelling and decision support for cross-border traffic management"
Interactions SP/FP	SP/RNE: cross-border topic
Actor(s)	TMS 1, TMS 2, TMS Operator 1, TMS Operator 2
Trigger	A deviation on Operational Plan for a cross-border timing point.
Pre-Condition(s)	Two TMS up and running controlling their lines with at least one common track sections, i.e. the cross-border track. Current plans are loaded, a train needs to go through the common track and it is delayed.
Input	Infrastructure containing the common track section and a capacity plan with at least one train that needs to pass through the common track section.
Result/Requirement	Both TMS have an Operational Plan updated with forecast for the given train.
Final State	Shared train forecast.
Sequence	1. A deviation for a cross border/area train is detected by the related module. 2. Forecast is updated for the above train. 3. Train information is sent to the neighbouring TMS by Cooperative module. 4. The neighbouring TMS updates its Operational Plan accordingly.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS Event Logger, • TMS Deviation Detection module, • TMS Forecast Calculation module, • TMS Operational Plan, • Cooperative Interface.
Responsible partner/person	MERMEC/Angelo Naselli
Notes	None

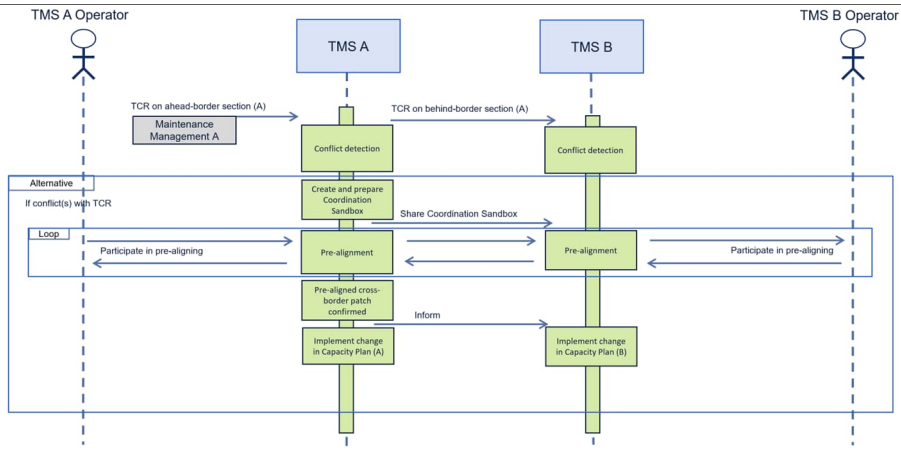
7.6. Use Cases for Subtask 11.3.6 (HACON)

In the following, the Use Cases corresponding to demonstration no. 12.6 in WS 1.2 “Operations” are specified. In subtask 11.3.6 HACON developed Traffic management modules for supporting decision alignment between two neighbouring TMS areas and IMs including cross-border traffic operation and required interfaces. The activities feed the related Destination 5 (WP 27) activities.

7.6.1. FP1-DEMO-12.6-UC-01 – Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts

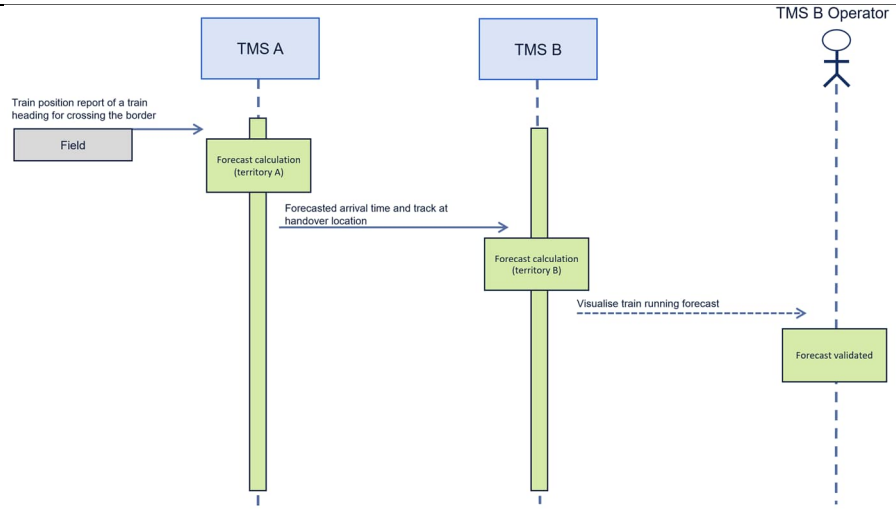
Use Case ID	**FP1-DEMO-12.6-UC-01**
Name	Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts

Partner	ADIF FM
Demo associated	Demo 12.6 (task 12.2.6); performed by HACON
Description	Short-term maintenance needs or accidental situation detected. Exchange of information between TMS. Pre-alignment between the parts of a journey including a border. Decision/alignment done before crossing the border.
Related to task/subtask(s)	Tasks 11.3.6, 12.2.6
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors" TE 9 - "Modelling and decision support for cross-border traffic management"
Interactions SP/FP	SP/RNE: cross-border topic; FP5-TRANS4M-R WP27
Actor(s)	TMS/TMS Operator
Trigger	Received maintenance or accidental restriction (TCR) affecting a cross-border track section.
Pre-Condition(s)	Two TMS A and B of neighbouring IM are active and sharing the cross-border line section up to the next major node on the territory of the opposite TMS/IM.
Input	• TCR (via Interface), • Alignment decisions (via HMI).
Result/Requirement	Pre-aligned and updated Operational Plans.
Final State	Up-to-date and aligned Operational Plans in both TMS.
Sequence	1. Starting point: Cross-border train operating from IM/TMS A to IM/TMS B without incidents. 2. Short-term maintenance needs or accidental situation detected arising in the TMS A and covered by a TCR received by the TMS which is affecting the cross-border train being delayed. 3. The TMS A informs TMS B about the change in the operation. 4. Pre-alignment of both IM/TMS of the changes to the Operational Plan including the affected cross-border train. 5. Alignment done and Operational Plan updated before crossing the border.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Required integration services, • TMS hardware featuring two TMS program instances.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	This scenario can be also given with an incident in the area B controlled by the TMS B.

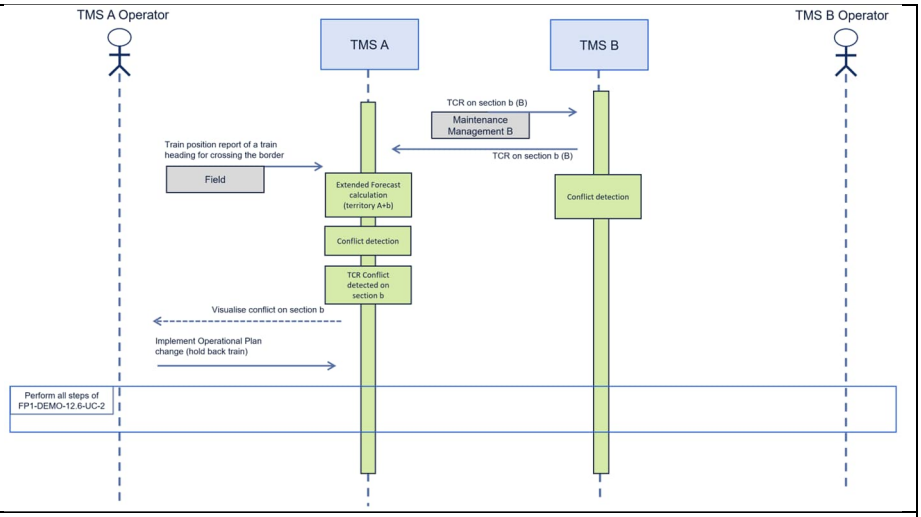
7.6.2. FP1-DEMO-12.6-UC-02 – Sending and receiving train running forecast information

Use Case ID	**FP1-DEMO-12.6-UC-02**
Name	Sending and receiving train running forecast information
Partner	HACON
Demo associated	Demo 12.6 (task 12.2.6)
Description	The TMS shall be able to receive forecast information from other sources, e.g., a neighbouring TMS.
Related to task/subtask(s)	Tasks 11.3.6, 12.2.6
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - “Real-time connection of rail networks as managed by TMS and involved actors”
Interactions SP/FP	SP/RNE: cross-border topic; FP5-TRANS4M-R WP27
Actor(s)	TMS/TMS Operator
Trigger	Estimated time of arrival received from neighbouring TMS at handling point.

Pre-Condition(s)	• Two TMS A and B of neighbouring IMs are active and sharing the cross-border line section up to the next major node on the territory of the opposite TMS/IM, • A planned inbound cross-border freight path available in local TMS.
Input	Forecasted arrival time at cross-border handling point (via Interface)
Result/Requirement	Updated forecast taking estimated time of arrival at handling point into account.
Final State	Up-to-date cross-border traffic forecast
Sequence	1. Train related to path started in foreign network. 2. Forecasted arrival time at handover point with local network received via TAF/TSI (e.g., by RNE/TIS or foreign TMS). 3. Forecast calculation in local TMS is triggered for the local fraction of the journey in accordance with the planned path (where possible). 4. Forecast result validated.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Required integration services, • TMS hardware featuring two TMS program instances.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.6.3. FP1-DEMO-12.6-UC-03 – Pre-aligned decisions cross-border

Use Case ID	**FP1-DEMO-12.6-UC-03**
Name	Pre-aligned decisions cross-border
Partner	HACON
Demo associated	Demo 12.6 (task 12.2.6)
Description	Aligning decisions by knowing capacity restrictions behind the border (until next node behind the border).
Related to task/subtask(s)	Tasks 11.3.6, 12.2.6
Impact on other task(s)	None
Technical Enabler(s)	TE 8 - "Real-time connection of rail networks as managed by TMS and involved actors" TE 9 - "Modelling and decision support for cross-border traffic management"
Interactions SP/FP	SP/RNE: cross-border topic; FP5-TRANS4M-R WP27
Actor(s)	TMS/TMS Operator
Trigger	TCR behind the border affecting a cross-border track section.
Pre-Condition(s)	• The TMS of an IM is active and features a the cross-border line section up to the next major node on the territory of the opposite TMS/IM. • A planned outbound cross-border freight path available in local TMS. • A TCR with defined end time behind the border (neighbouring network) affecting the planned path.
Input	Local territory Operational Plan adaptation to cope with TCR behind the border (via HMI).
Result/Requirement	Updated Operational Plan coping with TCR behind the border.
Final State	Up-to-date Operational Plan coping with TCR behind the border.
Sequence	1. Train related to path started in local network. 2. Forecast calculation from current position to next node behind the border triggered (according to planned path. 3. Conflict with TCR behind the border is detected and shown. 4. Local dispatcher holds back the train on local network to maintain capacity in area towards the border until TCR is gone. 5. Forecast result validated.
Diagram(s)	

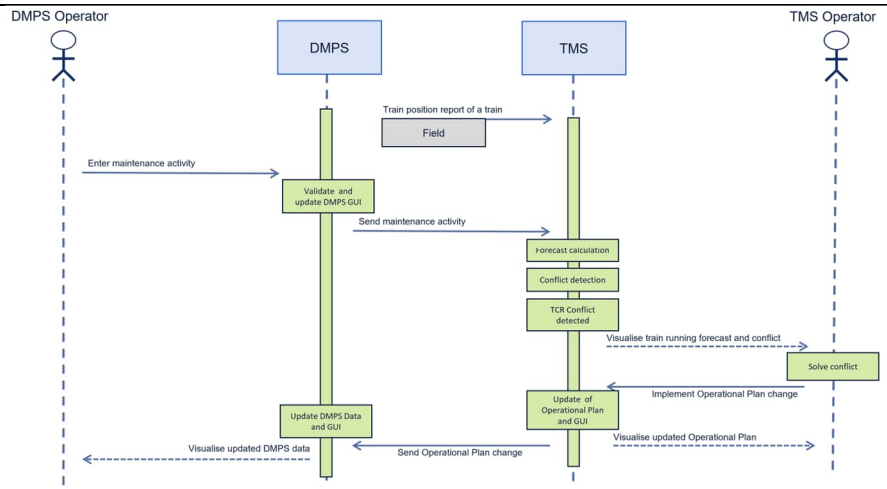
	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Required integration services, • TMS hardware featuring two TMS program instances.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7. Use Cases for Subtask 11.3.7 (HACON)

In the following, the Use Cases corresponding to demonstration no. 12.7 in WS 1.2 “Operations” are specified. In subtask 11.3.7 HACON developed interfaces for integration of TMS with external systems or services to improve the quality of automated or human decision making using the TMS. These include systems for station and yard management (considering requirements of FA 5) and digital asset maintenance as developed in FA 3 and more specifically in the FP 3 IAM4RAIL project WP 8. An electric traction system simulator is integrated with TMS to forecast and provide upcoming power restrictions for electric trains based on the current Operational Plan and a connection with RU related systems for crew/rolling stock management ensures anytime transparency about RU related, resource-based constraints are given

7.7.1. FP1-DEMO-12.7-UC-01 – Import and handling of a TCR

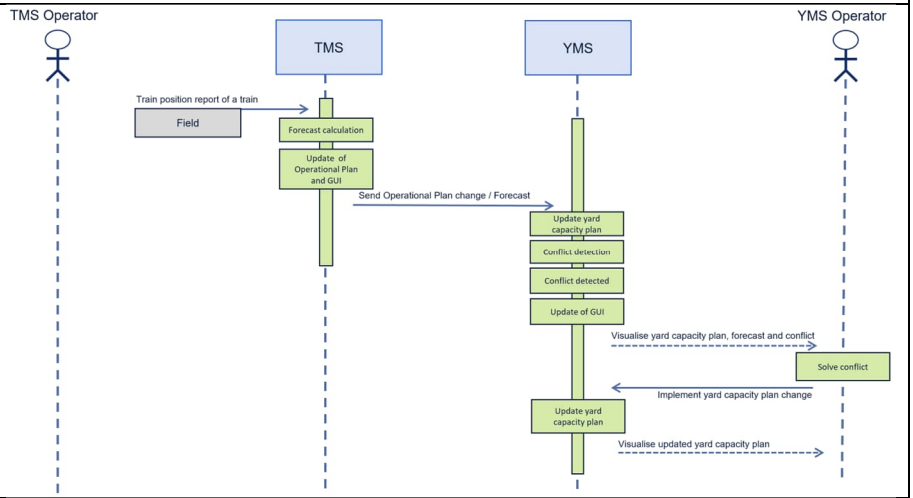
Use Case ID	**FP1-DEMO-12.7-UC-01**
Name	Import and handling of a TCR
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	Provide forecast / updated Operational Plan considering digital maintenance planning
Related to	Tasks 11.3.7, 12.2.7

task/subtask(s)	
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	FP3-IAM4RAIL: IAMS/DMPS integration for track maintenance information
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	TCR is imported/updated from track maintenance planning system DMPS (IAMS, FP 3, WP 8)
Pre-Condition(s)	• The TMS is active and features interfacing with Digital Maintenance Planning System (DMPS). • A planned freight path available in the TMS.
Input	TCR (via Interface)
Result/Requirement	Updated Operational Plan synchronised with connected DMPS and its processes considering its constraints and needs.
Final State	Updated Operational Plan available in TMS and connected systems considering their constraints and needs.
Sequence	1. A train related to a path starts in the local network. 2. A TCR is imported/updated from track maintenance planning system DMPS (IAMS, FP 3, WP 8). 3. The forecast calculation from current position shows up with conflict(s) with the imported TCR. 4. The TMS Operator adapts the Operational Plan to solve the conflict(s). 5. The Operational Plan is sent back to the DMPS.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • DMPS software,

	• Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.2. FP1-DEMO-12.7-UC-02 – Provision and handling of TMS Operational Plan changes in the Yard Management System

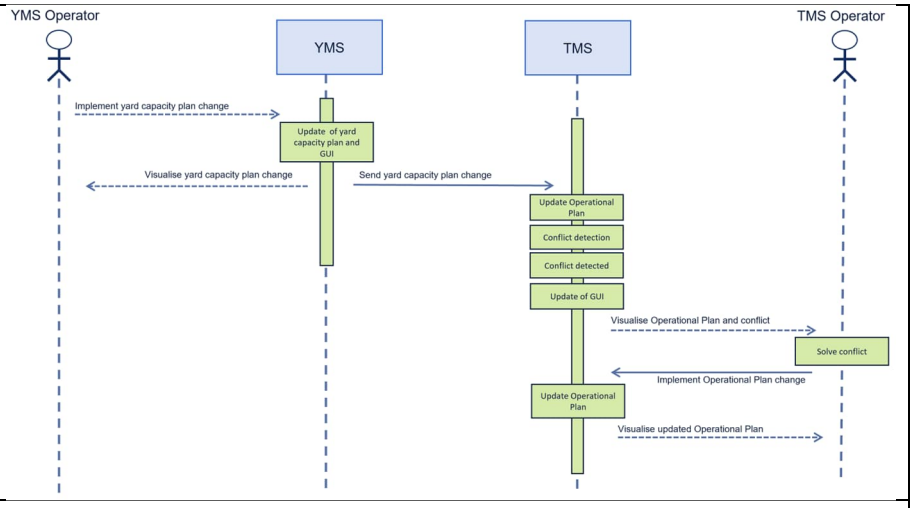
Use Case ID	**FP1-DEMO-12.7-UC-02**
Name	Provision and handling of TMS Operational Plan changes in the Yard Management System
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	The TMS provides an update of the Operational Plan and the train running forecast to the Yard Management System requiring an adaptation of the yard capacity plan.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	FP5-TRANS4M-R: integration of yard capacity production
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A change of the Operational Plan in the TMS is performed by a Traffic Controller or interface, affecting the arrival track or arrival/departure time in the yard / handling location or the arrival train consist information.
Pre-Condition(s)	• The TMS is active and features interfacing with a system for yard management • A planned freight path available in the TMS.
Input	Information for performing the change of the Operational Plan in the TMS to be initiated by a Traffic Controller or interface.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The TMS sends an updated Operational Plan and train running forecast for a train to the Yard Management System.

	2. The change of the Operational Plan for the train causes one or more conflicts with the planned yard track, track reservation, consist information or shunt moves for handling the train. 3. The conflict is solved by the Yard Operator by adapting the conflicting tracks, track reservations or shunt moves in the yard capacity plan, taking the updated consist and train running forecast into account.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.3. FP1-DEMO-12.7-UC-03 – Receipt and handling of Yard Capacity Plan changes in the TMS

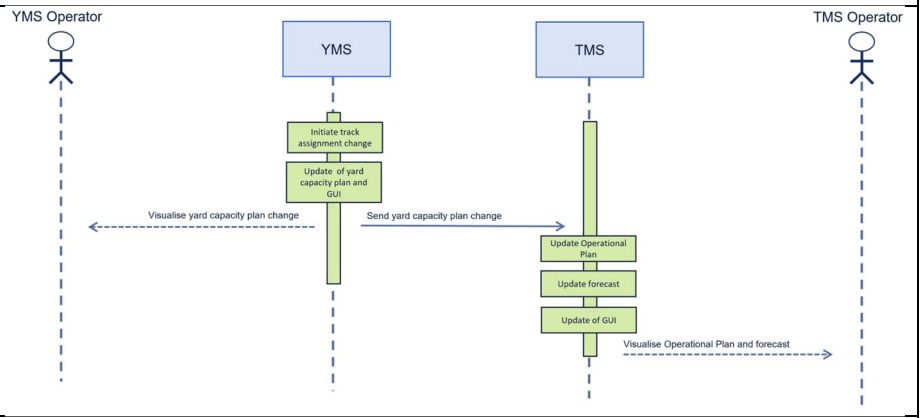
Use Case ID	**FP1-DEMO-12.7-UC-03**
Name	Receipt and handling of Yard Capacity Plan changes in the TMS
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	The Yard Management System provides an update of the Yard Capacity Plan to the TMS requiring an adaptation of the Operational Plan.

Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	FP5-TRANS4M-R: integration of yard capacity production
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A change of the Yard Capacity Plan in the Yard Management System is performed by a Yard Controller, affecting the departure track or the arrival time of a train consist in the departure track in the yard / handling location or the consist information of the departing train.
Pre-Condition(s)	• The TMS is active and features interfacing with a system for yard management. • A planned freight path available in the TMS.
Input	Information for performing the change of the Yard Capacity Plan in the Yard Management System to be initiated by a Yard Operator or interface.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in considering Yard Capacity Plan changes.
Sequence	1. The Yard Management System sends to the TMS an update of a. the departure track in the yard / handling location for a train and/or, b. the arrival time of a shunting move to make the consist available in the departure track and/or, c. the consist information of the departing train. 2. The change(s) cause one or more conflicts with the current Operational Plan. 3. The conflict(s) is (are) solved by the TMS Operator by adapting the train’s routing and timing information in the Operational Plan.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

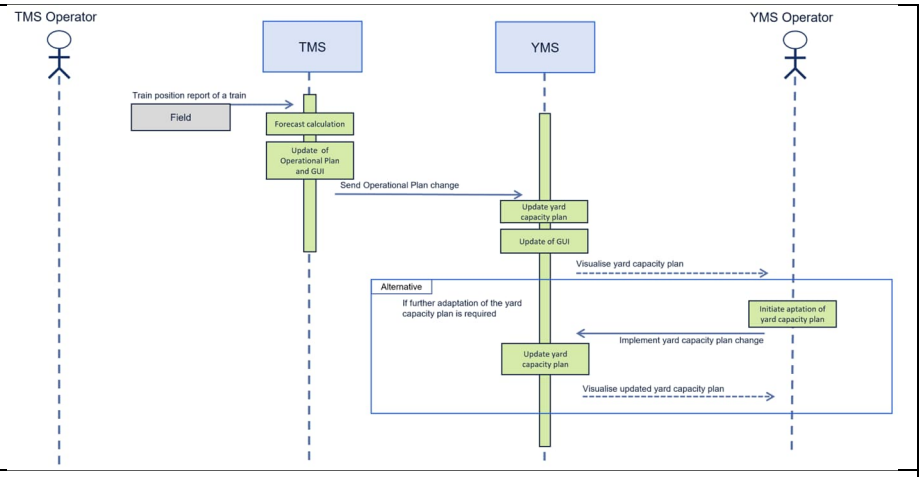
7.7.4. FP1-DEMO-12.7-UC-04 – Train running forecast of the TMS improved by integration of TMS with systems and processes related to yard or station management

Use Case ID	**FP1-DEMO-12.7-UC-04**
Name	Train running forecast of the TMS improved by integration of TMS with systems and processes related to yard or station management
Partner	ADIF
Demo associated	Demo 12.7 (task 12.2.7); performed by HACON
Description	Input received from yard/station planning systems by the TMS. Calculation of the train running forecast by the TMS considering this information.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	None

Actor(s)	TMS/TMS Operator, Operators of integrated systems
Trigger	TCR is imported/updated from track maintenance planning system DMPS (IAMS, FP 3, WP 8)
Pre-Condition(s)	• The TMS is active and features interfacing with systems for yard/station management • A planned freight path available in the TMS.
Input	TCR (via Interface)
Result/Requirement	Updated train running forecast improved considering their constraints and needs of yard/station management systems.
Final State	Updated forecast available in TMS considering the constraints and needs of yard/station management systems.
Sequence	1. The local system (Yard Management system or Station Management System) sets an operation with impact on the track assignment for the train of the TMS. 2. Local system informs to the TMS of the change of track assignment. 3. The TMS adjusts the track assigned considering the information received from the local system.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

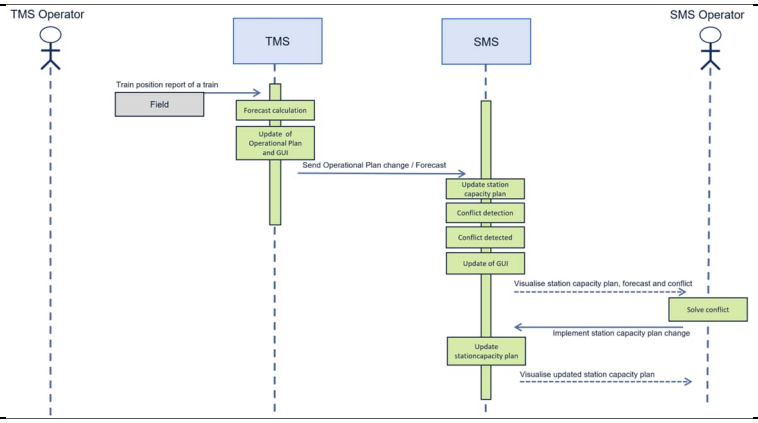
7.7.5. FP1-DEMO-12.7-UC-05 – Planning and/or management of systems and processes using information received from the TMS

Use Case ID	**FP1-DEMO-12.7-UC-05**
Name	Planning and/or management of systems and processes related to yard or station management, taking into account the information received from the TMS
Partner	ADIF
Demo associated	Demo 12.7 (task 12.2.7); performed by HACON
Description	The TMS sends to the other planning/management local systems (yard, stations) info of updated train running forecast and/or updated Operational Plan. The local systems use this information.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	None
Actor(s)	TMS/TMS Operator, Operators of integrated systems
Trigger	Cyclic trigger (e.g., 30 seconds) for providing the updated forecast.
Pre-Condition(s)	• The TMS is active and features interfacing with systems for yard/station management. • Condition in TMS leading to an update of the Operational Plan.
Input	Provoking a condition in TMS leading to an update of the Operational Plan (via HMI).
Result/Requirement	The local system received the updated information from the TMS and considers it to implement its actions.
Final State	The local system has adopted the TMS information and considers it for further processing.
Sequence	1. There is an update in the train's Operational Plan due to updated train running forecast. 2. The TMS informs the local system on the update. 3. The local system considers the updated information received from the TMS to implement its actions.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.6. FP1-DEMO-12.7-UC-06 – Provision and handling of TMS Operational Plan changes in the Station (Depot) Management System

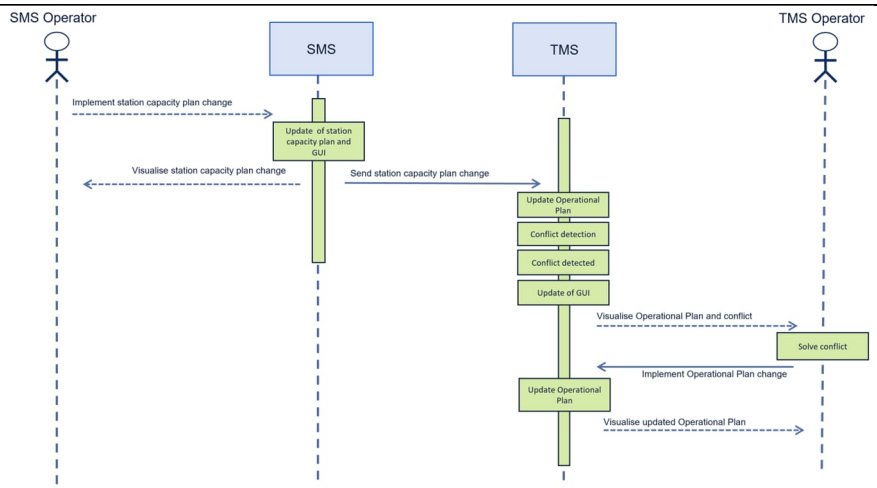
Use Case ID	**FP1-DEMO-12.7-UC-06**
Name	Provision and handling of TMS Operational Plan changes in the Station (Depot) Management System
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	The TMS provides an update of the Operational Plan and the train running forecast to the Station (Depot) Management System requiring an adaptation of the station capacity plan.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A change of the Operational Plan in the TMS is performed by a Traffic

	Controller or interface, affecting the arrival track or arrival/departure time in the station (depot) area / handling location or the arrival train consist information.
Pre-Condition(s)	• The TMS of an IM is active and features interfacing with a system for station management. • A planned passenger train path available in the TMS.
Input	Information for performing the change of the Operational Plan in the TMS to be initiated by a Traffic Controller or interface.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The TMS sends an updated Operational Plan and train running forecast for a train to the Station (Depot) Management System. 2. The change of the Operational Plan for the train causes one or more conflicts with the planned station track, track reservation, consist information or shunt moves for handling the train. 3. The conflict is solved by the Station (Depot) Operator by adapting the conflicting tracks, track reservations or shunt moves in the station capacity plan, taking the updated consist and train running forecast into account.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible	HACON/Rolf Gooßmann

partner/person	
Notes	None

7.7.7. FP1-DEMO-12.7-UC-07 – Receipt and handling of Station (Depot) Capacity Plan changes in the TMS

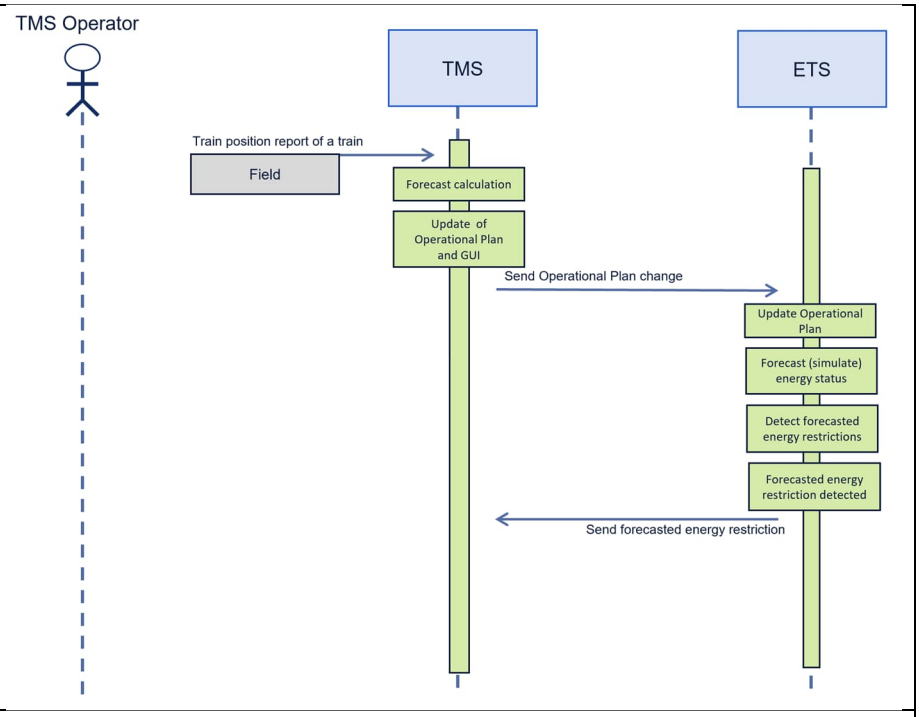
Use Case ID	**FP1-DEMO-12.7-UC-07**
Name	Receipt and handling of Station (Depot) Capacity Plan changes in the TMS
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	The Station (Depot) Management System provides an update of the Station (Depot) Capacity Plan to the TMS requiring an adaptation of the Operational Plan.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A change of the Station (Depot) Capacity Plan in the Station (Depot) Management System is performed by a Station (Depot) Controller, affecting the departure track or the arrival time of a train consist in the departure track in the station area / handling location or the consist information of the departing train.
Pre-Condition(s)	• The TMS is active and features interfacing with a system for station management • A planned passenger train path available in the TMS.
Input	Information for performing the change of the Station (Depot) Capacity Plan in the Station (Depot) Management System to be initiated by a Station (Depot) Operator or interface.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in considering Station Capacity Plan changes.
Sequence	1. The Station (Depot) Management System sends to the TMS an update of a. the departure track in the station area/ handling location for a train and/or,

	b. the arrival time of a shunting move to make the consist available in the departure track and/or, c. the consist information of the departing train. 2. The change(s) cause one or more conflicts with the current Operational Plan. 3. The conflict(s) is (are) solved by the TMS Operator by adapting the train's routing and timing information in the Operational Plan.
Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Yard/Station management software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.8. FP1-DEMO-12.7-UC-08 – Provision and handling of TMS Operational Plan changes in the Electric Traction System (ETS) performing the trackside Energy Management

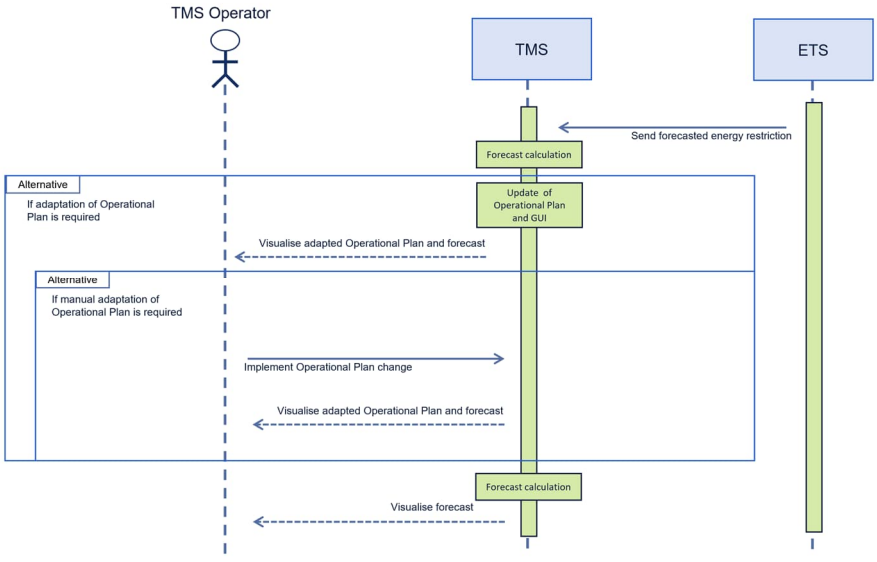
Use Case ID	**FP1-DEMO-12.7-UC-08**
Name	Provision and handling of TMS Operational Plan changes in the Electric Traction System (ETS) performing the trackside Energy Management
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)

Description	The TMS provides an update of the Operational Plan to the Electric Traction System (ETS) performing a forecast of energy consumption and detection of energy conflicts.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A change of the Operational Plan in the TMS is performed by a Traffic Controller or interface, affecting the train running in the Operational Plan.
Pre-Condition(s)	• The TMS is active and features interfacing with a system for track side energy management featuring the forecast of energy consumption and detection of energy conflicts. • Operational Plan with a sufficient number of trains available in the TMS for provoking energy conflicts.
Input	Information for performing the change of the Operational Plan in the TMS to be initiated by a Traffic Controller or interface.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The TMS sends an updated Operational Plan to the ETS. 2. In the ETS, the change of the Operational Plan causes one or more energy conflicts for trains operating in the different substation areas which lead to one or more energy restrictions for certain trains. 3. The train related energy restrictions are transferred back to the TMS.

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • ETS software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.9. FP1-DEMO-12.7-UC-09 – Receipt and handling of train related energy restrictions in the TMS

Use Case ID	**FP1-DEMO-12.7-UC-09**
Name	Receipt and handling of train related energy restrictions in the TMS
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	The Electric Traction System (ETS) provides forecasted energy restrictions for trains to the TMS requiring an adaptation of the train running forecast or Operational Plan.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling

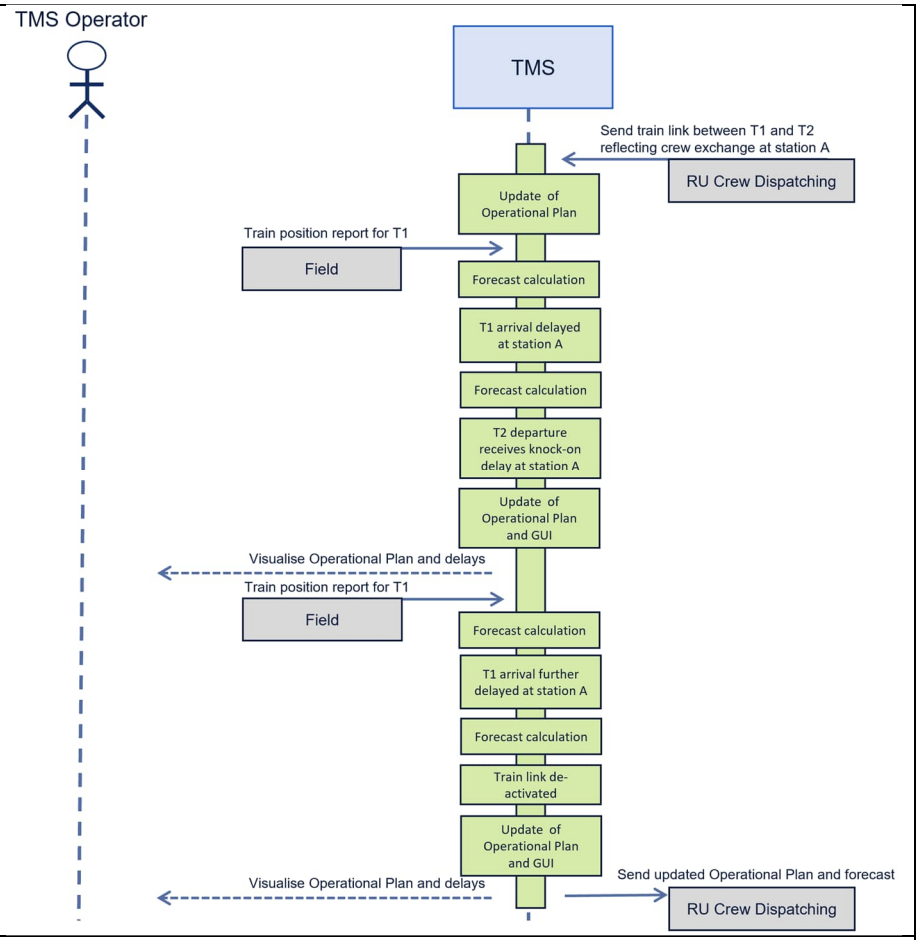
	stock dispatching”
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	A forecast of the energy consumption and detection of energy conflicts is performed by the ETS leading to train related energy restrictions.
Pre-Condition(s)	• The TMS of an IM is active and features interfacing with a system for track side energy management featuring the forecast of energy consumption and detection of energy conflicts. • Operational Plan with a sufficient number of trains available in the TMS for provoking energy conflicts.
Input	Operational Plan and train running forecast provided by the TMS.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available based on the previously detected energy restrictions of the train running.
Sequence	1. The Electric Traction System (ETS) sends energy restrictions in relation to the train running information to the TMS. 2. The TMS receives the energy restrictions and using them for the next cycle of calculating the train running forecast. 3. The forecast indicates the need for adapting the Operational Plan. 4. The Operational Plan is adapted by the TMS or Traffic Controller. 5. Next calculation cycle of train running forecast makes use of the adapted Operational Plan.
Diagram(s)	
Expected	11 2025

Implementation Date	
Involved components (System)	• TMS software, • ETS software, • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.10. FP1-DEMO-12.7-UC-10 – Consideration of crew links reflecting train crew exchanges between trains at stations

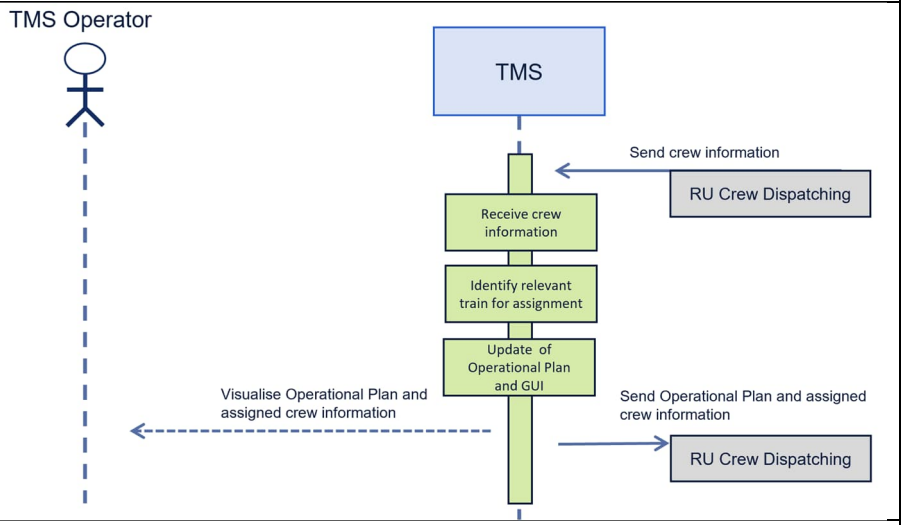
Use Case ID	**FP1-DEMO-12.7-UC-10**
Name	Consideration of crew links reflecting train crew exchanges between trains at stations
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	Provide forecast / updated Operational Plan considering crew links which reflect train crew exchanges between trains at stations.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	Message for new or changed train link indicating crew exchange between two trains stopping at a station received by the TMS.
Pre-Condition(s)	• The TMS is active and features consumption of train links received via an interface. • Operational Plan with sufficient number of trains available in the TMS for provoking delays because of the train links received.
Input	• Crew exchange related train links (via interface). • Adequate train position reports to provoke initial delays affecting the train links received.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.

Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The message including the train link (provided by crew dispatching system or simulation of it) reflecting a Driver exchange is received. 2. The Operational Plan is updated including a Control Rule reflecting the train link and controlling the train running forecast. 3. Because of adequate train position reports for the first train assigned to the Control Rule, the train running forecast shows up with a delayed arrival of the first train at the crew exchange location. 4. The delayed arrival does not allow anymore to maintain the minimum activity time required for the exchange of the driver at the station, leading to a knock-on delay of the second train. 5. The TMS forecast calculation reflects the delayed train running of the second train. 6. The first train is further delayed leading to exceeding the maximum delay threshold of the Control Rule and triggering automated de-activation of the Control Rule. 7. The TMS automatically updates the Operational Plan based on the already incurred delay of the second train. 8. The TMS sends the updated Operational Plan and train running forecast to the crew dispatching system (or simulation of it).

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software • Crew Dispatching System (or message viewer if not available) • Required integration services • Technical environment / hardware for above software
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.11. FP1-DEMO-12.7-UC-11 – Consideration of crew information

Use Case ID	**FP1-DEMO-12.7-UC-11**
Name	Consideration of crew information
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	Provide updated Operational Plan considering crew information.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7

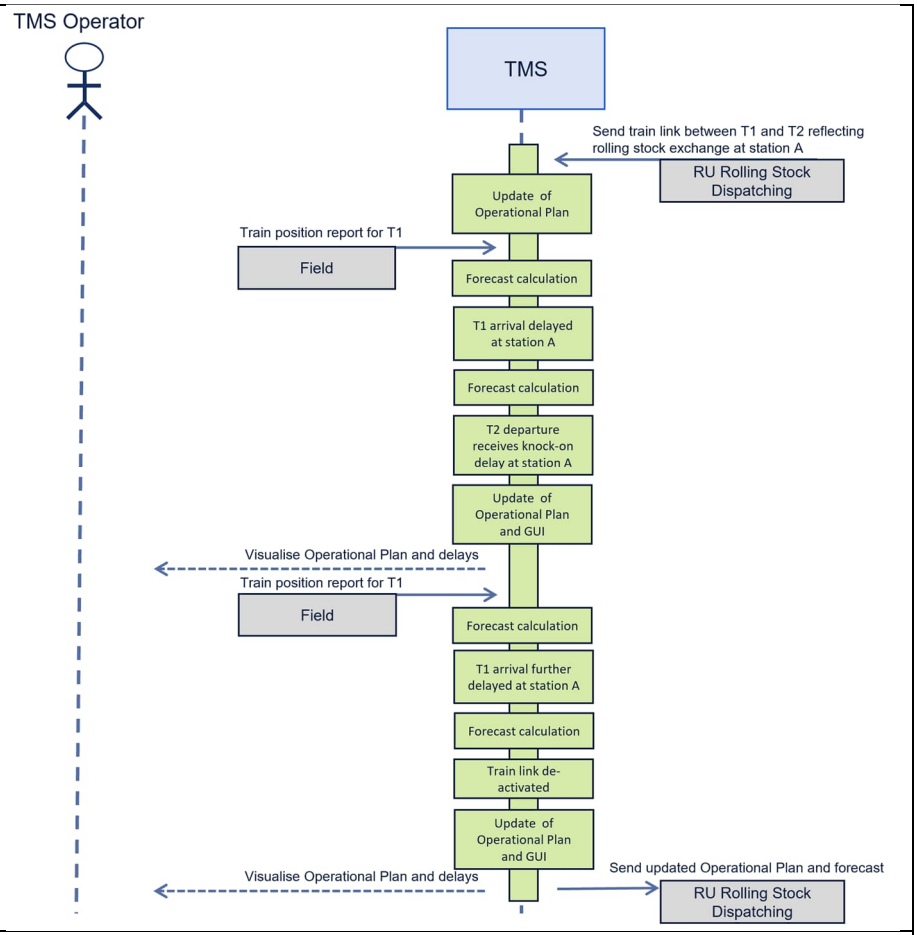
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	Message for new or changed crew information received by the TMS.
Pre-Condition(s)	• The TMS is active and features consumption of crew information received via an interface. • Operational Plan including the relevant train for which the crew information is provided available in the TMS.
Input	Crew information with assigned train ID (via interface).
Result/Requirement	Updated Operational Plan including the crew information for the relevant train.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The message including the crew information (provided by crew dispatching system or simulation of it) is received. 2. The train ID assigned to the crew information is used to identify and update the respective train information in the Operational Plan. 3. The TMS shows the assigned crew information in its User Interface. 4. The TMS sends the updated Operational Plan to the crew dispatching system (or simulation of it).
Diagram(s)	
Expected Implementation Date	11 2025
Involved components	• TMS software,

(System)	• Crew Dispatching System (or message viewer if not available), • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.12. FP1-DEMO-12.7-UC-12 – Consideration of rolling stock links reflecting train rolling stock exchanges between trains at stations

Use Case ID	**FP1-DEMO-12.7-UC-12**
Name	Consideration of rolling stock links reflecting train rolling stock exchanges between trains at stations
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	Provide forecast / updated Operational Plan considering crew links which reflect train rolling stock exchanges between trains at stations.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	Message for new or changed train link indicating rolling stock exchange between two trains stopping at a station received by the TMS.
Pre-Condition(s)	• The TMS is active and features consumption of train links received via an interface. • Operational Plan with sufficient number of trains available in the TMS for provoking delays because of the train links received.
Input	• Rolling stock exchange related train links (via interface) • Adequate train position reports to provoke initial delays affecting the train links received.
Result/Requirement	Updated Operational Plan synchronised with connected systems and processes considering their constraints and needs.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.

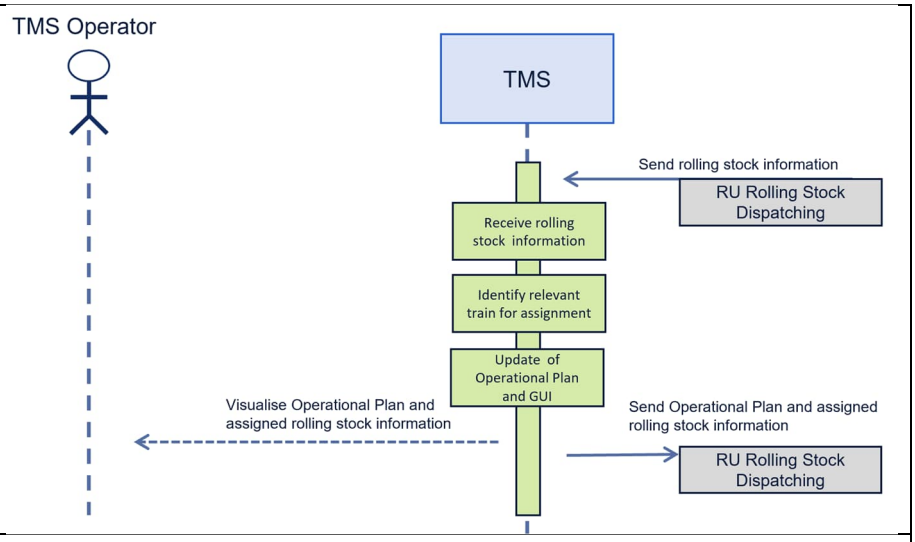
Sequence	1. The message including the train link (provided by rolling stock dispatching system or simulation of it) reflecting a rolling stock exchange is received. 2. The Operational Plan is updated including a Control Rule reflecting the train link and controlling the train running forecast. 3. Because of adequate train position reports for the first train assigned to the Control Rule, the train running forecast shows up with a delayed arrival of the first train at the crew exchange location. 4. The delayed arrival does not allow anymore to maintain the minimum activity time required for the exchange of the rolling stock at the station, leading to a knock-on delay of the second train. 5. The TMS forecast calculation reflects the delayed train running of the second train. 6. The first train is further delayed leading to exceeding the maximum delay threshold of the Control Rule and triggering automated de-activation of the Control Rule. 7. The TMS automatically updates the Operational Plan based on the already incurred delay of the second train. 8. The TMS sends the updated Operational Plan and train running forecast to the crew dispatching system (or simulation of it).

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Rolling Stock Dispatching System (or message viewer if not available), • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.7.13. FP1-DEMO-12.7-UC-13 – Consideration of rolling stock information

Use Case ID	**FP1-DEMO-12.7-UC-13**
Name	Consideration of rolling stock information
Partner	HACON
Demo associated	Demo 12.7 (task 12.2.7)
Description	Provide updated Operational Plan considering rolling stock

	information.
Related to task/subtask(s)	Tasks 11.3.7, 12.2.7
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	None
Actor(s)	TMS / TMS Operator, Operators of integrated systems
Trigger	Message for new or changed rolling stock information received by the TMS.
Pre-Condition(s)	• The TMS is active and features consumption of rolling stock information received via an interface. • Operational Plan including the relevant train for which the rolling stock information is provided available in the TMS.
Input	Rolling stock information with assigned train ID (via interface)
Result/Requirement	Updated Operational Plan including the rolling stock information for the relevant train.
Final State	Updated Operational Plan available in connected systems considering their constraints and needs.
Sequence	1. The message including the rolling stock information (provided by rolling stock dispatching system or simulation of it) is received. 2. The train ID assigned to the rolling stock information is used to identify and update the respective train information in the Operational Plan. 3. The TMS shows the assigned rolling stock information in its User Interface. 4. The TMS sends the updated Operational Plan to the rolling stock dispatching system (or simulation of it).

Diagram(s)	
Expected Implementation Date	11 2025
Involved components (System)	• TMS software, • Rolling stock Dispatching System (or message viewer if not available), • Required integration services, • Technical environment / hardware for above software.
Responsible partner/person	HACON/Rolf Gooßmann
Notes	None

7.8. Use Cases for Subtask 11.3.8 (TRV)

The demonstration no. 12.8 in WS 1.2 “Operations” is focused on the integration and exchange of information between TMS and YCS. The demonstration is closely connected to demonstration no. 4 in WS 1.1 “Planning”, as explained below.

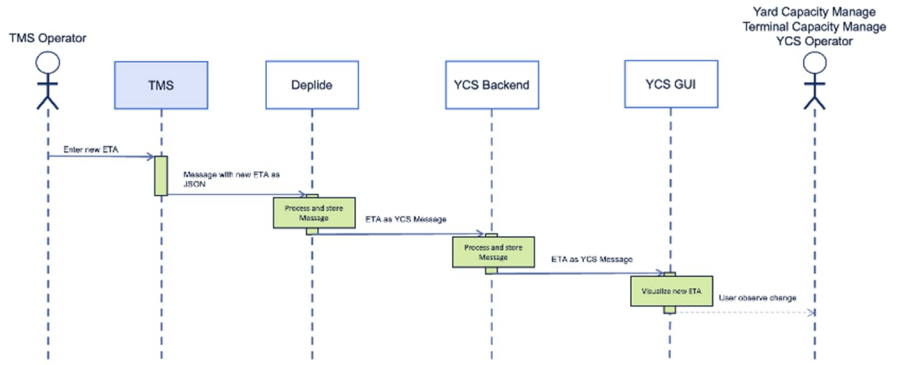
YCS is used for track allocation planning at an arrival/departure marshalling yard. The track allocation should be in line with the RTTP in the TMS. The RTTPs includes the trains’ estimated time of arrival and departure (ETA and ETD) of freight trains to/from the yard. The track allocation should also cover the needs for track usage by the marshalling operator and the terminal operator. In case the track allocation is not in line with these, there is a conflict. YCS is used for visualising and planning the track allocation and for resolving any conflict. The main Use Cases are thus to adjust track allocation in YCS whenever there is a changed ETA for a freight train (FP1-DEMO-12.8-UC-01) and to adjust the track allocation when the marshalling yard or terminal has a disruption, making their track need to be changed (FP1-DEMO-12.8-UC-02). These Use Cases have a strong connection to some Use Cases developed in WP4/WP5 for demonstration no. 12.4 of WS 1.1, namely UC-FP1-WP3-10, UC-FP1-WP3-11, UC-FP1-WP3-12 and UC-FP1-WP3-13. The Use Cases developed in WP 11 aims at integration and that TMS and YCS are in line with each other, while

the Use Cases in WP4/5 specify precures for the planning activities made by the users of the system. The Use Cases of WP 4/5 mentioned, can be viewed as sub-Use Cases of the Use Cases developed in WP 11.

Note that the TMS Operator and the YCS Operator is in fact the same person, in two different roles, i.e., the train traffic controller is the main user of both TMS and YCS.

7.8.1. FP1-DEMO-12.8-UC-01 – Sending and Receiving track allocation information between TMS and YCS

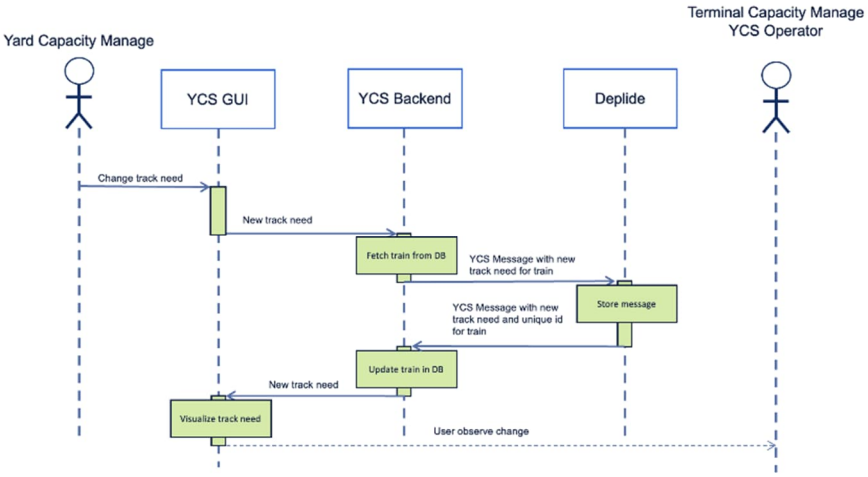
Use Case ID	**FP1-DEMO-12.8-UC-01**
Name	Sending and Receiving track allocation information between TMS and YCS.
Partner	TRV
Demo associated	Demo 12.8 (task 12.2.8)
Description	The TMS Operator changes the ETA of a freight train leading to an updated arrival time for the train's track allocation in the YCS.
Related to task/subtask(s)	Tasks 11.3.8, 12.2.8
Impact on other task(s)	None
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	FP5-TRANS4M-R
Actor(s)	TMS/TMS Operator, YCS/YCS Operator
Trigger	TMS Operator is informed that ETA of a freight train is changed.
Pre-Condition(s)	TMS-system's digital graph is used for RTTP-planning, initial track allocation plan exists in YCS, communication channel between TMS and YCS up and running.
Input	New estimate of freight train's ETA
Result/Requirement	Track allocation is in line with freight train's ETA and is conflict free. The TMS Operator has an updated view on track allocation that has impact on interaction with neighbouring area supervised and controlled by an YCS. The YCS Operator has an updated view on track allocation that has impact on interaction with neighbouring TMS area.
Final State	Track allocation is in line with freight train's ETA and is conflict free
Sequence	1. Train operator updates freight train's RTTP in TMS, thereby changing the train's ETA. 2. TMS sends updated ETA to YCS. 3. Track allocation on arrival yard is changed according to new ETA, i.e., times for start and end of track allocation is adjusted.

	4. YCS Operator resolves any potential conflicts by adjusting the track allocation. 5. (Consequential actions are handled in UC-FP1-WP4-11/12).
Diagram(s)	 TMS-operator changes ETA for train in TMS (by adjusting the RTTP). Deplide integrates to the TMS and fetches data messages as it is published. YCS Backend fetches the message from Deplide, processes the message and store the message. YCS GUI polls the YCS Backend for messages.
Expected Implementation Date	11 2025
Involved components (System)	• YCS • Trafikverket TMS “Digital graf” • Deplide • Trafikverket Railway API
Responsible partner/person	RISE/Martin Joborn
Notes	None

7.8.2. FP1-DEMO-12.8-UC-02 – Notifying TMS and YCS operators about disruptions and requests

Use Case ID	**FP1-DEMO-12.8-UC-02**
Name	Notifying TMS and YCS operators about disruptions and requests
Partner	TRV
Demo associated	Demo 12.8 (task 12.2.8)
Description	A need for changing the track allocation of a train in the YCS leads to an updated ETD for the train and updated departure time from the track in the TMS.
Related to task/subtask(s)	Tasks 11.3.8, 12.2.8
Impact on other task(s)	None

Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	FP5-TRANS4M-R
Actor(s)	TMS/TMS Operator, YCS/YCS Operator, Yard Capacity Manager, Terminal Capacity Manager
Trigger	Based on an operational deviation, the Marshalling operator and terminal operator have a need to change the handling time of a departing freight train that has an impact on the train’s ready-for-departure-time.
Pre-Condition(s)	A valid and conflict free track allocation plan exists in YCS. A disruption in operation (or similar) has occurred at the marshalling yard or terminal and as a consequence, the operations to prepare a departing train is delayed, leading to that the track allocation is not feasible.
Input	• Previously valid track allocation, • Updated train departure preparation plan.
Result/Requirement	Interactions between TMS and YCS Operators through their systems about disruptions and requests on changes in plan for track allocation.
Final State	Track allocation of departure yard is updated and conflict free. TMS and YCS are in sync regarding departure information.
Sequence	1. Yard Capacity Manager (alternatively Terminal Capacity Manager) adjusts departure preparation information in YCS. 2. Yard Capacity Manager adjusts track need of departure yard, resulting in a conflict in the track allocation. 3. YCS Operator resolves the conflict (see UC-FP1-WP5-13/14/15 for information regarding conflict resolution). 4. YCS Operator observes the updated train ready-for-departure time in YCS and make an estimate for ETD. 5. TMS Operator updates the RTTP in TMS, taking into consideration the train ready time and situation on the line. 6. TMS sends ETD (from RTTP) to YCS. 7. YCS updates its departure information, and the track allocation is updated accordingly.

Diagram(s)	 YCS user (Yard Capacity Manager, Terminal Capacity Manager or YCS Operator) create data, like track need, is pushed to YCS Backend. YCS Backend pushes data to Deplide, which process the data further. The processed data is read into YCS Backend and stored. YCS GUI polls Deplide for messages.
Expected Implementation Date	11 2025
Involved components (System)	• YCS • Trafikverket TMS “Digital graf” • Deplide • Trafikverket Railway API
Responsible partner/person	RISE/Martin Joborn
Notes	None

7.9. Use Cases for Subtask 11.3.9 (CEIT)

The demonstration no. 12.9 in WS 1.2 “Operations” is focused on IAMS interface, “Interface in view of the future autonomous inspection vehicle (AIV) for the infrastructure (Destination 3) and its integration with the Intelligent Asset Management System (IAMS).”

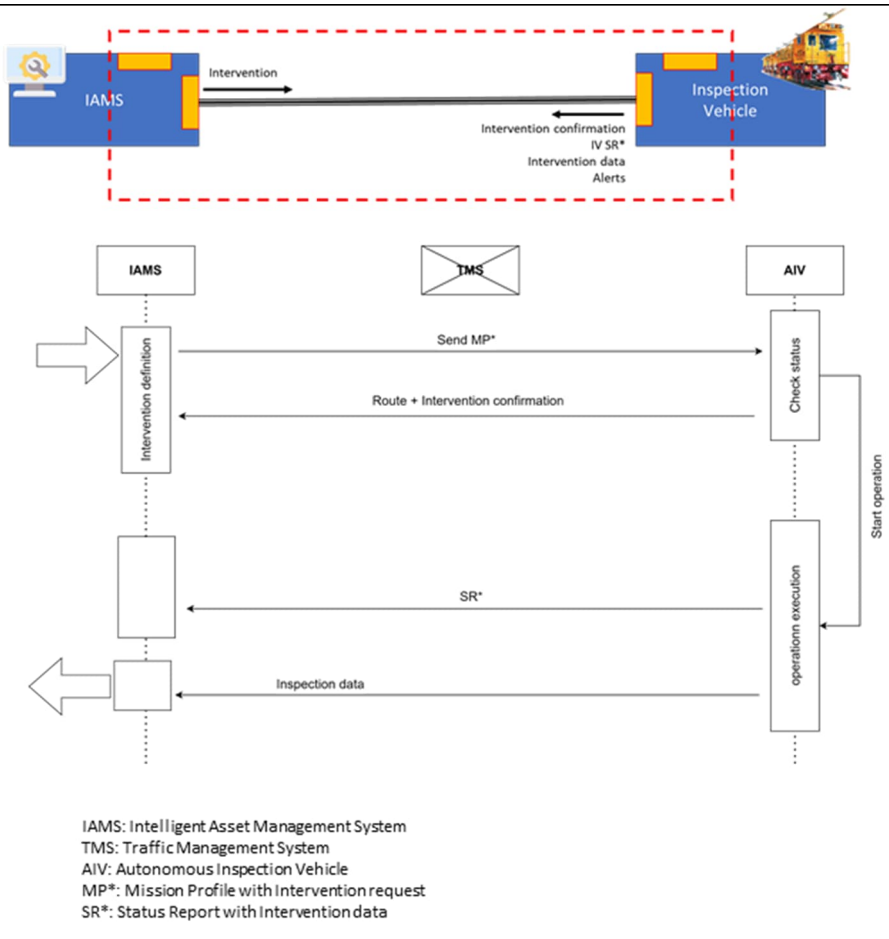
This interface is put in place to exchange information about asset status, planned interventions, allocated paths to execute inspections and interventions. There are three ways of interacting with the AIV foreseen: IAMS to AIV directly, IAMS and TMS to AIV directly and IAMS and TMS to AIV and IAMS to TMS.

The Use Case associated with Subtask 11.3.9 cover these three ways of interacting with the AIV. The first case covers, IAMS to AIV, which is foreseen to be implemented within MOTIONAL. The second case describes the alternative sequence for IAMS and TMS to AIV, and finally, the third case is for IAMS and TMS to AIV and IAMS to TMS.7.9.17.9.1

Additional information of Demonstration no. 12.9 ca be found in deliverable 10.1.

7.9.1. FP1-DEMO-12.9-UC-01 – IAMS-AIV interface

Use Case ID	**FP1-DEMO-12.9-UC-01**
Name	IAMS-AIV interface
Partner	CEIT
Demo associated	Demo 12.9 (task 12.2.9)
Description	Definition and development of the Interface of the future autonomous Inspection Vehicle for the infrastructure (FP 3) and its integration with the Intelligent Asset Management System (IAMS). To exchange information about asset status, planned interventions, and allocated paths to execute inspections and interventions.
Related to task/subtask(s)	Tasks 11.3.9, 12.2.9
Impact on other task(s)	Tasks 11.1 and 11.2 about development requirements and alignment
Technical Enabler(s)	TE 10 - “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”
Interactions SP/FP	FP3-IAM4RAIL
Actor(s)	IAMS, Autonomous Inspection Vehicle (AIV)
Trigger	IAMS generates an intervention order for AIV
Pre-Condition(s)	• IAMS and AIV communication stablished, • IAMS obtains AIV location info from AIV.
Input	• Required inspection intervention (Intervention), • Inspection Vehicle location,

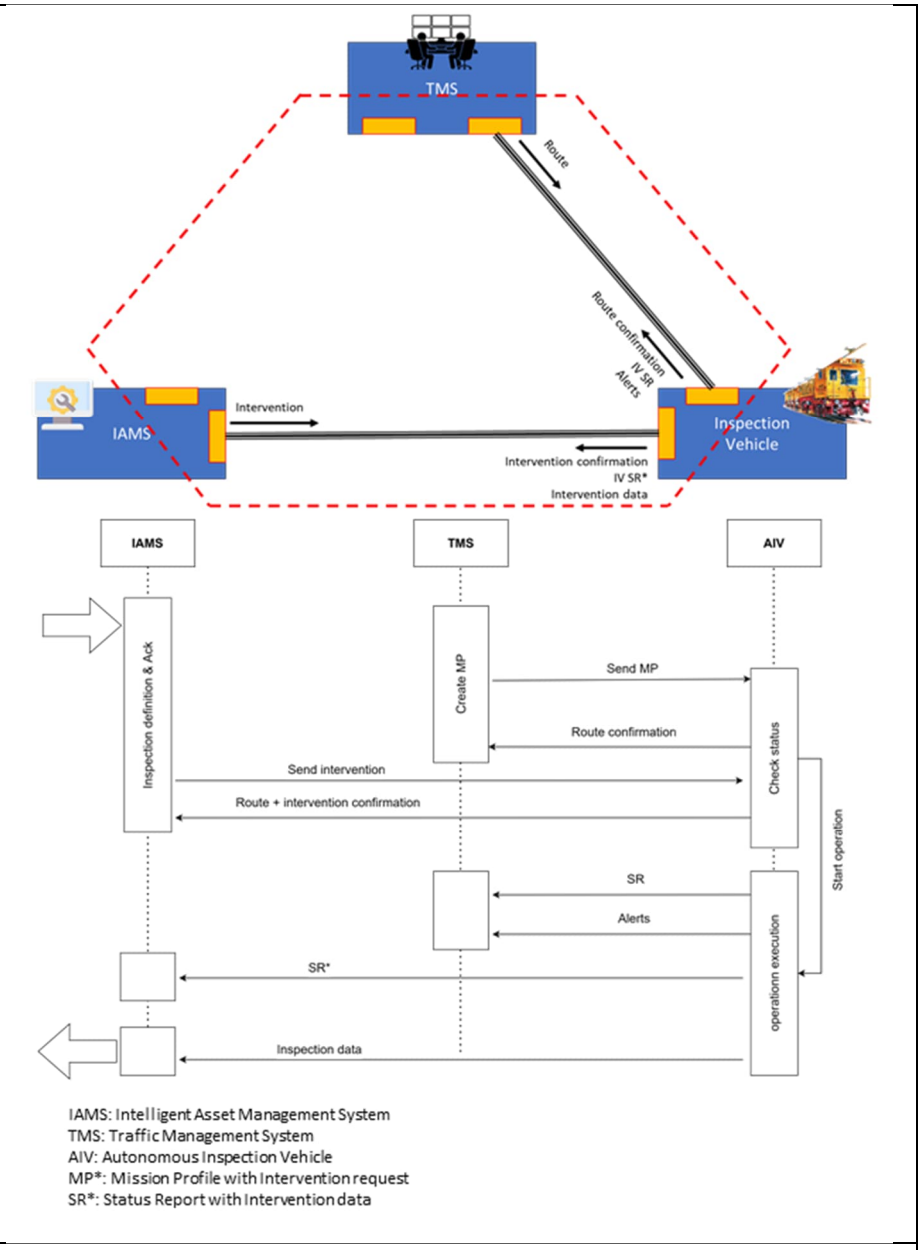
	• Allocated path for inspection vehicle based on asset status and planned interventions.
Result/Requirement	Definition and development of an interface enabling the following: • AIV receives the Intervention request, • IAMS receives Intervention data, Alerts and Status Report*
Final State	Interface operational that allows the following: • AIV finished intervention and parked in its final location. • IAMS with intervention data and alerts.
Sequence	1. IAMS requests the interventions of the Inspection Vehicle (AIV) on specific track paths to Inspection Vehicle directly (AIV). 2. Inspection Vehicle (AIV) receives the route for the intervention and the intervention on the specific track from IAMS. 3. During the intervention AIV sends the Status Report* (SR*) and Alerts, if any, to IAMS. 4. After the intervention, AIV sends the intervention data to IAMS.
Diagram(s)	

Expected Implementation Date	11 2024
Involved components (System)	Single PC with the SW developed with virtual docker interface.
Responsible partner/person	CEIT/Jaizki Mendizabal, Alfredo Artiles
Notes	Use case related to FP3-IAM4RAIL, WP 3

7.9.2. FP1-DEMO-12.9-UC-02 – TMS-IAMS, IAMS-AIV interface

Use Case ID	**FP1-DEMO-12.9-UC-02**
Name	TMS-IAMS, IAMS-AIV interface
Partner	CEIT
Demo associated	Demo 12.9 (task 12.2.9)
Description	Definition and development of the Interface of the future autonomous Inspection Vehicle for the infrastructure (FP 3) and its integration with the Intelligent Asset Management System (IAMS). To exchange information about asset status, planned interventions, and allocated paths to execute inspections and interventions.
Related to task/subtask(s)	Tasks 11.3.9, 12.2.9
Impact on other task(s)	Tasks 11.1 and 11.2 about development requirements and alignment
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	FP3-IAM4RAIL
Actor(s)	IAMS, Inspection Vehicle (AIV)
Trigger	IAMS generates an intervention order for AIV
Pre-Condition(s)	• IAMS and AIV communication stablished, • IAMS obtains AIV location info from AIV.
Input	• Required inspection intervention (Intervention), • Inspection Vehicle location, • Allocated path for inspection vehicle based on asset status and planned interventions.
Result/Requirement	Definition and development of an interface enabling the following: • AIV receives the Intervention request, • IAMS receives Intervention data, Alerts and Status Report*.
Final State	Interface operational that allows the following: • AIV finished intervention and parked in its final location, • IAMS with intervention data and alerts.

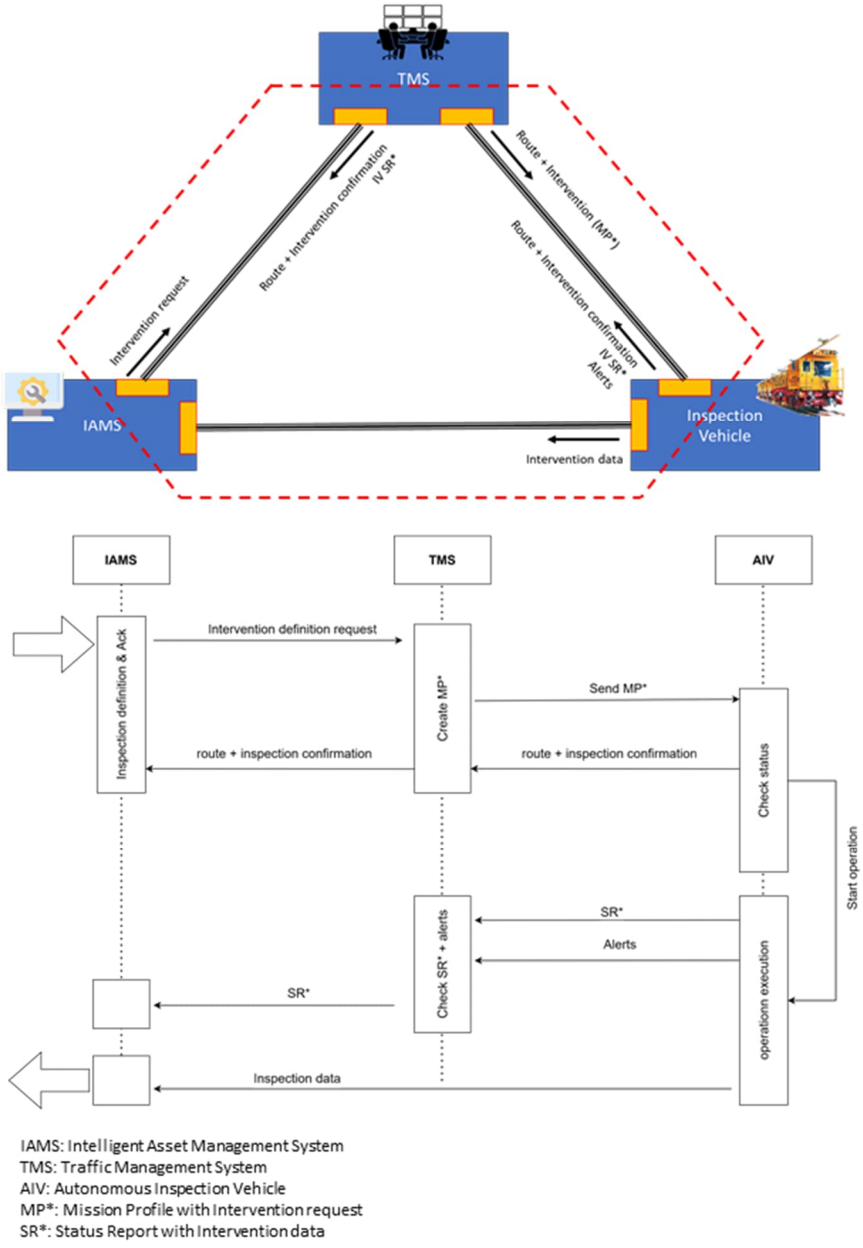
Sequence	1. IAMS requests to TMS the intervention to be sent to the Inspection Vehicle (AIV). 2. TMS sends the Mission Profile (MP) to the AIV with the route where AIV will travel. 3. AIV confirms the Route to TMS. 4. IAMS requests the interventions of the Inspection Vehicle (AIV) on specific track paths to Inspection Vehicle directly (AIV). 5. Inspection Vehicle (AIV) receives the route for the intervention and the intervention on the specific track from IAMS. 6. Inspection Vehicle (AIV) confirms the reception of the request to IAMS. 7. During the intervention AIV sends the Status Report (SR) and Alerts, if any, to TMS. 8. During the intervention AIV sends the Status Report* (SR*) to IAMS. 9. After the intervention, AIV sends the intervention data to IAMS.

Diagram(s)	
Expected Implementation Date	11 2024
Involved components (System)	Single PC with the SW developed with virtual docker interface.
Responsible partner/person	CEIT/Jaizki Mendizabal, Alfredo Artiles
Notes	Use case related to FP3-IAM4RAIL WP 3

7.9.3. FP1-DEMO-12.9-UC-03 – TMS-IAMS, IAMS-AIV, TMS-AIV interface

Use Case ID	**FP1-DEMO-12.9-UC-03**
Name	TMS-IAMS, IAMS-AIV, TMS-AIV interface
Partner	CEIT

Demo associated	Demo 12.9 (task 12.2.9)
Description	Definition and development of the Interface of the future autonomous Inspection Vehicle for the infrastructure (FP3) and its integration with the Intelligent Asset Management System (IAMS) and the Traffic Management System (TMS). To exchange information about asset status, planned interventions, and allocated paths to execute inspections and interventions.
Related to task/subtask(s)	Tasks 11.3.9, 12.2.9
Impact on other task(s)	Tasks 11.1 and 11.2 about development requirements and alignment.
Technical Enabler(s)	TE 10 - "Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching"
Interactions SP/FP	FP3-IAM4RAIL
Actor(s)	TMS, IAMS, Inspection Vehicle (AIV)
Trigger	IAMS generates an intervention order for AIV
Pre-Condition(s)	• IAMS and AIV communication stablished, • IAMS obtains AIV location info from AIV.
Input	• Required inspection intervention (Intervention), • Inspection Vehicle location, • Allocated path for inspection vehicle based on asset status and planned interventions.
Result/Requirement	Definition and development of an interface enabling the following: • AIV receives the Intervention request, • IAMS receives Intervention data, Alerts and Status Report*.
Final State	Interface operational that allows the following: • AIV finished intervention and parked in its final location, • IAMS with intervention data and alerts.
Sequence	1. IAMS requests to TMS the intervention to be sent to the Inspection Vehicle (AIV). 2. TMS sends the Mission Profile* (MP*) to the AIV with the route where AIV will travel and with the requests of interventions of the Inspection Vehicle (AIV) on specific track paths. 3. Inspection Vehicle (AIV) receives the route to travel for the intervention and the intervention on the specific track from IAMS. 4. AIV confirms to TMS, the route and the reception of the interventions request.

	5. During the intervention AIV sends the Status Report* (SR*) and Alerts, if any, to TMS. 6. During the intervention TMS sends the Status Report* (SR*) to IAMS. 7. After the intervention, AIV sends the intervention data to IAMS.
Diagram(s)	
Expected Implementation Date	11 2024
Involved components (System)	Single PC with the SW developed with virtual docker interface.
Responsible partner/person	CEIT/Jaizki Mendizabal, Alfredo Artiles

Notes	Use case related to FP3-IAM4RAIL WP 3

8. Specification of processes and requirements for communication

This chapter collects for each demonstration planned in WP 12, the requirements for processes and related communication between systems and modules of the respective demonstration systems especially with regards to the use of harmonised interfacing as e.g., TD2.9 IL/TCCS model (System Pillar) or Telematics TSI. This approach enables the basis for supporting and enhancing the interoperable data exchange between systems and modules related to Traffic Management Systems which is to be maintained by the System Pillar.

Related with Deliverable D10.2 “Data Definition for demonstrators in WPs 11-18” in the framework of the Flagship Project 1 – [MOTIONAL] as described in the EU-RAIL MAWP, the requirements delivered in this document were developed in cooperation with Task 10.3 "Specification of demonstrator environment/framework and identification of data structures" in which demonstrator environments/frameworks are identified and the high-level data requirements enabling the demonstration activities are specified. The relevant guidelines delivered by WP2 about setting up requirements and coordination activities were also considered.

This chapter is divided into subsections linked to the alignment activities of Task 11.1 and the Task 11.2 "Specifications" based on the related high-level requirements and Use Cases delivered by WP10, considering input from corresponding activities of Shift2Rail. Task 11.3 "Development of prototypes" with its subtasks 11.3.1 to 11.3.9 in turn are associated with each of the developments covered in WP 11.

As a result, a complete set of requirements that have been agreed upon between all partners involved in the work package, broadly categorised into functional, non-functional, and operational requirements is given.

- The functional requirements specify the intended features and functions of the system.
- The non-functional requirements define system attributes and give specifications on how the system should perform, and the operational requirements ensure compliance with RU-/IM-internal, national, and EU-wide regulations.

These requirements were developed with a view towards fulfilment of the High-Level requirements defined in D10.1 [3] for the MAWP’s Technical Enablers 8, 9 and 10 covering specification, and development of use-cases, processes and interfaces needed to achieve a much higher integration level of functions and decision processes including increase of the precision of the traffic prediction.

As introductory text, each demo partner must provide a brief description, what components/systems are/should be connected to the demonstrator configuration in a future TMS, potentially referring to the existing TMS architecture (RCA, …).

In Table 4 below the template to be used for functional requirements is shown.

Requirement ID	***WP11_Demo<demo no>_FRQ_xxx***
Requirement	*Give a descriptive name or title to the requirement so that it is easily identifiable.*
Type	*Functional*
Priority	*Shall: Indicates a strong obligation or a requirement that must be compulsorily fulfilled.* *Should: Indicates a recommendation or requirement that is considered important, but not necessarily mandatory.* *May: Indicates an option or permission. This word suggests that an action or condition is permitted, but not required.*
Main goal	*Concisely describe the fundamental purpose of the requirement.*
Assumptions	*Any assumptions or conditions assumed in relation to the functional requirement. These assumptions may include important information that is not specifically stated in the requirement but is considered essential to compliance with the requirement. (Integration or interaction with existing systems, user interaction, …)*
Specifications	*Detailed description of the requirement. It includes a clear explanation of what the system shall/should/may do or the actions that shall/should/may be supported.*
Additional information and background	*Any additional information or comments that are relevant to the requirement. This may be helpful to provide clarification or additional context. It should be clear and directly related to the description of the requirement.* *Link to the related High-Level Requirements of the TE specification shall be included here.*

Table 4: Template for the definition of the functional requirements

Table 5 below shows the template to be used for the non-functional requirements.

Requirement ID	***WP11_Demo<demo no>_NFRQ_xxx***
Requirement	*Give a descriptive name or title to the requirement so that it is easily identifiable.*
Type	*Non-functional*
Priority	*Shall: Indicates a strong obligation or a requirement that must be compulsorily fulfilled.* *Should: Indicates a recommendation or requirement that is considered important, but not necessarily mandatory.* *May: Indicates an option or permission. This word suggests that an action or condition is permitted, but not required.*
Main goal	*Concisely describe the fundamental purpose of the requirement.*
Assumptions	*Any assumptions or conditions assumed in relation to the non-functional requirement. These assumptions may include important information that is not specifically stated in the requirement but is considered essential to compliance*

	with the requirement. (Valid input data, resource availability, compliance with standards or regulations, …)
Specifications	*Detailed description of the requirement. It describes the features or constraints that shall/should/may be met, such as performance, security, scalability, …*
Additional information and background	*Any additional information or comments that are relevant to the requirement. This may be helpful to provide clarification or additional context. It should be clear and directly related to the description of the requirement.*

Table 5: Template for the definition of the non-functional requirements

8.1. Processes and communication requirements for Subtask 1 (ATSA)

In subtask 11.3.1 ATSA developed interfaces from the Communication Platform to the Timetable Management applications and to the Traffic Control (RBC, Interlocking).

The prototype work was focused around designing the integration between Timetable Management Application (TMS) and Traffic Control (CTC system) over Communication Platform (COM-P) being an ATSA implementation resulting from the S2R Integration Layer concept.

The work around the integration prototype was focused on:

- designing a generic and interoperable API of the IL (COM-P) to support communication with TMS and CTC.
- designing and implementing adaptors for existing CTC and TMS systems allowing them to use a generic COM-P API.
- extending internal COM-P domains to handle and provide all information being published to or requested from COM-P.

8.1.1. Logical architecture

The solution involves the following existing ATSA systems:

- Traffic Management System (TMS).
- Centralised Traffic Control CTC system.
- Communication Platform (COM-P).

To integrate the already existing systems via COM-P, dedicated adaptors were designed. The primary purpose of them is to align system-specific APIs into generic, interoperable API of the COM-P.

In Figure 2 below, the subsystems involved in the interaction are shown in a logical architecture diagram. Arrows represent information flows between systems in the scope of the implemented integration approach.

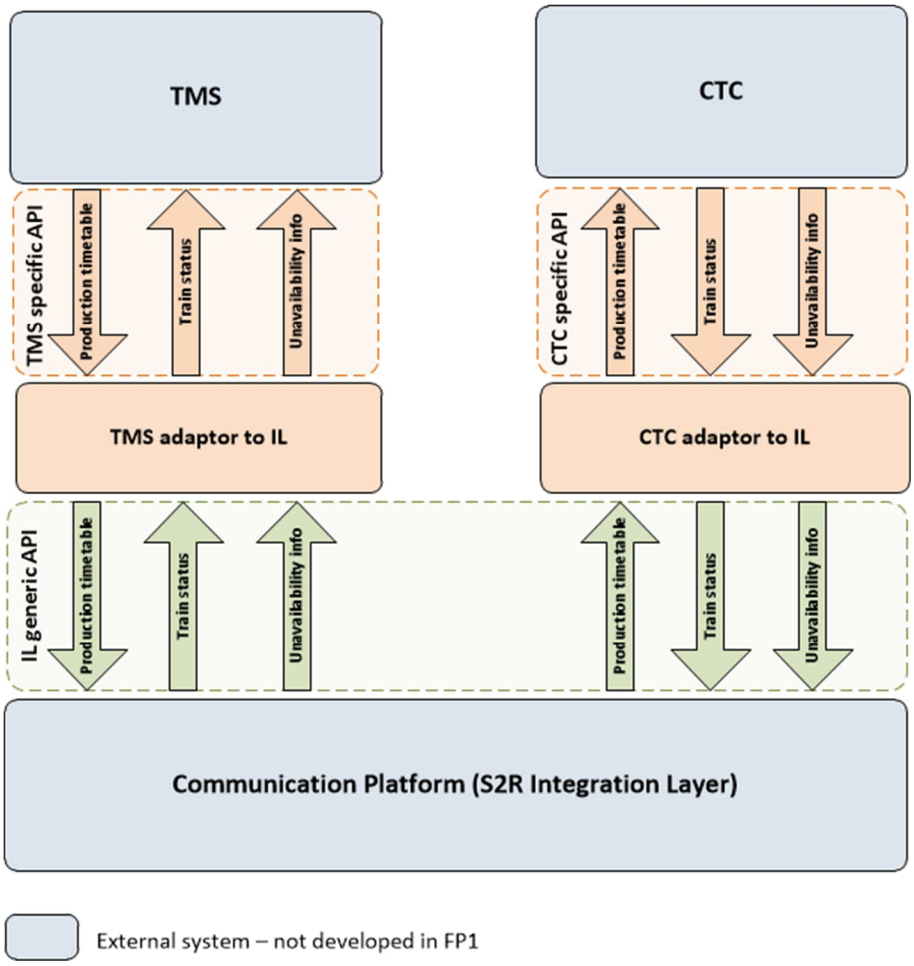


Figure 2: Logical architecture of demonstration 12.1

8.1.2. Functional requirements

Requirement ID	**WP11_Demo12.1_FRQ_001**
Requirement	COM-P shall provide a generic timetable information exchange interface
Type	Functional
Priority	Shall
Main goal	The generic interface allows to integrate different systems via the COM-P that exchange information from a timetable area.
Assumptions	The COM-P should work independently of all cooperating client systems exchanging timetable information via the interface.
Specifications	The interface shall provide a set of operations allowing a COM-P client system to store information on a COM-P, read information from a COM-P and being notified about information change. Each operation shall define parameter in a form of a DTO (Data Transfer Object) allowing to pass it as its argument. Actions initiated by the COM-P client shall support possibilities to: • Publish complete, new timetable

	• Update already published timetable • Get the timetable • Get individual trip from the timetable The COM-P shall provide notification about timetable modifications and allows COM-P clients to subscribe for this notification.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

Requirement ID	**WP11_Demo12.1_FRQ_002**
Requirement	COM-P shall provide a generic train status information exchange interface.
Type	Functional
Priority	Shall
Main goal	The generic interface allows to integrate different systems via the COM-P that exchange information from a train operation area.
Assumptions	The COM-P should work independently of all cooperating client systems exchanging timetable information via the interface.
Specifications	The interface shall provide a set of operations allowing a COM-P client system to store information on a COM-P, read information from a COM-P and being notified about information change. Each operation shall define a parameter in a form of a DTO (Data Transfer Object) allowing to pass it as its argument. Actions initiated by the COM-P client must support possibilities to: • Publish train status • Get train status The COM-P must provide notification about new train status publication and allows COM-P clients to subscribe for this notification.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1

Requirement ID	**WP11_Demo12.1_FRQ_003**
Requirement	COM-P shall provide a generic restrictions / limitations information exchange interface.
Type	Functional
Priority	Shall
Main goal	The generic interface allows to integrate different systems via the COM-P that exchange information from a restriction / limitations area. It should allow to exchange unavailability information about railway infrastructure objects.
Assumptions	The COM-P should work independently of all cooperating client systems exchanging timetable information via the interface.
Specifications	The interface shall provide a set of operations allowing a COM-P client system to store information on a COM-P, read information from a COM-P and being notified about information change.

	Each operation shall define parameter in a form of a DTO (Data Transfer Object) allowing to pass it as its argument. Actions initiated by the COM-P client must support possibilities to: • Publish unavailability information for a specific railway infrastructure object. • Update unavailability status of specific railway infrastructure object. • Get status of specific railway infrastructure object. The COM-P must provide notification about new unavailability status being published on COM-P and allows clients to subscribe for this notification.
Additional information and background	Linked to TE 8 and TE 10, High-Level Requirements 8.2, 10.2, 10.3.

8.1.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.1_NFRQ_001**
Requirement	The COM-P interfaces shall be interoperable.
Type	Non-functional
Priority	Shall
Main goal	The COM-P interface should allow to integrate different systems delivered by different vendors that need to exchange information from one or more railway areas supported by the COM-P.
Assumptions	The COM-P Interface build out of operations and data structures passed as their arguments should be interoperable. Shall not use any client system specific operations or concepts. It should stay on a generic level and not be influenced or controlled by any of client system.
Specifications	The list of operations defined by COM-P API should contain universal set of operations allowing interaction with the data. The DTO structure used to pass information with the operation should be independent of the client systems specific definitions.
Additional information and background	None.

Requirement ID	**WP11_Demo12.1_NFRQ_002**
Requirement	The COM-P should allow the integration of existing systems without need of their modifications or extensions
Type	System
Priority	Shall
Main goal	Dedicated components / adaptors should be delivered to allow interaction an existing client systems using its own private and specific interface with the COM-P. The adaptor should be responsible for adopting this specific interface into generic COM-P interface.
Assumptions	Usage of the adaptor should be limited to the situations where client system

	cannot use COM-P generic API by itself.
Specifications	The adaptors should work as COM-P plugins and a dedicated client system adaptor should be installed only when client system needs to communicate with COM-P.
Additional information and background	None.

8.1.4. Components and functions

Subsystems in ATSA demonstrator that are taking part in the interactions are as follows:

- TMS: provides the most actual production timetable, subscribes for train status information to optimise the operational timetable, and unplanned limitations (unavailability info).
- CTC: manages the train traffic according to received production timetable, delivers train status on IL to be shared with other systems (TMS). The CTC delivers information about railway infrastructure object status – the unavailability info.
- COM-P – distributes information between systems.

Within the current ATSA prototype a concept of clients´ systems adaptors to COM-P was developed. The main role of a client system adaptor to COM-P is to align the external system specific API with the generic / interoperable API of the COM-P.

Alignment includes the data structure and processes that do not have to be the same on the external system and on COM-P side.

The adaptor concept to COM-P eliminates the need of external system extensions or modifications which can be costly, problematic or even not possible.

Each external system adaptor is also a plug-in to the COM-P. In this way it can be installed with the COM-P or not, and the installations of COM-P can differ from each other from a perspective of installed plugins and the same connected systems.

There is still no obligation that the client system needs to use a dedicated adaptor to connect to the COM-P. The preferred solution is to natively use the generic / interoperable COM-P API by external systems directly.

8.1.5. Interfaces

The generic / interoperable API of the Communication Platform utilises two approaches for communication:

1. The synchronous one – it is used to publish information on the COM-P or ask for information. The REST technology is used for this purpose. The REST API is organised as a set of GET, POST, PUT, DELETE operations with DTO (Data Transfer Object) passing as arguments of an operation.

2. The asynchronous one – it is used for client systems notifications about changes on COM-P. For this purpose, the messaging technology is used. The notification transfers usually only most important data. The client system can decide itself what should be its the next step after receiving such notification. It can take some internal action or ask COM-P for additional information.

Examples of COM-P notifications are:

- New timetable is available
- New train status was published
- Infrastructure element became unavailable

For systems that needs to be integrated with COM-P but cannot use its native API directly a solution with dedicated adaptor to COM-P is proposed.

8.2. Processes and communication requirements for Subtask 2 (PKP)

Subtask 11.3.2 involves PKP developing a robust integration solution designed specifically for the data exchange and storage system, commonly referred to as a Data Lake. The objective of this solution is to facilitate seamless data exchange through well-defined and efficient interfaces, enabling the transfer of various types of data between different systems and stakeholders. In addition to supporting data transfer, this integration solution also includes mechanisms for assessing the quality of incoming data, ensuring that only high-quality, reliable information is stored and processed within the Data Lake. This quality assessment capability will help in maintaining data integrity, accuracy, and consistency across the platform, which are essential for effective data-driven decision-making.

Moreover, the integration solution encompasses functionalities for metadata generation. Metadata, or 'data about data,' provides context and meaning to the raw data, making it easier for users and systems to understand, locate, and utilise information within the Data Lake. With these metadata generation tools, the system will automatically generate essential descriptors and tags, classifying data elements and enabling quick access and searchability across vast datasets. This feature will not only streamline data management but will also support compliance with data governance standards and best practices.

Ultimately, this integration solution will serve as a bridge to connect various disparate decision support systems, which may currently operate in isolation or with limited interoperability. By integrating these systems, the solution aims to create a unified platform where data can be shared and accessed securely, allowing for comprehensive analyses, insights, and decisions that leverage a broader, interconnected data ecosystem.

8.2.1. Logical architecture

Upon request, the system provides the decision maker i.e. station operator with prepared information allowing the evaluation of trans-border attractivity of a given station. It collects three components:

- The Data Lake (DL), stores and prepares all the relevant data for the municipal level operation of the station and related operators. It is responsible for accessing data among the others from TMS and preparing it in the relevant way.
- The Decision Support System (DSS) prepares the analysis using data obtained from DL which consists of trans-border traffic potential of the considered station provided given constraints (both temporal and geographical). In case of repeated requests for the same constraints already generated analysis is stored in the DL.
- The Dashboarding system is a BI type of software which serves both as an interface for providing constraints to the decision support system and as a visualisation platform allowing the usage of the analysis.

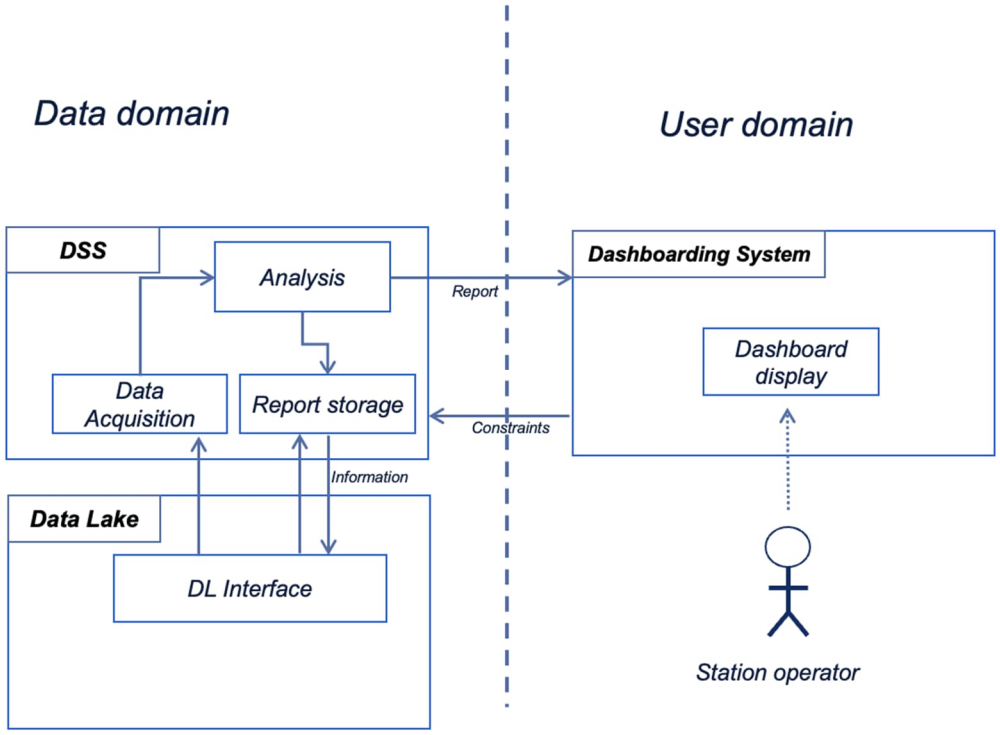


Figure 3: Logical architecture of demonstrator 12.2

Figure 3 shows the logical architecture of the system:

- The DSS uses Data Lake information necessary for appropriate valuation and marketing of real estate. One of the methods of increasing the attractiveness of a railway station is promoting its accessibility as a transfer hub. An aspect that is neglected is the trans-border travel availability. Often, even station operators do not know how accessible the station is just by few railway connections. The System will leverage data centralisation of available trans-border travel data into reliable information about international reach of the considered station.
- The overall purpose – system will provide the decision maker (station operator) with information about trans-border reach of individual station, including accessibility and timing of connection to selected Destinations. This shall be suited for the purposes of individual station operator, depending on its level in the organisation. Two cases of application can be easily identified – one for large transport hubs, connecting major cities across borders, and the smaller case of stations near the border where railway traffic can supplement hiking trips for example through Carpathian Alps.

- System will interface with Data Lake solution containing necessary information for system operation. In particular it will be able to access appropriately processed timetables from international databases and geolocated information about station locations. It will also interface with dashboards allowing efficient specification of necessary support information.

8.2.2. Functional requirements

Requirement ID	**WP11_Demo12.2_FRQ_001**
Requirement	Generation and provision of a report for station operators with prepared information allowing the evaluation of trans-border attractivity of a given station
Type	Functional
Priority	Should
Main goal	Obtaining a complete report in accordance with required contents.
Assumptions	The station operator provides the search parameters: • date, • starting station, • time limits in hours. for which he wants to receive a report.
Specifications	The system should include a report for station operators on prepared information allowing the evaluation of trans-border attractivity of a given station. The report prepares and stores all the relevant data for the municipal level operation of the station and related operators.
Additional information and background	Linked to TE 9, High-Level Requirement 9.4.

8.2.3. Non-functional requirements

Requirement ID	**WP11_Demo12.2_NFRQ_001**
Requirement	Clear presentation of data for the operator
Type	Non-functional
Priority	Should
Main goal	Data panels should be designed in such a way that operators can quickly filter the information necessary to make decisions about cross-border travel and present the necessary data in a transparent manner.
Assumptions	The design of dashboards must be consulted with rail operators.
Specifications	System has to be scalable in a way, that will allow adding new stations and new Data Lake matrices without impending operation of decision support mechanisms.
Additional information and background	None.

Requirement ID	WP11_Demo12.2_NFRQ_002
Requirement	Time to create the report
Type	Non-functional
Priority	Should
Main goal	Obtaining a complete report in accordance with the given constraints within the given time.
Assumptions	The station operator provides the search parameters: • date, • starting station, • time limits in hours and uses them for starting the report.
Specifications	Preparing of the report takes no longer than 5 minutes.
Additional information and background	Linked to TE 9, High-Level Requirement 9.4.

8.2.4. Components and functions

The demonstration system features the following components and functions:

- Dashboarding system: Information visualisation system for reports obtained from DSS.
- DSS: A specialised system for collecting information and processing it to obtain a report for analysts.
- Data Lake: A central point for collecting information in the system from multiple sources.

8.2.5. Interfaces

The interfaces in this system play a pivotal role in enabling seamless data exchange, ensuring that each component—Data Lake, Decision Support System, and Dashboarding System—can interact effectively to deliver valuable insights to decision makers. Each interface is designed to facilitate smooth data flow, access, and interaction between these components, guaranteeing that data is collected, transformed, and visualised as required by the system's end-users.

1. **Interface between Decision Support System (DSS) and the Data Lake:** This interface enables the DSS to access and retrieve necessary data from the Data Lake. The interface performs essential functions, such as querying data, validating access permissions, and transforming data into an analyzable format. It ensures that the DSS receives up-to-date, high-quality data that has been pre-processed according to the requirements of municipal-level operations and trans-border traffic analysis.
2. **Interface between Dashboarding System and Data Lake and DSS:** This interface acts as a bridge between the BI Dashboarding System, the Data Lake, and the DSS. It enables users to input specific constraints (e.g., geographic and temporal filters) into the Dashboarding System, which are then relayed to the DSS to generate relevant analyses. The interface also facilitates access to previously stored results in the Data Lake, allowing rapid retrieval of existing insights. Furthermore, it serves as a data retrieval channel, pulling visualisable data from both the DSS and Data Lake and feeding

it into the dashboard for user-friendly visualisation. This interface is designed to support real-time interactions, allowing decision makers to modify parameters and instantly see updated analyses, thus enhancing the system's responsiveness and interactivity.

3. **ETL Interface for Data Lake Management:** This interface is responsible for Extracting, Transforming, and Loading (ETL) data into the Data Lake. It collects data from various sources, such as TMS, and conducts essential transformation processes—standardising, cleaning, and structuring the data for consistency. This interface is integral to maintaining the Data Lake's accuracy, as it automatically updates data in response to any changes in external sources, ensuring the lake contains current information. Additionally, it supports data integration and scheduling, allowing data to be processed and loaded based on predefined intervals or specific triggers.

8.3. Processes and communication requirements for Subtask 3 (STS)

Subtask 11.3.3 STS developed an interface sending information from TMS Planning subsystem to an ATO-TS control module to maximise the energy efficiency of the train operation in a short-term action.

8.3.1. Logical architecture

The aim of this prototype is to develop an evolution of TMS – ATO-TS interface involving a new detailed timetable data to optimise traffic condition and to reduce the energy consumption during train operations. For this purpose, an interface between TMS Planning Subsystem and ATO-TS Control Subsystem is provided to reduce the energy consumption during train operations.

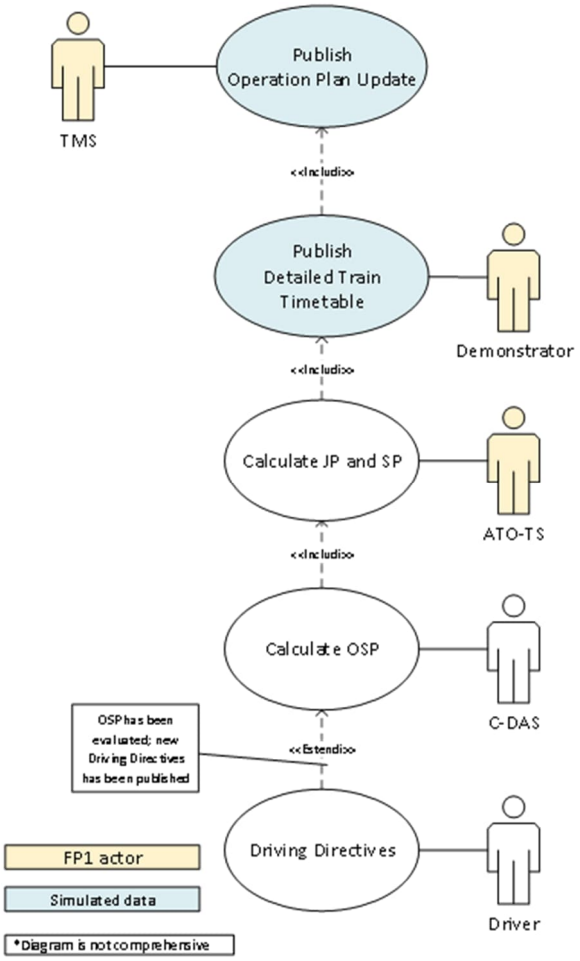


Figure 4: Logical architecture of demonstration 12.3

In detail, the TMS Planning Subsystem generates a detailed timetable capable of providing intermediate timing points useful to the ATO-TS Control Subsystem for JP-SP packet generation to be sent to the C-DAS system, see also Figure 4. This C-DAS system uses intermediate timing point data to calculate the energy efficient speed profile enabling the train to achieve the planned timetable with optimum energy usage.

8.3.2. Functional requirements

Requirement ID	WP11_Demo12.3_FRQ_001
Requirement	The TMS shall provide the operation plan in the IL
Type	Functional
Priority	Shall
Main goal	The TMS provides the Operational Plan to the ECO-DRIVE TMS module through the IL.
Assumptions	The data to be provided by the TMS in the IL should be standardised and in line with the Concept Data Model (CDM). ECO-DRIVE is a TMS module, that, starting from the last received timetable, calculates the energy efficient speed profile, and generates a detailed timetable to be sent to ATO-TS via IL and then to C-DAS C using Subset 126 (CCS TSI).
Specifications	The TMS shall provide in the Integration Layer the operation plan, that includes timetables, capacity reservations (e.g., Train run, shunting movement, stabling) and capacity limitations (e.g., planned maintenance work).
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

Requirement ID	WP11_Demo12.3_FRQ_002
Requirement	Energy savings-oriented TMS dynamic headway conflict resolution
Type	Functional
Priority	Shall
Main goal	The TMS, when applying the energy savings-oriented conflict resolution selected by the operator, will try to keep constant the speed (and the separation) of the trains that are part of the conflict, thus, intrinsically reducing the number of accelerations and decelerations. This will provide to ECO-DRIVE module improved timing constraints.
Assumptions	ECO-DRIVE module will receive the new timetable that solves the conflict and then generate the Detailed Time Table to be given to ATO-TS.
Specifications	None.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

Requirement ID	WP11_Demo12.3_FRQ_003
Requirement	ECO-DRIVE shall generate the Detailed Timetable for the ATO
Type	Functional
Priority	Shall
Main goal	ECO-DRIVE, starting from the last received timetable, calculates the energy efficient speed profile, and generates a detailed timetable to be sent to ATO-

	TS via IL and then to C-DAS C using Subset 126 (CCS TSI).
Assumptions	ECO-DRIVE module will then generate the Detailed Timetable to be given to ATO-TS.
Specifications	None.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

Requirement ID	**WP11_Demo12.3_FRQ_004**
Requirement	The ATO-TS shall generate the ATO plan based on the Detailed Timetable.
Type	Functional
Priority	Shall
Main goal	The ATO-TS generates the ATO plan to be sent to the different ATO-OBU.
Assumptions	The Detailed Timetable available in the IL should be standardised and in line with the CDM. The boundary between TMS and ATO-TS functions should be clearly defined.
Specifications	The ATO trackside shall generate from the Detailed Timetable available in the IL the required information for the ATO plan inside a given bandwidth of operation performance. The plan shall consider the line characteristics and the train composition and shall provide for each chunk of the Detailed Timetable the acceleration/deceleration/coasting/cruising directives to be applied.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

8.3.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.3_NFRQ_001**
Requirement	Communication interface between TMS and ATO-TS.
Type	Non-functional
Priority	Shall
Main goal	Define the interface between TMS and ATO-TS.
Assumptions	Currently no standardised interface between TMS and ATO exists.
Specifications	The data format shall follow the format defined in the MOTIONAL WP 15, Sub-Task 15.4.4.
Additional information and background	None.

Requirement ID	**WP11_Demo12.3_NFRQ_002**
Requirement	The interface between ATO-TS and ATO-OBU meet the interface defined in the Subset-126.
Type	Non-functional

Priority	Shall
Main goal	The interface between ATO-TS and ATO-OBU follows the CCS TSI.
Assumptions	None.
Specifications	The ATO trackside shall implement the communication with all registered ATO vehicles and provides the standardised interface between ATO-TS and ATO OBU defined in the Subset-126 (CCS TSI).
Additional information and background	None.

8.3.4. Components and functions

ECO-DRIVE: A module for the TMS that generates a detailed timetable to be sent to the ATO-TS to minimise energy consumption.

8.3.5. Interfaces

The module developed uses the existing interface between TMS and ATO-TS.

8.4. Processes and communication requirements for Subtask 4 (INDRA)

Subtask 11.3.4 INDRA develops interfaces from the TMS to wayside C-DAS operation system focusing on speed profile functionalities.

Nowadays, the communication between the TMS and C-DAS is not implemented in the current systems. This communication is able to provide updated information related to the real-time traffic plan to wayside C-DAS system in order to update and improve the calculation of the speed profiles and share out it with the trains through the onboard C-DAS.

8.4.1. Logical architecture

These interfaces allow the evolution from S-DAS to C-DAS providing updated speed profiles in a regular basis.

The prototype system (see Figure 5) is designed to facilitate the interface between the Traffic Management System (TMS) and the Connected Driver Advisory System (C-DAS) to enhance real-time speed profile functionalities. The logical architecture comprises the following components and interactions:

- TMS (Traffic Management System):
  - Real-Time Management Module: Provides real-time data including the planned train schedule with modifications.
  - Router (ARS) and CTC: Provide route availability information to the C-DAS.
- Integration layer (IL): Facilitates the exchange of data between TMS and C-DAS TS.
- C-DAS (Connected Driver Advisory System):
- Trackside System (C-DAS TS): Receives the planned train schedule and route availability from the TMS and sends status reports including train position and speed back to the TMS.
- Onboard System (C-DAS OB): Calculates speed profiles and provides advisories to the train driver based on the data received from the C-DAS TS.

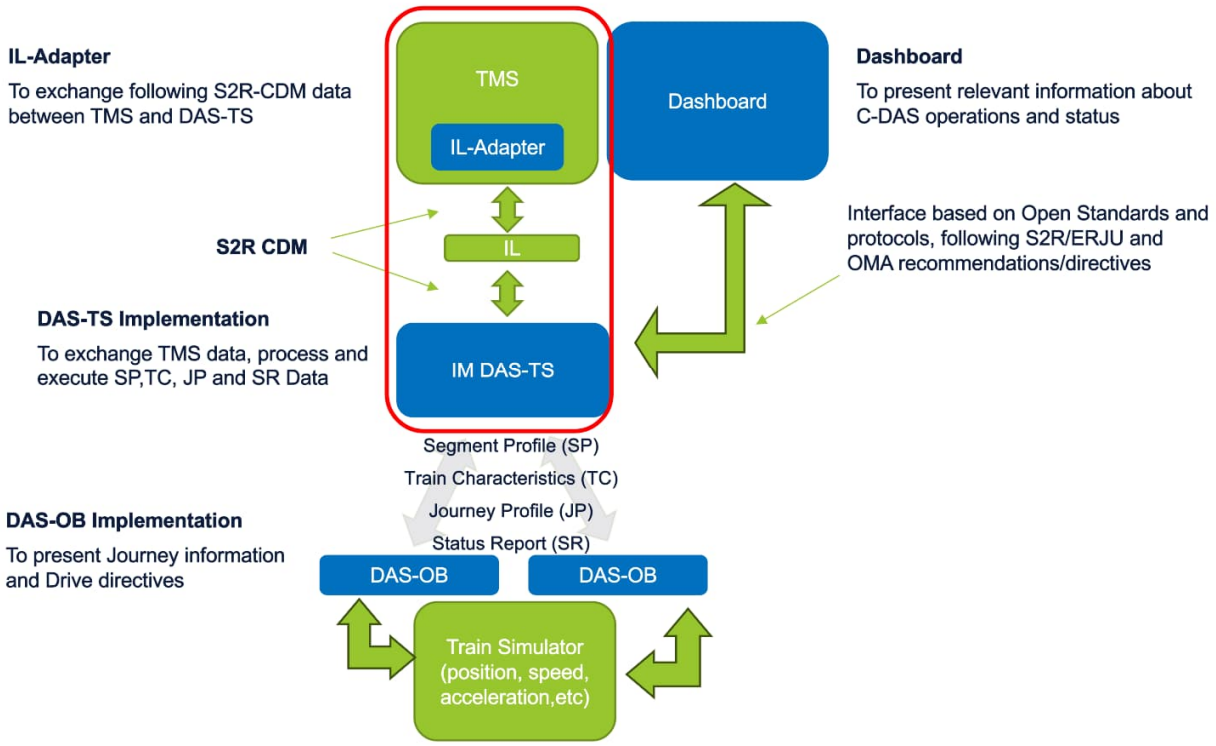


Figure 5: Logical architecture of demonstration 12.4

8.4.2. Functional requirements

Requirement ID	**WP11_Demo12.4_FRQ_001**
Requirement	The TMS shall provide the target run to C-DAS-TS through the IL
Type	Functional
Priority	Shall
Main goal	The TMS provides the target run to the C-DAS-TS through the IL.
Assumptions	• The data to be provided by the TMS in the IL shall be standardised and in line with the Canonical Data Model (CDM). • The boundary between TMS and C-DAS-TS functions shall be clearly defined.
Specifications	The TMS shall provide in the Integration Layer the target run, which includes the trips operations points, trips date, the times for each trip.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

Requirement ID	**WP11_Demo12.4_FRQ_002**
Requirement	The C-DAS-TS shall provide the trains speed and position to TMS through the IL
Type	Functional
Priority	Shall

Main goal	The C-DAS-TS provides the trains speed and position to the TMS through the IL.
Assumptions	• The data to be provided by the C-DAS-TS in the IL shall be standardised and in line with the Canonical Data Model (CDM). • The boundary between TMS and C-DAS-TS functions shall be clearly defined.
Specifications	The C-DAS-TS shall provide in the Integration Layer the trains speed and position.
Additional information and background	Linked to TE 8, High-Level Requirement 8.1.

8.4.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.4_NFRQ_001**
Requirement	Standardised communication interface between TMS and C-DAS-TS
Type	Non-functional
Priority	Shall
Main goal	The interface between TMS and C-DAS-TS shall be standardized.
Assumptions	• Communication standardisation between TMS and C-DAS-TS shall use data defined in Canonical Data Model (CDM). • Messages for communication protocol may include heartbeat, dataRequest, dataResponse, dataNotification.
Specifications	The TMS and C-DAS-TS shall use a standardised communication interface.
Additional information and background	None.

Requirement ID	**WP11_Demo12.4_NFRQ_002**
Requirement	Robustness of the communication interface between TMS and C-DAS-TS
Type	Non-functional
Priority	Shall
Main goal	Ensure the communication interface remains stable and operational under various conditions, including high traffic volume and intermittent network connectivity.
Assumptions	It is assumed that the communication interface will be used in real-world operational environments with potential network fluctuations and disturbances.
Specifications	The communication interface shall include mechanisms for error detection, correction, and recovery to maintain uninterrupted data exchange.
Additional information and background	None.

8.4.4. Components and functions

Below the key components and their functions are listed.

Traffic Management System (TMS):

- Allows to plan and re-plan the timetable of the trains.
- Calculates de target timetable (RTTP) of the trains and sends the information to the integration layer.
- Dashboard: Displays information about C-DAS operations and status, based on standardised protocols and **recommendations.**

Integration Layer

- IL-Adapter: Facilitates the exchange of the planned train schedule (RTTP) between TMS and C-DAS TS using the S2R CDM standard.
- Integration Layer (IL): Serves as the communication bridge between TMS and C-DAS TS.

DAS-TS Implementation (IM DAS-TS):

- Implementation Module: Receives and processes the planned train schedule (RTTP) from TMS, and sends necessary data to DAS-OB.

8.4.5. Interfaces

The interfaces between TMS and C-DAS TS are bidirectional. The interface from TMS to C-DAS TS provides the planned train schedule and route availability with data type Real-Time Train Plan (RTTP) through Custom integration layer based on protocol S2R CDM (Shift2Rail Common Data Model). The interface from C-DAS TS to TMS provides the real-time train status including speed and position with data type Status Report (SR) through Custom integration layer based on protocol S2R CDM.

TMS to C-DAS TS:

- Data Type: Real-Time Train Plan (RTTP).
- Protocol: Custom integration layer based on S2R CDM (Shift2Rail Common Data Model).
- Function: Provides the planned train schedule and route availability.

C-DAS TS to TMS:

- Data Type: Status Report (SR).
- Protocol: Custom integration layer based on S2R CDM.
- Function: Sends real-time train status including speed and position.

8.5. Processes and communication requirements for Subtask 5 (MERMEC)

Subtask 11.3.5 MERMEC developed traffic management system modules implementing interfaces between neighbouring TMS and IMs focused on cross-border traffic management.

Nowadays TMS have some limitations in communication which usually does not contain important data such as border train delays for instance. When a train goes from station A to station B passing national cross-area, TMS 1, which owns station A, evaluates conflicts and delays, while TMS 2 evaluates them when the train leaves the border station. If the communication is performed with the aim of harmonising rail traffic between two neighbouring TMS, then TMS 2 could evaluate conflicts and delays of the given train as soon as TMS 1 starts sending data.

A similar approach could be easily extended to an international cross border scenario.

8.5.1. Logical architecture

The demonstrator (see Figure 6) provides a system in which to validate the interface between two TMS. Every TMS shares information regarding the border area, such as train delay and conflicts.

For the Use Cases FP1-DEMO-12.5-UC-01 and FP1-DEMO-12.5-UC-02 the TMS involved modules are the Deviation, Forecast, Conflict Detection, Conflict Resolution and the TMS-to-TMS Communication Interface. The output is an updated Operational Plan.

In the FP1-DEMO-12.5-UC-01 the TMS the operator resolves a conflict for a train at a specific border timing point and this solution is sent through the TMS-to-TMS Communication Module to remote to be approved.

In the FP1-DEMO-12.5-UC-02 the TMS-to-TMS Communication Module detects delay changes at a specific border timing point for each individual train passing at that point and manages it sending to the right Destination (e.g. local modules if received from remote or vice versa).
The user interface is at least a Train Graph and a train schedule detail view.

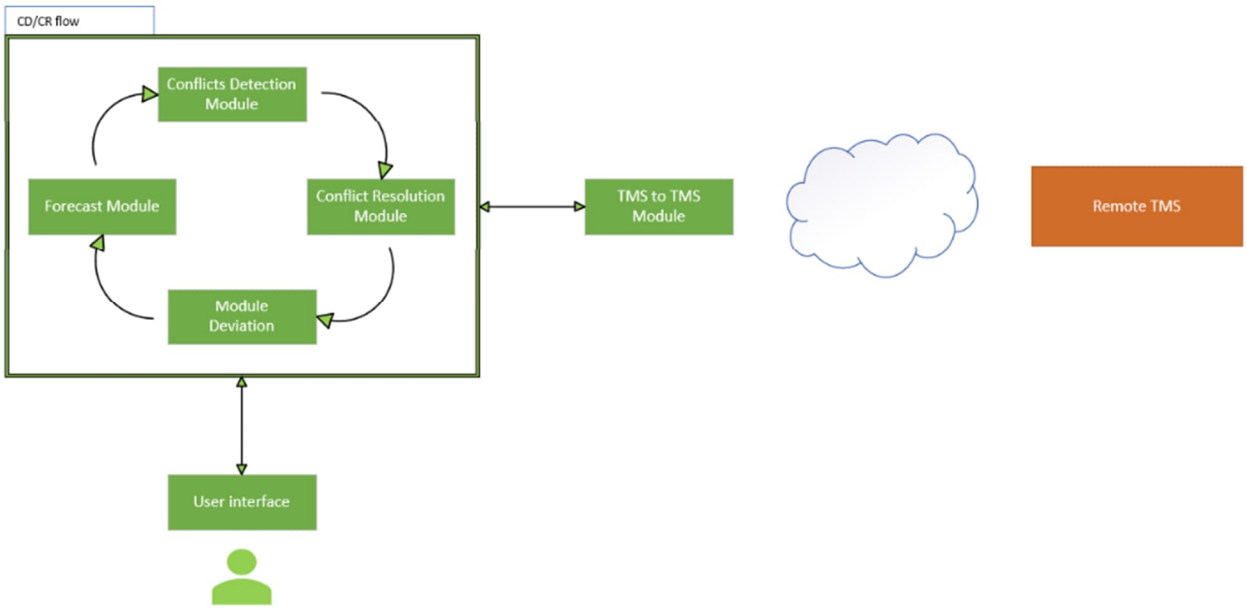


Figure 6: Logical architecture of demonstration 12.5

8.5.2. Functional requirements

Requirement ID	**WP11_Demo12.5_FRQ_001**
Requirement	The TMS border interface shall send forecast information for border trains.
Type	Functional
Priority	Shall
Main goal	Improving cross-area trains forecast evaluation by using the neighbour TMS forecast.
Assumptions	The oriented track point (e.g., the System Pillar infra DirTrackEdgePoint for border station and its track sections) is known into the topology data of both TMS.
Specifications	A variation on the forecast calculation for a cross-area train shall trigger the sending of the forecast message information.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_002**
Requirement	The TMS border interface shall receive forecast information for border trains.
Type	Functional
Priority	Shall
Main goal	Improving cross-area trains forecast evaluation by using the neighbour TMS forecast.
Assumptions	The oriented track point (e.g., the System Pillar infra DirTrackEdgePoint for border station and its track sections) is known into the topology data of both TMS.

Specifications	An inbound forecast message for a cross-area train shall be managed.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_003**
Requirement	The TMS border interface should exchange the information needed to evaluate the forecast on the target TMS.
Type	Functional
Priority	Should
Main goal	Improving cross-area trains forecast evaluation by using the neighbour TMS forecast.
Assumptions	The oriented track point (e.g., the System Pillar infra DirTrackEdgePoint for border station and its track sections) is known into the topology data of both TMS.
Specifications	The TMS border interface should contain at least the following information for border trains: • Train Identification (i.e. Train number, Origin, Departure time) • Movement (i.e. the timing point and time information)
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_004**
Requirement	The TMS border interface should exchange the information needed to justify the delay of specific train.
Type	Functional
Priority	Should
Main goal	Improving cross-area trains information.
Assumptions	The oriented track point (e.g., the System Pillar infra DirTrackEdgePoint for border station and its track sections) is known into the topology data of both TMS.
Specifications	The TMS border interface should contain at least the following information for border trains: • Notes (i.e. a list of delay justification notes)
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_005**
Requirement	The TMS border interface shall send the incoming capacity of the border station.
Type	Functional
Priority	Shall

Main goal	Improve forecast and conflict detection and resolution by considering also the capacity of the TMS behind the border
Assumptions	The TMS shall have a common cross-border track
Specifications	When the TMS receives a forecast for an incoming border train, it sends back the incoming capacity available for the border station.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirement 8.5 and 9.4.

Requirement ID	**WP11_Demo12.5_FRQ_006**
Requirement	The TMS border interface shall receive the incoming capacity of the border station.
Type	Functional
Priority	Shall
Main goal	Improve forecast and conflict detection and resolution by considering also the capacity of the TMS behind the border.
Assumptions	The TMS shall have a common cross-border track.
Specifications	An inbound capacity message for a border station shall be managed.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirement 8.5 and 9.4.

Requirement ID	**WP11_Demo12.5_FRQ_007**
Requirement	The TMS border interface shall notify a possible solution of a detected conflict in the cross-border area.
Type	Functional
Priority	Shall
Main goal	Resolve a cross-border area conflict.
Assumptions	The TMS shall have a common cross-border track.
Specifications	A possible conflict solution, e.g. establishing a priority for the occupation of the common resource, shall be notified to border TMS to be evaluated and approved.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_008**
Requirement	The TMS border interface shall receive a possible solution of a detected conflict in the cross-border area.
Type	Functional
Priority	Shall
Main goal	Resolve a cross-border area conflict.
Assumptions	The TMS shall have a common cross-border track.

Specifications	A possible conflict solution shall be notified to border TMS to be evaluated and approved.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.5_FRQ_009**
Requirement	The TMS border interface shall send the response to a received possible solution of a detected conflict in the cross-border area.
Type	Functional
Priority	Shall
Main goal	Resolve a cross-border area conflict.
Assumptions	The TMS shall have a common cross-border track, and a possible solution of a detected conflict in the cross-border area has been received.
Specifications	A response to a possible conflict solution shall be notified to border TMS with the following information: • Approved or rejected.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirement 8.2 and 9.4.

Requirement ID	**WP11_Demo12.5_FRQ_010**
Requirement	The TMS border interface shall receive the response to a received possible solution of a detected conflict in the cross-border area.
Type	Functional
Priority	Shall
Main goal	Resolve a cross-border area conflict.
Assumptions	The TMS shall have a common cross-border track, and a possible solution of a detected conflict in the cross-border area has been sent, and a response to the solution has been received
Specifications	The response is evaluated and if: • Accepted, the conflict must be considered as solved, • Rejected, the conflict must be evaluated again.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirement 8.2 and 9.4

Requirement ID	**WP11_Demo12.5_FRQ_011**
Requirement	Conflict display of predefined cross area path in TMS 1
Type	Functional
Priority	Shall
Main goal	Ensure that the operator responsible knows the conflict and choose a solution.
Assumptions	Given a predefined path on a cross-area train, in which there is a conflict, a

	warning should be displayed in the TMS responsible so that a decision can be made in advance.
Specifications	A conflict prevents operation as planned. For this reason, a warning shall be displayed in the TMS so that the Operator 1 can replan the cross-area train route.
Additional information and background	Linked to TE 9, High-Level Requirements 9.2 and 9.4.

Requirement ID	**WP11_Demo12.5_FRQ_012**
Requirement	Display the conflict solution proposed in TMS 2
Type	System Integration
Priority	Shall
Main goal	Reach an agreement between Operator 1 and Operator 2.
Assumptions	Operator 2 accepts or rejects the proposal solution. If Operator 2 rejects the proposal, he can add what is his solution to the conflict.
Specifications	A conflict prevents the operation as planned. For this reason, a warning shall be displayed on TMS B with the solution proposed by the TMS A Operator. Operator B must accept or reject the proposal depending on the situation in its control area. If he rejects the proposed solution, he must add a note so that the next proposal solution is appropriate to the situation.
Additional information and background	Linked to TE 9, High-Level Requirements 9.2 and 9.4.

Requirement ID	**WP11_Demo12.5_FRQ_013**
Requirement	Integrate an algorithm for real-time automatic conflict detection
Type	Functional
Priority	Shall
Main goal	Detect conflicts between the two TMS based on the real-time data received.
Assumptions	Both TMS have to implement the conflict detection. Additionally, with the integration, the two TMS will receive information in real time for automatic conflict detection.
Specifications	The TMS shall include a conflict detection module featuring an integrated algorithm for real-time automatic conflict detection using the information received in real time. The conflict detection module will detect and notify the Operator that there is a conflict. This must respond to the notice by choosing

	a possible solution to the conflict. The conflict solution will be sent to Operator 2 to accept or reject the proposal. If the Operator 2 does not accept it, he must provide feedback to reach a solution. When the conflict solution is accepted by both Operators it will be synchronised in both TMS.
Additional information and background	The system that could perform this function would be the TMS Deviation Detection module.

8.5.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.5_NFRQ_001**
Requirement	Integration of Cross-Area Real-Time Traffic Management
Type	Non-functional
Priority	Shall
Main goal	Obtain information about traffic management in real time in the cross-area TMS.
Assumptions	None.
Specifications	The data provided by the cross-area TMS shall be standardised in the same format.
Additional information and background	TMS-IL adapters may be used for enabling this requirement.

8.5.4. Components and functions

The involved system components are the following:

- The **Deviation** Module changes the Operational Plan evaluating the status report acquired from the field.
- The **Forecasting** Module computes the motion of a single train, given its scheduled timetable and the actual constraints on the railway infrastructure.
- The **Conflict Detection** Module searches for conflicts, once the actual motion of each train has been computed according to the forecasting module.
- The **Conflict Resolution** Module searches for possible actions to be taken in order to eliminate the occurrence of any conflicts and, at the same time, minimise the impact on the train scheduling.
- The **User Interface** Module is at least a Train Graph and a train schedule detail view.
- The **TMS-to-TMS Communication** Module detects a deviation or a conflict solution involving trains running on a specific border timing point and sends it to the remote TMS. When receives messages from the remote TMS it informs the above modules.

8.5.5. Interfaces

In the “FP1-DEMO-12.5-UC-01 Cooperative conflict resolution (two TMS)” TMS coordinate to find a shared solution on neighbouring conflicts. The interface provides an instance of a publishing/subscribing service with different groups defined, one for each TMS:

conflict solution proposal
conflict response (confirmed/rejected)

The group identifier is unique and defined as a specific pathname following the SP directives (i.e.: “<TMS_ID>/CR/Solution” and <TMS_ID>/CR/Response”).
An example of proposal and response messages is the following:

```
{
      "RequestIdentifier": "00058",
      "FirstTrainIdentification": {
            "TrainNumber": "90230",
            "Station of origin": "5498",
            "Departure DateTime": "2024-07-22T09:10:00"
      },
      "FirstTrackEdgePoint" : "1/1122/EM/01",
      "SecondTrainIdentification": {
            "TrainNumber": "90231",
            "Station of origin": "5412",
            "Departure DateTime": "2024-07-22T10:12:00"
      },
      "SecondTrackEdgePoint" : "1/1801/EM/02",
      "Note" : ""
}

{
"RequestIdentifier": "00058",
"Result: "Accepted",
"Note": "Fine for me"
}
```

In the “FP1-DEMO-12.5-UC-02 Exchanging real time train data regarding the border stations” the TMS exchanges messages with neighbouring TMS to publish the real time train data. The interface provides an instance of a publishing/subscribing service with different groups defined, one for each border point. The group identifier unique and defined as a specific pathname following the SP directives (i.e.: “<TMS_ID>/<SP_PATH>/Forecast”). Any border TMS that is interested in real-time data regarding the trains passing through the border point shall subscribe to the related group.
The TMS publishes forecast messages for all the trains leaving the point on the other side the one who is waiting the incoming trains receives and elaborates the messages. The forecast massage is written using the JSON notation and contains:

- the unique identifies of the train,
- the movement of the train and
- the real and estimated arrival and departure times.

An example of message is the following:


```
{
	"TrainIdentification": {
		"TrainNumber": "90230",
		"Station of origin": "5498",
		"Departure DateTime": "2024-06-27T03:10:00"
		},
	"Movement": {
		"Id": "98498/SL",
		"Type": 1,
		"Location": {
			"trackEdge": "1/1603/19",
			"pos": 89,
			"sameDir": false
		},
		"Times": [{
			"Type": 6,
			"DateTime": "2024-06-27T05:35:00"
		}]
	}
}
```


8.6. Processes and communication requirements for Subtask 6 (HACON)

In Subtask 11.3.6 HACON developed TRL 6 interfaces and TRL 5 decision Traffic management modules for supporting decision alignment between two neighbouring TMS areas and IMs including cross-border traffic operation and required interfaces. The activity feeds the related Destination 5 (WP 27) activities.

8.6.1. Logical architecture

The demonstrator provides the technical basis for demonstrating interactions between two TMS's allowing for cross-border (international) Use Cases as well as cross-area border (national) Use Cases. This set-up allows a variety of different show cases under various constrained network conditions and resulting effects. The TMS' graphical user interface features Train Graphs, network views as well as train schedule detail views.
The overall logical architecture of the demonstrator system is shown in the Figure 7 below.

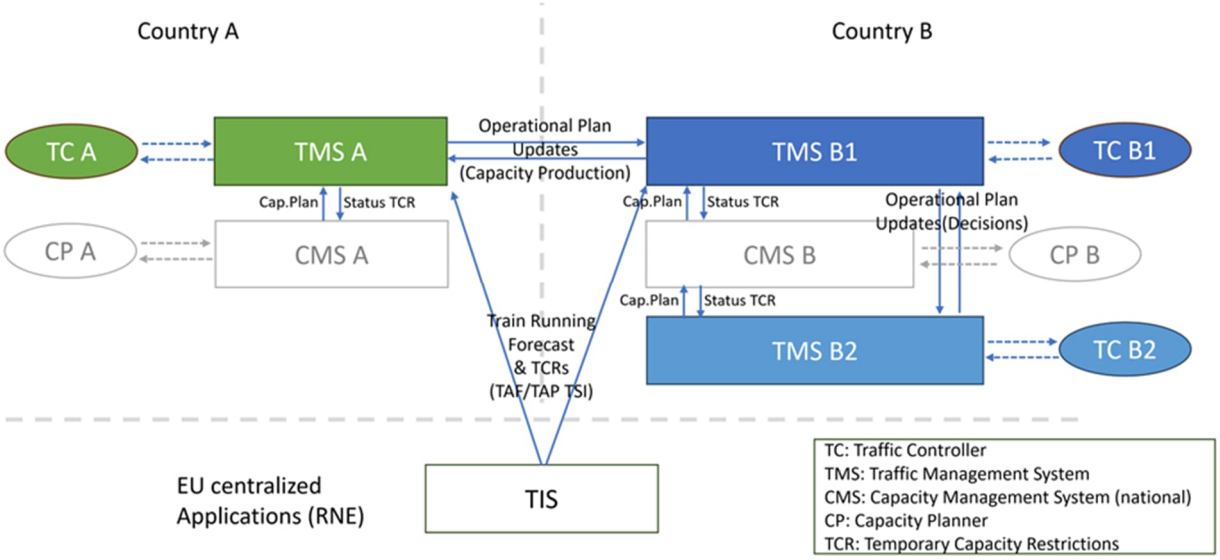


Figure 7: Logical architecture of demonstration 12.6

The main objectives are to align traffic and network status view and TMS decisions for cross-border or cross-area trains based on:

- Realistic forecast calculation,
- Multiple, alternative solution scenarios and
- Considering constraints/needs of both involved IMs or area Traffic Controllers (TCs).

8.6.2. Functional requirements

Requirement ID	**WP11_Demo12.6_FRQ_001**
Requirement	Forecast information integrated with the neighbouring TMS for the correct management of cross-border trains
Type	Functional
Priority	Shall
Main goal	To improve the TMS forecast calculation quality for international trains by using the TMS forecast result of the neighbouring TMS.
Assumptions	The handling-point (e.g., border station) and its track sections is modelled in the topology data of both TMS in a consistent way.
Specifications	Trigger forecast calculation of a cross-border train in the TMS of IM B based on the arrival time at a track location of the cross-border handling-point resulting from forecast calculation of that train in TMS of IM A as neighbouring IM to IM B.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4.

Requirement ID	**WP11_Demo12.6_FRQ_002**
Requirement	Managing first arrival times at track positions of handover-locations

Type	Functional
Priority	Shall
Main goal	Ability of a TMS to include in the Operational Plan first arrival times of trains starting at a track position of the handling-point (e.g., border station) and consider them for the forecast calculation.
Assumptions	None.
Specifications	The TMS shall be able to manage first arrival times of trains departing from track positions of handover-points and use them as the assumed start time for the forecast calculation.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4. This feature is required to use and document forecasted handover-times delivered by the TMS of a neighbouring IM. It can be seen as a perquisite for FRQ_001.

Requirement ID	**WP11_Demo12.6_FRQ_003**
Requirement	Managing and using minimum dwell times at handover-locations
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to include in the Operational Plan minimum dwell times of the handling-point (e.g., border station) and consider them for the forecast calculation.
Assumptions	None.
Specifications	The TMS shall be able to manage minimum dwell times at handover-points and consider them for the forecast calculation. A minimum dwell time shall be used for the forecast calculation of a train if the forecasted arrival at the handover-point plus minimum dwell time is later than the planned departure of that train at that point.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2. This feature is required to provide realistic forecast results in case of larger delay of international trains arriving at the handover-points in support of FRQ_001.

Requirement ID	**WP11_Demo12.6_FRQ_004**
Requirement	Transparent 'Corridor-TMS view' of capacity usage on track and signalling level for traffic management on freight corridors.
Type	Functional
Priority	Shall
Main goal	Provide an 'eye-to-eye-level' traffic management view to support coordination between freight corridor management and national traffic managers for disruption mitigation.
Assumptions	National TMS on the corridor integrated with Corridor TMS.
Specifications	The Corridor-TMS view shall be able to provide a transparent view of capacity usage on track and signalling level for the interconnected national corridor sections based on updates of forecast and Operational Plan changes received from national TMS.

Additional information and background	Linked to TE 8, High-Level Requirement 8.3 and 8.4.

Requirement ID	**WP11_Demo12.6_FRQ_005**
Requirement	Receipt of arrival forecast for an inbound train at the handover point
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to consider the received forecasted arrival time and track at the cross-border handling point for the local forecast calculation based on forecasted arrival times for trains approaching the border on the neighbouring network.
Assumptions	Telematics TSI (former TAF/TAP TSI) message feed available.
Specifications	The TMS shall be able to receive a forecasted arrival time at a cross-border handover point defined in the local network via Telematics TSI (former TAF/TAP TSI).
Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-02.

Requirement ID	**WP11_Demo12.6_FRQ_006**
Requirement	Forecast calculation for inbound international train in local TMS based on received arrival forecast at handling points on the local network.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to consider the received forecasted arrival time and track at the cross-border handling point for the local forecast calculation based on forecasted arrival times for trains approaching the border on the neighbouring network.
Assumptions	Telematics TSI (former TAF/TAP TSI) message feed available.
Requirements	The TMS shall consider the received forecasted arrival time and track at a cross-border handover point defined in the local network to use it as a starting point and time for the next cycle of calculation of the train running forecast triggered by the TMS on the local network. As far as possible, the routing locations, departure times and minimum dwell times of the associated planned international path shall be used as a basis for the forecast calculation on the local network.
Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-02.

Requirement ID	**WP11_Demo12.6_FRQ_007**
Requirement	Forecast calculation for outbound international train in local TMS up to next major node on neighbouring network.

Type	Functional
Priority	Shall
Main goal	Ability of a TMS to anticipate upcoming issues behind the border by extending the train running forecast to a relevant line section on the neighbouring network.
Assumptions	Local infrastructure model extended by relevant line section on the neighbouring network being compliant with local forecast calculation feature.
Specifications	The TMS shall be able to perform a forecast calculation for a cross-border train with its current train position on the extended local network up to the next major node on the neighbouring network. As far as possible, the routing locations, departure times and minimum dwell times of the associated planned international path shall be used as a basis for the forecast calculation on the extended local network.
Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-03.

Requirement ID	**WP11_Demo12.6_FRQ_008**
Requirement	Import of Capacity Plan received from CMS.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to make use of up-to-date capacity plans including TCR, train paths and planned train links on the extended local network.
Assumptions	CMS available and capable to provide the new or updated capacity plan objects via an interface shared with the TMS.
Specifications	The TMS shall be able to receive new or updated capacity plan objects (TCR, train paths and train links) for the extended local network from a connected CMS via an interface and use them for the traffic control on the local network.
Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-03. Also linked to WP4_Demo12.6_FRQ_001 in Deliverable D4.1 and WP11_Demo12.7_FRQ_001.

Requirement ID	**WP11_Demo12.6_FRQ_009**
Requirement	Visibility of foreign line section behind the border location and related train and TCR objects.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to allow for an extended network view including line sections behind the border up to the next major node on the foreign network and related train and TCR objects. This is required for a pre-alignment of required Operational Plan changes between the two national TMS involved.
Assumptions	Topology information of the foreign network sections available.
Specifications	The TMS shall be able to make use of an extended national topology model including line sections behind the border up to the next major node on the foreign network.

Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-03.

Requirement ID	**WP11_Demo12.6_FRQ_010**
Requirement	Conflict detection on foreign line section behind the border location.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to allow for detection of conflicts on the extended network.
Assumptions	Related topology information of the foreign network sections available.
Specifications	The TMS shall be able to detect and show conflicts on the extended network including line sections behind the border up to the next major node on the foreign network. This is required for a pre-alignment of required Operational Plan changes between the two national TMS involved.
Additional information and background	Linked to TE 8, High-Level Requirements 8.2, 8.3, 8.4 and Use Case FP1-DEMO-12.6-UC-03.

Requirement ID	**WP11_Demo12.6_FRQ_011**
Requirement	Implement the control decision ‘hold back train’ on the local network.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to control traffic using the ‘hold back train’ rule.
Assumptions	None.
Specifications	The TMS shall be able to allow the Traffic Controller to implement a ‘hold back train’ rule at a defined location for a train and a TCR reflecting the control decision taken. The implemented rule is set into state ‘active’.
Additional information and background	Required for Use Case FP1-DEMO-12.6-UC-03.

Requirement ID	**WP11_Demo12.6_FRQ_012**
Requirement	Implement the control decision ‘hold back train’ on the local network.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to control traffic using the ‘hold back train’ rule.
Assumptions	None.
Specifications	The forecast calculation of the TMS shall consider active control decisions.
Additional information and background	Required for Use Cases FP1-DEMO-12.6-UC-03, linked to requirement WP11_Demo12.6_FRQ_007.

Requirement ID	**WP11_Demo12.6_FRQ_013**

Requirement	Set-up and sharing change scenarios ('sandboxes') in the Operational Plan with the neighbouring IM/TMS.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to participate in joint pre-alignment of cross-border Operational Plan changes with the neighbouring IM/TMS.
Assumptions	Visibility of foreign line section behind the border location and related trains and TCR, i.e., WP11_Demo12.6_FRQ_008 and WP11_Demo12.6_FRQ_009 fulfilled.
Specifications	The TMS shall be able to create a change scenario of the Operational Plan on the line section towards the border location/handling point including a TCR and impacted trains and to share it with the neighbouring IM/TMS.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirements 8.5, 9.2, 9.4 and Use Case FP1-DEMO-12.6-UC-01.

Requirement ID	**WP11_Demo12.6_FRQ_014**
Requirement	Access rights in conjunction with Operational Plan change scenarios ('sandboxes') shared with the neighbouring IM/TMS for alignment on cross-border line sections.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to participate in joint pre-alignment of cross-border Operational Plan changes with the neighbouring IM/TMS.
Assumptions	Visibility of foreign line section behind the border location and related capacity objects, i.e., WP11_Demo12.6_FRQ_008 and WP11_Demo12.6_FRQ_009 fulfilled.
Specifications	The TMS shall be able to respect defined access rights in conjunction with change scenarios ('sandboxes') of the Operational Plan shared with the neighbouring IM/TMS.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirements 8.5, 9.2, 9.4 and Use Case FP1-DEMO-12.6-UC-01.

Requirement ID	**WP11_Demo12.6_FRQ_016**
Requirement	Status transition of change scenarios ('sandboxes') shared with the neighbouring IM/TMS for alignment on cross-border line sections.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to participate in joint pre-alignment of cross-border Operational Plan changes with the neighbouring IM/TMS.
Assumptions	Visibility of foreign line section behind the border location and related train and TCR objects, i.e., WP11_Demo12.6_FRQ_008 and WP11_Demo12.6_FRQ_009 fulfilled.
Specifications	The TMS shall provide the capability for a status transition of change scenarios

	('sandboxes') of the Operational Plan shared with the neighbouring IM/TMS. The status values need to at least comprise 'New', 'In Progress', 'Confirmed'.
Additional information and background	Linked to TE 8 and TE 9, High-Level Requirements 8.5, 9.2, 9.4 and Use Case FP1-DEMO-12.6-UC-01.

8.6.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.6_NFRQ_001**
Requirement	Using Telematics TSI for exchanging forecasted times and track locations at handover-points.
Type	Non-functional
Priority	Shall
Main goal	To allow for interoperability, support a smooth migration and facilitate a reduction of TMS implementation costs.
Assumptions	Common Interface (CI) availability to allow Telematics TSI message exchange. Telematics TSI allowing for transfer of detailed track locations in the TMS forecast.
Specifications	The integrated forecast information for the TMS for IMs' capacity production shall make use of a standardised interface based on Telematics TSI.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4. Telematics TSI may also be used for consideration of TIS (RNE) based estimated arrival times at handover locations which might be relevant for trains currently operating in non-neighbouring networks but would arrive at the local network at a later time.

Requirement ID	**WP11_Demo12.6_NFRQ_002**
Requirement	Minimum performance for exchanging forecasted times and track locations at handover-points.
Type	Non-functional
Priority	Shall
Main goal	To ensure relevance and support a smooth use in Traffic Management involving international trains.
Assumptions	Common Interface (CI) availability to allow Telematics TSI message exchange. Telematics TSI allowing for transfer of detailed track locations in the TMS forecast.
Specifications	The maximum time between availability of forecast in TMS A and availability of forecast in TMS B based on the arrival time and track location at handover point received from TMS A shall not exceed 20 seconds.
Additional information and background	Linked to TE 8, High-Level Requirement 8.2 and 8.4. Telematics TSI may also be used for consideration of TIS (RNE) based estimated arrival times at handover locations which might be relevant for trains currently operating in non-neighbouring networks but would arrive at the local network at later time.

8.6.4. Components and functions

The components involved in the demonstrator set-up are:

- TMS A application instance representing the national TMS of country A
- CMS A application instance representing the national CMS of country A integrated with TMS A
- TMS B1 application instance representing a regional TMS of country B for area 1 sharing a cross-border section with country A
- TMS B2 application instance representing a regional TMS of country B for area 2 sharing a cross-area border section with area 1
- CMS B application instance representing the national CMS of country B integrated with TMS B1 and TMS B2.
- EU-centralised application TIS (either via TIS test connector or TIS simulation if not available)
- Operational Plan updates are performed by responsible TMS A, B1 and B2 and exchanged with the TMS sharing a cross-border or cross-area border section.
- Capacity Plan updates are provided by CMS to the connected TMS to provide updated agreed plans
- New operational TCR and updates are provided by TMS to the national CMS for improved quality of Capacity Plans.
- The EU centralised Train Information System (TIS) provides updated train running forecast and TCR information to TMS A and TMS B1.

The methodology followed is:

- Scenario preparation in the integrated systems for triggering different impact quality (different TCR combinations and related changes of forecast timing, routing, non-compliance with rules).
- Specific focus on 'looking-behind-the-border'-capability and inbound and outbound train effects.
- Comparing forecast/decision results with results based on non-availability of integrated information.
- Initiation, creation and management of Sand-Boxes for decision making.
- Comparing non-aligned decision scenarios with aligned ones.

8.6.5. Interfaces

The involved components are using Telematics TSI messages for exchanging train path and TCR related information. Since the TCR message definitions are not yet included in the published final TSI, the latest Telematics TSI draft version including this definition is used. The message exchange is performed using the Apache KAFKA message broker.

8.7. Processes and communication requirements for Subtask 7 (HACON)

In Subtask 11.3.7 HACON develops interfaces for integration of TMS with services such as station and yard management systems (considering requirements of FA 5), integration with digital maintenance module as used in FA 3 (FP3-IAMS4RAIL WP 8), electric traction system component to forecast and provide power restrictions for electric trains, and crew/rolling stock management systems.

8.7.1. Logical architecture

The demonstrator 12.7 provides the technical basis for demonstrating interactions between a TMS and systems for yard/station capacity planning, infrastructure maintenance planning and RU users involved. In addition, the integrated ETS simulator system provides energy constraints to be considered in the TMS. This set up allows a variety of different show cases under various constrained train, traffic and network conditions and resulting effects. The graphical user interface will feature Train Graphs, network views as well as train schedule details views. Since the system does not include a crew/rolling stock dispatching system, the dispatcher of the RU will make use specific views emulating such a system to reflect the required changes of resource links as assigned to trains.

The overall logical architecture of the demonstrator system is shown in the Figure 8 below.

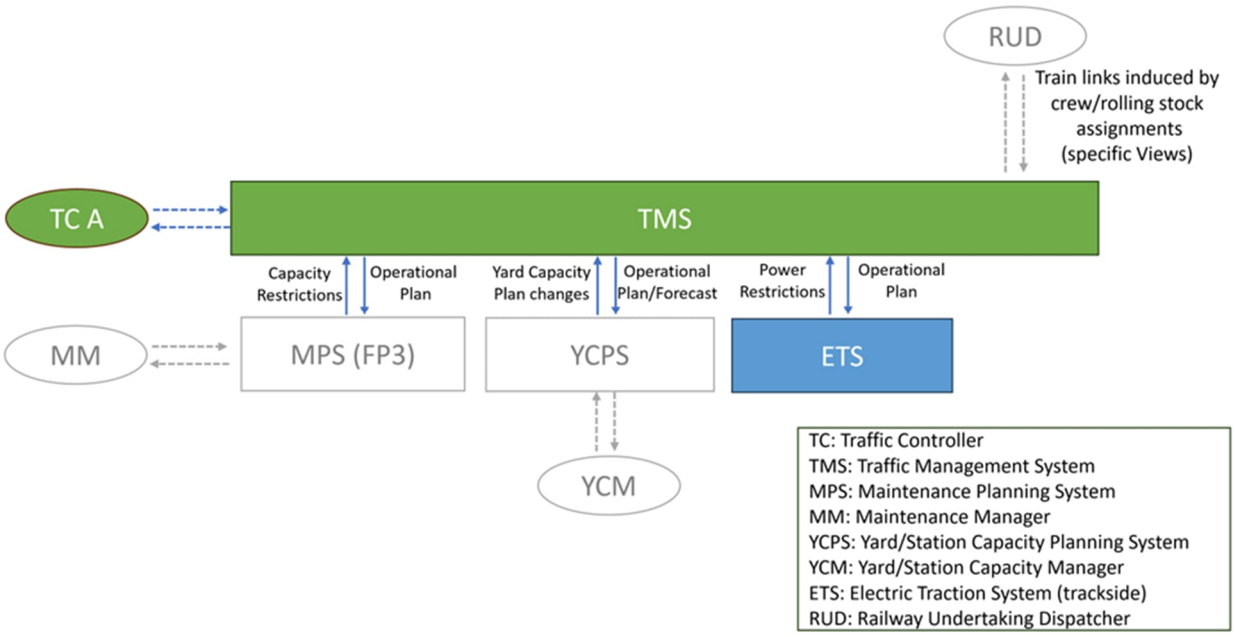


Figure 8: Logical architecture view of demonstrator 12.7

The main objectives of the demonstrations are to show how the quality of TMS decisions can be improved by integration of additional information provided by the connected systems on the one hand. On the other it will become evident how the quality of decision making and processing in the connected systems can be improved by making the current Operational Plan / forecast provided by the TMS available to them. This will be achieved mainly by:

- Scenario preparation in the integrated systems for triggering different impact quality (changes of forecast timing, routing, non-compliance with rules, conflicts).
- Comparing TMS forecast/decision results with results based on non-availability of integrated information.

8.7.2. Functional requirements

Requirement ID	**WP11_Demo12.7_FRQ_001**
Requirement	Import and handling of a TCR received from DMPS
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to make use of up-to-date TCR delivered by connected maintenance planning system (DMPS).
Assumptions	DMPS available and capable to provide the new or updated TCR via an interface shared with the TMS.
Specifications	The TMS shall be able to receive a new or updated TCR from the connected DMPS via an interface and use it for the traffic control. The TCR needs to be compliant with the conflict detection and handling function of the TMS to allow a correct identification of a TCR/train conflict and a reduction of the maximum speed in case of a Temporary Speed Restriction for the forecast calculation.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_002**
Requirement	TMS providing up-to-date Operational Plan and train running forecast to the DMPS.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to send an updated Operational Plan and a train running forecast to the connected maintenance planning system (DMPS).
Assumptions	DMPS available and capable to receive the Operational Plan update and train running forecast via an interface shared with the TMS.
Specifications	The TMS shall be able to send am updated Operational Plan and train running forecast to the connected DMPS via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_003**
Requirement	Provision of TMS Operational Plan and train running forecast updates to the Yard Management System.
Type	Functional

Priority	Shall
Main goal	Ability of a TMS to inform the Yard Management System about Operational Plan changes and/or train running forecast.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to send an updated Operational Plan and train running forecast for a train to the Yard Management System. The Operational Plan update shall contain inter alia, yard arrival track, yard arrival time and train consist information. The train running forecast shall contain inter alia, forecasted arrival time at the yard arrival track.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Case FP1-DEMO-12.7-UC-01, FP1-DEMO-12.7-UC-3.

Requirement ID	**WP11_Demo12.7_FRQ_004**
Requirement	TMS receives updated information from the Yard Capacity Plan managed by the Yard Management System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to receive and use updated information from the Yard Management System requiring Operational Plan changes.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to receive and use updates of • the departure track in the yard / handling location for a train, • the arrival time of a shunting move to make the consist available in the departure track, • the consist information of the departing train, provided by the Yard Management System to adapt the Operational Plan.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Cases FP1-DEMO-12.7-UC-01, FP1-DEMO-12.7-UC-2.

Requirement ID	**WP11_Demo12.7_FRQ_005**
Requirement	Provision of TMS Operational Plan and train running forecast updates to the Station (Depot) Management System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to inform the Station (Depot) Management System about Operational Plan changes and/or train running forecast.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to send an updated Operational Plan and train running

	forecast for a train to the Station Management System. The Operational Plan update shall contain inter alia, station (depot) arrival track, station arrival time and train consist information. The train running forecast shall contain inter alia, forecasted arrival time at the station arrival track.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Case FP1-DEMO-12.7-UC-3.

Requirement ID	**WP11_Demo12.7_FRQ_006**
Requirement	TMS receives updated information from the Station (Depot) Capacity Plan managed by the Station (Depot) Management System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to receive and use updated information from the Station (Depot) Management System requiring Operational Plan changes.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to receive and use updates of • the departure track in the station area / handling location for a train, • the arrival time of a shunting move to make the consist available in the departure track, • the consist information of the departing train, provided by the Station (Depot) Management System to adapt the Operational Plan.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_007**
Requirement	Provision of TMS Operational Plan updates to the Electric Traction System (ETS) for trackside energy management.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to keep the ETS updated with the current Operational Plan.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to send an updated Operational Plan to the ETS. The Operational Plan update shall contain train/movement related information including arrival times at the operational planning locations.
Additional information and background	Linked to TE 10, High-Level Requirement 10.3 and Use Case FP1-DEMO-12.7-UC-3.

Requirement ID	WP11_Demo12.7_FRQ_008
Requirement	TMS receives energy restrictions from ETS and using them for Operational Plan adaptions
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to receive and use updated information from the Electric Traction System (ETS) requiring Operational Plan changes.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS shall be able to receive and use updates of energy restrictions as e.g., temporary power outages impacting the forecasted running of trains as provided by the Electric Traction System to adapt the forecast calculation supporting the adaptation of the Operational Plan. This may lead to impact on train acceleration or complete blockage of affected track sections.
Additional information and background	Linked to TE 10, High-Level Requirement 10.3 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	WP11_Demo12.7_FRQ_009
Requirement	TMS considering crew exchange information provided by a Crew Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to receive and use crew exchange information for updating the train running forecast and Operational Plan.
Assumptions	Existing Crew Dispatching System (or message viewer if not available) capable to send crew exchange information via an interface shared with the TMS.
Specifications	The TMS shall be able to receive crew exchange information from a connected Crew Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	WP11_Demo12.7_FRQ_010
Requirement	TMS providing up-to-date Operational Plan and train running forecast to the Crew Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to send an updated Operational Plan and a train running forecast to the connected Crew Dispatching System.
Assumptions	Existing Crew Dispatching System (or message viewer if not available) capable to receive the Operational Plan update and train running forecast via an interface shared with the TMS.
Specifications	The TMS shall be able to send am updated Operational Plan and train running

	forecast to the connected Crew Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_011**
Requirement	TMS considering crew information provided by a Crew Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to show crew information assigned to a train in the Operational Plan.
Assumptions	Existing Crew Dispatching System (or message viewer if not available) capable to send crew information assigned to a train via an interface shared with the TMS.
Specifications	The TMS shall be able to receive crew information assigned to a train from a connected Crew Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_012**
Requirement	TMS considering crew qualification provided by a Crew Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to show crew qualification assigned to a train in the Operational Plan.
Assumptions	Existing Crew Dispatching System (or message viewer if not available) capable to send crew qualification assigned to a train via an interface shared with the TMS.
Specifications	The TMS shall be able to receive crew qualification assigned to a train from a connected Crew Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_013**
Requirement	TMS considering rolling stock exchange information provided by a Rolling Stock Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to receive and use rolling stock exchange information for updating the train running forecast and Operational Plan.
Assumptions	Existing Rolling Stock Dispatching System (or message viewer if not available)

	capable to send rolling stock exchange information via an interface shared with the TMS.
Specifications	The TMS shall be able to receive rolling stock exchange information from a connected Rolling Stock Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_014**
Requirement	TMS providing up-to-date Operational Plan and train running forecast to the Rolling Stock Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to send an updated Operational Plan and a train running forecast to the connected Rolling Stock Dispatching System.
Assumptions	Existing Rolling Stock Dispatching System (or message viewer if not available) capable to receive the Operational Plan update and train running forecast via an interface shared with the TMS.
Specifications	The TMS shall be able to send am updated Operational Plan and train running forecast to the connected Rolling Stock Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_015**
Requirement	TMS considering rolling stock information provided by a Rolling Stock Dispatching System.
Type	Functional
Priority	Shall
Main goal	Ability of a TMS to show rolling stock information assigned to a train in the Operational Plan.
Assumptions	Existing Rolling Stock Dispatching System (or message viewer if not available) capable to send rolling stock information assigned to a train via an interface shared with the TMS.
Specifications	The TMS shall be able to receive rolling stock information assigned to a train from a connected Rolling Stock Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_016**
Requirement	TMS considering rolling stock qualification provided by a Rolling Stock Dispatching System.

Type	Functional
Priority	Shall
Main goal	Ability of a TMS to show rolling stock qualification assigned to a train in the Operational Plan.
Assumptions	Existing Rolling Stock Dispatching System (or message viewer if not available) capable to send rolling stock qualification assigned to a train via an interface shared with the TMS.
Specifications	The TMS shall be able to receive rolling stock qualification assigned to a train from a connected Rolling Stock Dispatching System via an interface.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4 and Use Case FP1-DEMO-12.7-UC-01.

Requirement ID	**WP11_Demo12.7_FRQ_017**
Requirement	Visualisation of rolling stock information
Type	Functional
Priority	Should
Main goal	To have useful information about rolling stock (model, railway undertaking, length of train, load information, …)
Assumptions	Rolling stock information is displayed/available on the TMS by integration with other systems.
Specifications	Useful information for rail traffic management should be available in the TMS. The operator should be able to access it, to have the capability to perform operations such as dispatching a train to an area where the available length is limited.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4.

Requirement ID	**WP11_Demo12.7_FRQ_018**
Requirement	Automatic detection of rolling stock conflicts
Type	Functional
Priority	Should
Main goal	Detect conflicts related to the rolling stock
Assumptions	Rolling stock information is displayed/available on the TMS by integration with other systems.
Specifications	Automatic detection of rolling stock conflicts would consist of alerting the Operator to anomalies related to the rolling stock. It would also be useful to detect inconsistencies with the Operational Plan. For example, it is typical for the same rolling stock to make consecutive trips changing only the identifier and/or the crew. If for some reason that train suffers a breakdown that prevents it from continuing, a warning would be displayed to the Operator because this train will not be able to serve the next trip. In addition, the TMS will automatically try to mitigate the incident, either by

	suspending the linked outbound train, delaying it or proposing alternative available rolling stock.
Additional information and background	Linked to TE 10, High-Level Requirement 10.4.

8.7.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.7_NFRQ_001**
Requirement	Use of Telematics TSI for sending updated information from the Yard Management System to the TMS.
Type	Non-functional
Priority	Should
Main goal	Ability of a TMS to receive and use updated information from the Yard Management System using standard protocols.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS should be able to receive and use Telematics TSI protocol for receiving updates of • the departure track in the yard / handling location for a train, • the arrival time of a shunting move to make the consist available in the departure track, • the consist information of the departing train, provided by the Yard Management System.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Case FP1-DEMO-12.7-UC-01, FP1-DEMO-12.7-UC-2 and WP11_Demo12.7_FRQ_004.

Requirement ID	**WP11_Demo12.7_NFRQ_002**
Requirement	Use of Telematics TSI for sending updated information from the Station (Depot) Management System to the TMS.
Type	Non-functional
Priority	Should
Main goal	Ability of a TMS to receive and use updated information from the Station (Depot) Management System using standard protocols.
Assumptions	• Communication between both systems technically possible. • Baseline and plan data compatible between both systems.
Specifications	The TMS should be able to receive and use Telematics TSI protocol for receiving updates of • the departure track in the station area / handling location for a train, • the arrival time of a shunting move to make the consist available in the departure track, • the consist information of the departing train,

	provided by the Station (Depot) Management System.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1 and Use Case FP1-DEMO-12.7-UC-01 and WP11_Demo12.7_FRQ_005.

8.7.4. Components and functions

The components involved in the demonstrator set-up are:

- TMS application instance representing a regional TMS; consuming the inbound information from connected systems; provides Operational Plan/forecast to them.
- (Digital) Maintenance Planning System connected to the TMS; consumes Operational Plan for aligning maintenance decisions; provides updated maintenance restriction information (TCR) to TMS. For the demonstrations, the DMPS prototype developed in FP 3 IAM4RAIL WP 8 will be used.
- Yard/Station Capacity Planning System connected to TMS; consumes Operational Plan/forecast for adapting the local plan accordingly; provides local plan updates back to TMS to adapt Operational Plan where required.
- Electric Traction System (trackside) simulator; consumes Operational Plan updates to feed the simulation of Electric Traction System operation in a defined operational time horizon (e.g., 4 hours); provides back power restrictions as operational constraints to be considered by TMS.
- JSON-based messaging UI for monitoring and controlling a simulated Railway Undertaking resource dispatching system interface; shows Operational Plan updates received from TMS; provides new or updated rolling stock or crew related information to be assigned to the Operational Plan in the TMS.

8.7.5. Interfaces

The involved components are using Telematics TSI messages for exchanging train path and TCR related information. Since the TCR message definitions are not yet included in the published final TSI, the latest Telematics TSI draft version including this definition is used. The message exchange is performed using the Apache KAFKA message broker.

8.8. Processes and communication requirements for Subtask 8 (TRV)

Subtask 11.3.8 TRV develops interface of TMS to Yard Coordination System (YCS) 2.0 in Malmö node, see e.g. (FR8RAIL III, 2024) for more information regarding YCS. In short, the aim of YCS is to coordinate the Operational Planning at the arrival/departure part of a marshalling yard, where several different actors The development is strongly connected to TRV/RISE developments in WP 4, in the sense that both contributes to the YCS-system. System diagram below, shows components or systems that will be connected for the demonstration system and what information is exchanged between the connected components/systems.

8.8.1. Logical architecture

Efficient interaction between TMS and YCS users, to contribute to smooth and easy control and supervision of traffic in the border area between YCS and TMS is the main objective, assessing the TMS-YCS integration and operations on performance, capacity, track allocation, punctuality and human factor. The Figure 9 below illustrates the logical architecture of the system setup. The YCS module is connected to the TMS of Trafikverket (denoted Digital graf). YCS collects input data from the TMS. This far we have not identified a need to send information back to the TMS. Instead, the TMS Operator is also a user to the YCS, and he/she performs planning tasks in both YCS and TMS. Other main users of YCS are the Yard Capacity Planner, that is responsible for the marshalling planning, and the Terminal Capacity Manager, responsible for the capacity planning of the intermodal terminal. All three identified users of YCS both receives data from and input data to YCS.

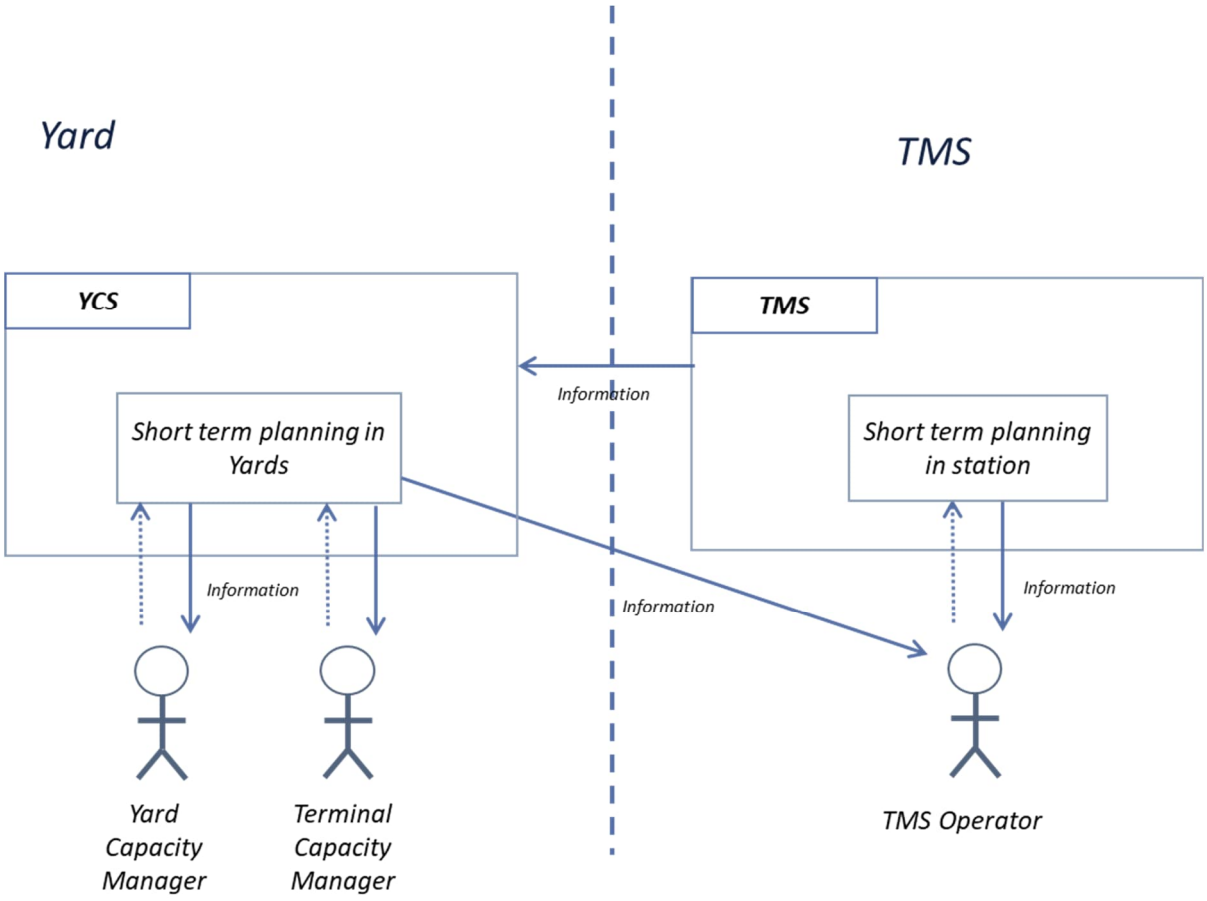


Figure 9: Logical architecture of demonstrator 12.8

8.8.2. Functional requirements

For further functional requirements regarding allocation planning functionality in YCS, see (MOTIONAL D4.1).

Requirement ID	WP11_Demo12.8_FRQ_001
Requirement	Handling of ETA in TMS and YCS
Type	Functional
Priority	Shall
Main goal	Define what system is responsible to define the ETA and ETD
Assumptions	The TMS-system includes handling and updating of RTTP. TMS Operator is responsible for updating RTTP in TMS.
Specifications	The ETA and ETD is part of the RTTP. Thus, the ETA and ETD are data "owned" by TMS and is updated by TMS Operator. To reduce confusion where to handle different data, ETA and ETD cannot be changed in YCS. As soon as ETA or ETD is changed in TMS, this information is sent and illustrated in YCS.
Additional information and background	Linked to TE 10, High-Level Requirement 10.1.

Requirement ID	WP11_Demo12.8_FRQ_002
Requirement	Track allocation, track reservation and track need
Type	Functional
Priority	Shall
Main goal	Define how track allocation is planned between the different user roles.
Assumptions	Planning of track allocation at arrival/departure yard is separated from the roles of planning marshalling operations and terminal operations. The YCS Operator is responsible for the arrival/departure yard planning.
Specifications	A track allocation is determined by track number, start time and end time. The YCS Operator is responsible for the track allocations at the arrival/departure yard. In YCS, the YCS Operator makes track reservations, which corresponds to that a certain track is reserved for a train during a time period. The Yard Capacity Manager and Terminal Capacity Manager has "track need", and the YCS Operator creates track reservations to cover the track need.
Additional information and background	The YCS Operator and TMS Operator is most often the same person. Linked to TE 10, High-Level Requirement 10.1.

Requirement ID	WP11_Demo12.8_FRQ_003
Requirement	Data integrity between YCS user roles
Type	Functional
Priority	Shall
Main goal	Define that data is "owned" by different roles, and roles cannot change other role's data.
Assumptions	None
Specifications	Each data is owned be a specific role (user) of YCS. Another role cannot change the data belonging to another role. Key examples: YCS Operator owns: track assignment, start and end time of track reservations

	Yard Capacity Manager owns: track need data related to both train arrival, train departure and shunting operations from marshalling yard Terminal Capacity Manager owns: track need data related to both train arrival, train departure and shunting operations from marshalling yard
Additional information and background	There are other data, not included in examples above, in the system that also belong to the different roles. Linked to TE 10, High-Level Requirement 10.1.

Requirement ID	**WP11_Demo12.8_FRQ_004**
Requirement	Information sharing between YCS Operator, Yard Capacity Manager and Terminal Capacity Manager.
Type	Functional
Priority	Shall
Main goal	Define that all users can see most data owned by all other roles.
Assumptions	None
Specifications	The data and track allocation should be transparent between the roles, so the users should be able to see the data handled by other roles, even if they cannot change the data.
Additional information and background	Creating transparency is a key functionality of the system. Linked to TE 10, High-Level Requirement 10.1.

Requirement ID	**WP11_Demo12.8_FRQ_005**
Requirement	Data sharing from YCS
Type	Functional requirement
Priority	Shall
Main goal	Data in YCS should be possible to export.
Assumptions	None
Specifications	Data in YCS should be possible to export to surrounding systems.
Additional information and background	In demonstration implementation, RISE platform for data sharing “Deplide” will be used for data sharing. This far, no consumer of data from YCS is defined. Linked to TE 10, High-Level Requirement 10.1.

8.8.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.8_NFRQ_001**
Requirement	Information synchronisation between TMS and YCS
Type	System performance
Priority	Shall
Main goal	Key data, like ETA and ETD, should be synchronised immediately between TMS and YCS.
Assumptions	None

Specifications	Time delay between a change in TMS and until it is updated in YCS should be less than 5 seconds.
Additional information and background	None

Requirement ID	**WP11_Demo12.8_NFRQ_002**
Requirement	Information security
Type	Non-functional requirement
Priority	Shall
Main goal	System should have relevant information security level.
Assumptions	None.
Specifications	All information in YCS should be handled according to security level K3. Versions with test data, e.g. used in demonstrations, can have security level K2.
Additional information and background	None.

8.8.4. Components and functions

The system is based on:

- Coordination of line capacity management and yard capacity management
- Coordination of yard track allocation between the actors at the marshalling yard (including multimodal terminal)

The setup with TMS-YCS integration will be prepared for users to be able to carry out operational scenarios to validate functions, robustness, performance and user interface.

The TMS sends ETA and ETD via a “public” interface.

Deplide uses Apache Kafka to store messages temporarily. For the YCS application Deplide use two topics. In the topic ‘trv.closeddata.digitalgraf.raw’ the message from TMS is stored, as is. In topic ‘ycs.raw’, the processed data from the TMS is stored, and input data from YCS users, like track needs.

YCS Backend fetches messages from Deplide’s topic ‘ycs.raw’ and store them in a database. YCS GUI applications polls YCS Backend regularly for new messages. Users of YCS GUI applications may also send data to YCS Backend, like track needs. These messages are pushed to Deplide’s topic ‘ycs.raw’ and is stored in the YCS Backend database, see also Figure 10 below.

Via Deplides topic ‘ycs.raw’ future research applications may integrate with YCS and use YCS data.

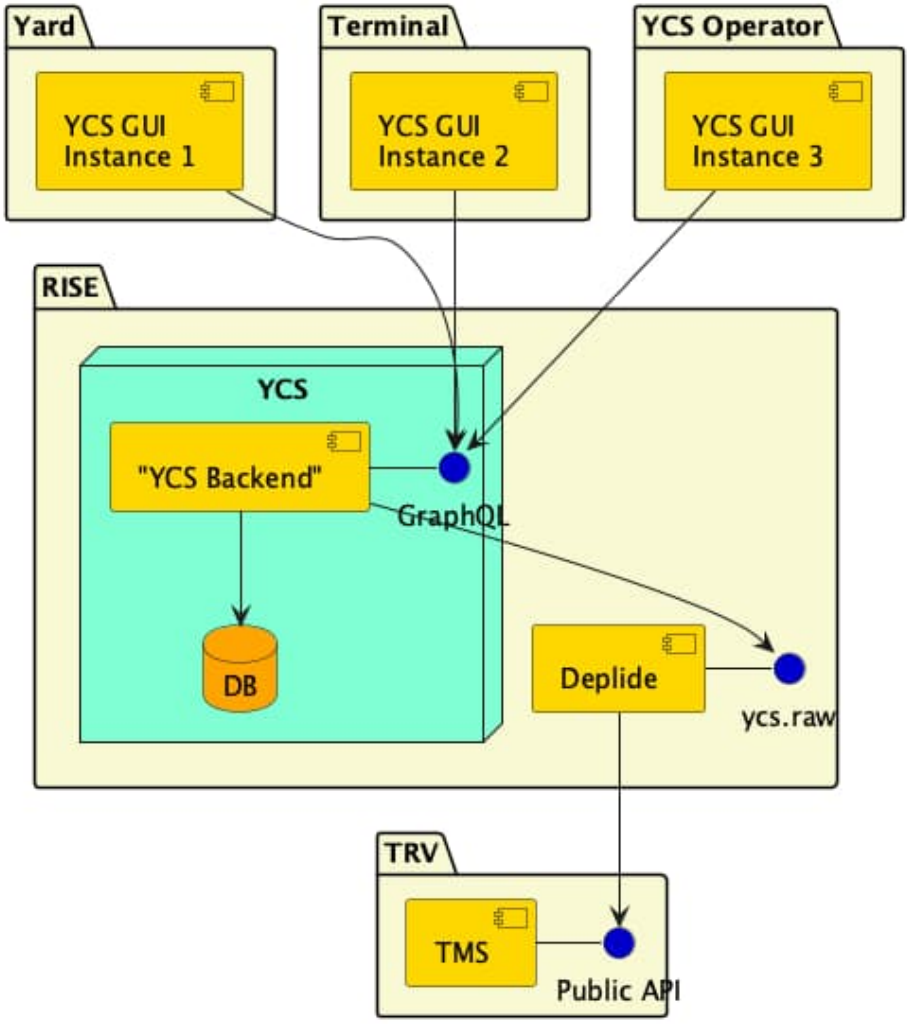


Figure 10: Components of demonstrator 12.8

8.8.5. Interfaces

TMS pushes ETA and ETD messages via a "public" interface that Deplide integrates with. The interface is public, but Deplide needs to authenticate before using it. The interface uses JSON as serialisation format.

YCS Backend integrate with Deplide's Apache Kafka topic 'ycs.raw' to fetch messages from the TMS, and to push input data from YCS users.

The YCS GUI is a single page application that is run in a web browser. YCS GUI and YCS Backend uses GraphQL as interface between them. YCS Backend is a GraphQL server. YCS GUI is the GraphQL client and polls the backend server for messages in regular intervals.

8.9. Processes and communication requirements for Subtask 9 (CEIT)

In Subtask 11.3.9 CEIT developed an interface in view of the future autonomous inspection vehicle

(AIV) for the infrastructure (Destination 3) and its integration with the Intelligent Asset Management System (IAMS). To exchange information about asset status, planned interventions and allocated paths to execute inspections and interventions, three ways of interacting with the AIV are foreseen: IAMS to AIV directly, IAMS and TMS to AIV directly and IAMS and TMS to AIV and IAMS to TMS.

8.9.1. Logical architecture

In the Logical Architecture used for demonstration 12.9 diagram all three ways are merged.

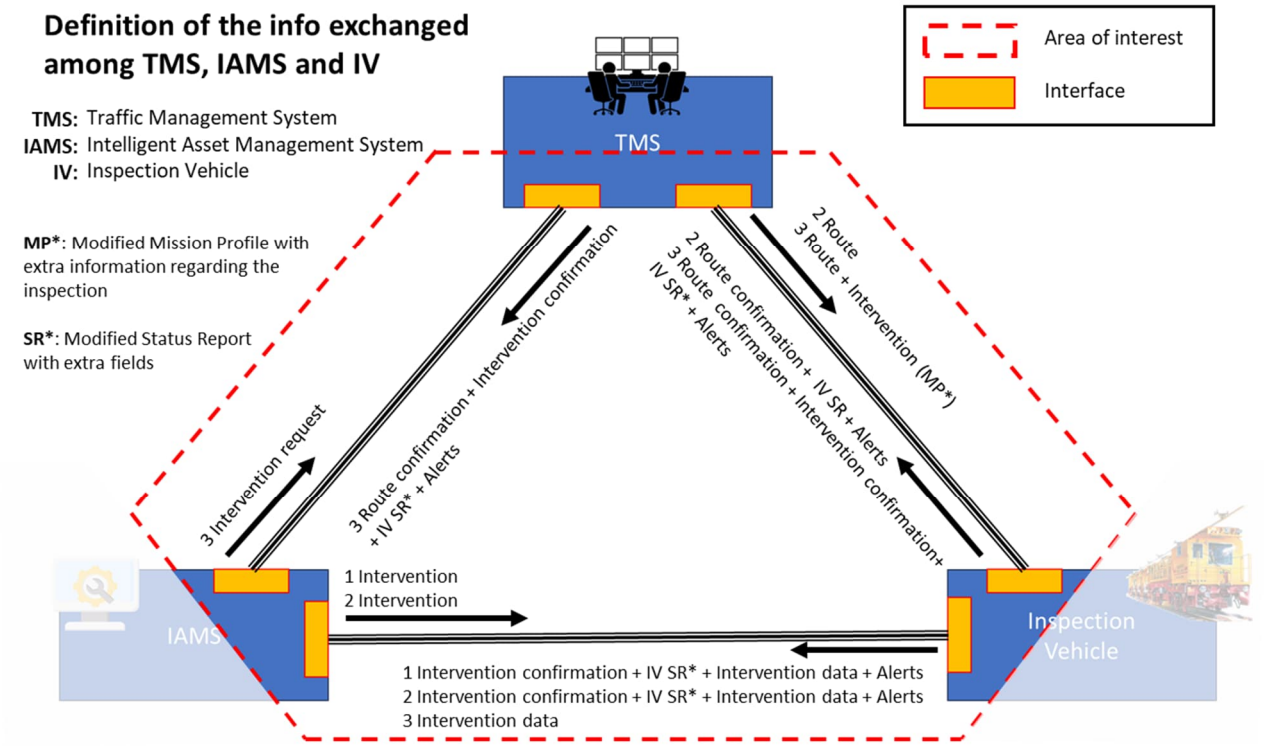


Figure 11: System overview diagram of the IAMS-TMS-AIV interfaces

In the frame of MOTIONAL the Use Case 1 FP1-DEMO-12.9-UC-01 was implemented where the IAMS and the AIV are connected as shown in next figure:

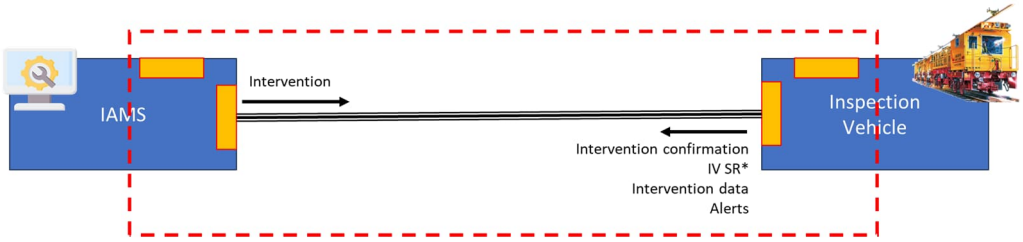


Figure 12: System overview diagram of the IAMS-AIV interfaces for FP1-DEMO-12.9-UC-01

The demonstrator provides the technical basis for demonstrating improved interactions between an AIV, an IAMS and a TMS for the definition and exchange of information that will allow optimised inspection activities by means of the interaction of IAMS, TMS and AIV. In MOTIONAL the AIV-IAMS interface was developed. For the resulting demonstration, it will be deployed using two machines, one for IAMS the other for AIV, where the different scenarios for the interface among them will be demonstrated.

The implementation of this demonstrator followed the methodology below:

- Define the information to be exchanged among AIV, IAMS, and TMS in the three cases foreseen: (1) IAMS to AIV directly, (2) IAMS and TMS to AIV directly and (3) IAMS and TMS to AIV and IAMS to TMS.
- Develop the interface between AIV and IAMS and test it in a single machine.
- Deploy the interface between two machine and test it cabled.
- Deploy a wireless link between two machines and test it wirelessly.

8.9.2. Functional requirements

Requirement ID	**WP11_Demo12.9_FRQ_001**
Requirement	IAMS transmits Intervention request to AIV
Type	Functional
Priority	Shall
Main goal	The IAMS transmits the Intervention request to the AIV by means of the MP* (Mission Profile with Intervention information) before the Intervention starts.
Assumptions	• The IAMS has generated an intervention request that can be carried out by the corresponding AIV according to its availability, equipment available and location. • The IAMS is connected to the AIV.
Specifications	The IAMS shall create a message with MP* (Mission Profile with Intervention information) to be transmitted to the AIV.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_002**
Requirement	AIV receives Intervention request from IAMS
Type	Functional
Priority	Shall
Main goal	The AIV receives the Intervention request from the IAMS by means of the MP* (Mission Profile with Intervention information) before the Intervention starts.
Assumptions	• The AIV is connected to IAMS. • The IAMS has transmitted the Interventions request.
Specifications	The AIV shall receive a message with MP* (Mission Profile with Intervention information) transmitted by the IAMS.

Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_003**
Requirement	AIV transmits Route and Intervention confirmation to IAMS
Type	Functional
Priority	Shall
Main goal	The AIV transmits Route and Intervention confirmation to the IAMS before the Intervention starts.
Assumptions	• The AIV has received from the IAMS an MP* with the Intervention request and route that is feasible for AIV. • The AIV is connected to IAMS.
Specifications	The AIV shall create the message Route and Intervention confirmation to be transmitted to the IAMS.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_004**
Requirement	IAMS receives Route and Intervention confirmation from AIV
Type	Functional
Priority	Shall
Main goal	The IAMS receives the Route and Intervention confirmation from the AIV before the Intervention starts.
Assumptions	• The AIV has transmitted the Route and Intervention confirmation to the IAMS. • The IAMS is connected to AIV.
Specifications	IAMS receives the message with Route and Intervention confirmation transmitted by AIV.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_005**
Requirement	AIV transmits Status Report and Alerts to IAMS
Type	Functional
Priority	Shall
Main goal	The AIV transmits Status Reports and Alerts to the IAMS, while the Intervention is being carried out.
Assumptions	• The AIV has received from the IAMS an MP* with the Intervention request and route that is feasible for AIV. • The AIV has accepted the Intervention request.

	• The AIV has started the Intervention. • The AIV is connected to the IAMS.
Specifications	The AIV shall create the message SR* (Status Report and Alerts) to be transmitted to the IAMS while the Intervention is being carried out.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_006**
Requirement	IAMS receives Status Report and Alerts from AIV
Type	Functional
Priority	Shall
Main goal	The IAMS receives Status Reports and Alerts from the AIV, while the Intervention is being carried out.
Assumptions	• The AIV has transmitted a Status Report and Alerts to the IAMS. • The IAMS is connected to the AIV.
Specifications	The IAMS shall receive the message with Status Report and Alerts transmitted by the AIV, while the Intervention is being carried out.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_007**
Requirement	AIV transmits Inspection Data to IAMS
Type	Functional
Priority	Shall
Main goal	The AIV transmits Inspection Data to the IAMS, once requested Intervention has ended.
Assumptions	• The AIV has completed the Intervention requested. • The AIV is connected to IAMS.
Specifications	The AIV shall create the message with the Intervention Data to be transmitted to IAMS, once the requested Intervention has ended.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

Requirement ID	**WP11_Demo12.9_FRQ_008**
Requirement	IAMS receives Inspection Data from AIV
Type	Functional
Priority	Shall
Main goal	The IAMS receives the Inspection Data from AIV, once the requested Intervention has ended.

Assumptions	• The AIV transmits Inspection Data to the IAMS. • The IAMS is connected to the AIV.
Specifications	IAMS receives the message with Inspection Data transmitted by AIV, once requested Intervention has ended.
Additional information and background	Linked to TE 10, High-Level Requirement 10.2.

8.9.3. Non-Functional requirements

Requirement ID	**WP11_Demo12.9_NFRQ_001**
Requirement	Communication interface between IAMS and AIV
Type	Non-functional
Priority	Shall
Main goal	The interface between the IAMS and the AIV uses the Integration Layer.
Assumptions	Standardisation of the communication between the IAMS and the AIV using the Integration Layer.
Specifications	The interface between the IAMS and the AIV shall use the Integration Layer.
Additional information and background	None.

8.9.4. Components and functions

The IAMS-AIV interface deployment will consist of the following components (see Figure 13):

- IAMS: it consists of a machine that will host the IAMS-AIV interface and the functions to generate the information to the transmitted and to process the information received. Moreover, a display will be employed to configure and monitor the process.
- AIV: it consists of an on-board machine that will host the IAMS-AIV interface and the functions to generate the information to the transmitted and to process the information received. Moreover, a display will be employed to configure and monitor the process.
- Wireless network: a wireless network will be used to test the IAMS-AIV interface.

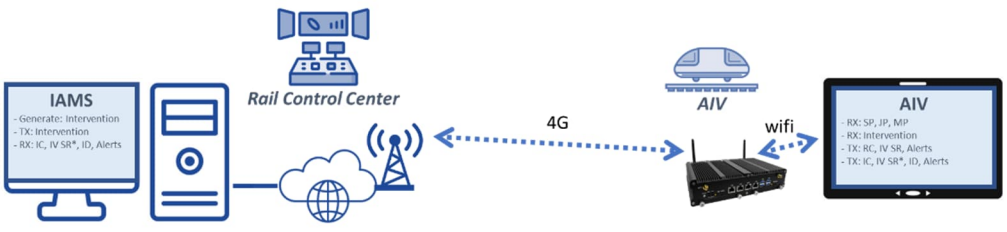


Figure 13: Diagram of the IAMS-AIV interface deployment prototype

8.9.5. Interfaces

There are three interfaces in the system, which differ depending on the case.

- Case 1 FP1-DEMO-12.9-UC-01: AIV runs alone in an isolated track. Interface between AIV and IAMS. No TMS considered.
- Case 2 FP1-DEMO-12.9-UC-01: TMS considers AIV as a regular train and therefore TMS deals with no details about inspection. Interface between AIV and IAMS and IAMS and TMS.
- Case 3 FP1-DEMO-12.9-UC-01: IAMS, TMS and AIV interconnected sharing information.

In the table below, the information to be exchanged via the AIV, IAMS and TMS interface is listed.

From	To	Info	Case
IAMS	IV	Intervention	1,2
IV	IAMS	Location	1,2,3
IV	IAMS	Intervention confirmation	1,2
IV	IAMS	IV SR*	1,2
IV	IAMS	Intervention data	1,2,3
IV	IAMS	Alerts	1,2
TMS	IV	Route	2,3
TMS	IV	Interventions (MP*)	3
IV	TMS	Route confirmation	2,3
IV	TMS	Intervention confirmation	3
IV	TMS	IV SR	2
IV	TMS	IV SR*	3
IV	TMS	Alerts	2,3
IV	TMS	Intervention confirmation	3
TMS	IAMS	Route Confirmation	3
TMS	IAMS	Intervention confirmation	3
TMS	IAMS	IV SR*	3
TMS	IAMS	Alerts	3
IAMS	TMS	Intervention request	3

CASE 1: *AIV runs alone in an isolated track. No TMS considered*
CASE 2: *TMS considers AIV as a regular train No details about inspection*
CASE 3: *IAMS, TMS y AIV interconnected sharing info*

Table 6: Information exchanged via the AIV, IAMS and TMS interface

9. Conclusions

The present report constitutes the deliverable D11.1 *Specification of selected Processes and Communication between applications* of the WP 11 *Development - Integration of TMS and processes including cross-border traffic management* in the EU-Rail Project FP1 MOTIONAL.

To fulfil the objective of this report, a complete and aligned set of Use Cases and related functional and non-functional requirements for demonstrations in relation to the technical capabilities that are to be developed and demonstrated under WP 11 and WP 12 were provided. These capabilities are addressing the Technical Enablers TE 8 “Real-time connection of rail networks as managed by TMS and involved actors”, TE 9 “Modelling and decision support for cross-border traffic management” as well as TE 9 “Integration of TMS with a) yard management system and processes; b) station management system and processes; c) energy management (Electric Traction System); d) real-time crew / rolling stock dispatching”.

The formulation of the Use Cases and requirements specification delivered in this report was based on the state-of-the-art analysis in WP 11 and inputs provided by inter alia, WP10, the System Pillar and RNE as well as the Flagship projects IAM4RAIL (MAWP Destination 3), TRANS4M-R (MAWP Destination 5) and FutuRe (MAWP Destination 6). The creation of this report followed a classical requirement engineering approach featuring repeated sequences of iterative “information gathering” and writing stages being separated by review phases.

The present specifications are used by the involved project partners as an applicable base for the implementation of demonstrations 1 to 9 of the WS 1.2 within the FA 1 (MAWP Destination 1). However, the project partners are aware of potential needs to improve or enhance the Use Cases and requirements as a consequence of feedback sessions maintained throughout the WP 12 especially in conjunction with specific network characteristics or planning situations faced when extending tests and network data scope within the different demonstration environments during the activities performed in the WP 12. The finalised Use Cases and requirements considering the feedback, lessons learnt, and other insights are planned to be incorporated into the future deliverable D12.1 of WP 12.

10. References

[1] FR8RAIL III D2.3 *Demonstration of enhanced and integrated line- and yard planning and possibilities for implementation*, Deliverable 2.3 of the Shift2Rail project FR8RAIL III, 2024.

[2] MOTIONAL D4.1 *Integration of planning systems,* Deliverable 4.1 of the EURAIL project MOTIONAL, 2024.

[3] MOTIONAL D10.1 *Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high level design for demonstrators in WPs 11-18,* Deliverable 10.1 of the EURAIL project MOTIONAL, 2024.

[4] MOTIONAL D10.2 *Definition of Data elements for demonstrators in WPs 11-18,* Deliverable 10.2 of the EURAIL project MOTIONAL, 2024.

[5] Shift2Rail IP5 *Demonstration of enhanced + integrated line- and yard planning and possibilities for implementation*, 2024, Video; https://youtu.be/LR_QJG3OvXU?feature=shared

[6] X2Rail-2 D6.1 *System Requirement Specification (SRS) for the Integration Layer*, Deliverable 6.1 of the Shift2Rail project X2Rail-2, 2020.

[7] X2Rail-4 D9.1 *Amendment to the SRS of the Integration Layer*, Deliverable 9.1 of the Shift2Rail project X2Rail-4, 2022.

End-of-the document