Deliverable 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

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1. Executive Summary

This document constitutes the Deliverable 10.1 “Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high-level design for demonstrators in WPs 11-18” in the framework of the Flagship Project FP1-MOTIONAL.

This report belongs to Europe’s Rail FP1-MOTIONAL specification phase. The FP1- MOTIONAL project focuses on improving network management planning and control, as well as rail mobility management in a multimodal environment in Europe. Research and innovation activities are broken down into several areas grouping the TEs (Technical Enablers) identified in the MAWP (Multi Annual Working Plan). The present document addresses the features associated with WS (Workstream) 1.2 “Operations” covering from TEs 8 to 17 (see Chapter 6).

The objective of deliverable 10.1 is to align, prepare and deliver the high-level specification of requirements, high-level design and high-level use cases based on a state-of-the-art analysis undertaken in conjunction with TEs 8 to 17. The deliverable is created based on the outcomes of Tasks 10.1 and Task 10.2 from WP10 “Alignment of specifications”. The high-level specification is performed in parallel with the more detailed specification carried out in WP11, 13, 15 and 17.

In the project proposal, 10 technical enablers were associated with WS1.2 “Operations” which is constituted by WP11/WP12 (Integration of TMSs and processes including cross-border traffic management), WP13/WP14 (Improved resilience and efficiency of disruption management), WP15/16 (Linking TMS to ATO/C-DAS for optimised operations) and WP17/WP18 (Automated decisions and decision support for traffic management optimisation). In this report each of the technical enablers is described in detail, including alignment with previous results, current state of practice, assigned development needs and high-level requirements (see Chapter 6).

Additionally, all demonstrations in Workstream 1.2 are introduced and described, together with their related high-level use cases (see Chapter 7 and Chapter 8). Also, an extensive mapping is carried out and presented in this deliverable. There are 25 demonstrations, and they are all mapped against the use cases, technical enablers and high-level requirements defined for each technical enabler (see Chapter 9). Finally, the alignment and interactions between WP11-WP18 demonstrations and other FP1 WPs, other Flagship Projects and SP are collected (see Chapter 10).

3 of the 25 demos are divided into sub-demos. This is the case of Demo 10 divided in 3 sub-demos, Demo 13 divided into 4 sub-demos and Demo 15 divided into 3 sub-demos (see Chapter 8).

D10.1 (due at M18) has been prepared during the first phase of the FP1-MOTIONAL project to provide the required inputs for the next phases, development and demonstration phases. This serves as a basis for next steps and work, and also helps to better understand the scope of future developments and demonstrations.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
AE	ATO Execution
AI	Artificial Intelligence
API	Application Programming Interface
APS	Automatic Protection System
ARS	Automatic Route Setting
ATO	Automated Train Operation
ATO-OB	Automated Train Operation-On Board
ATO-TS	Automated Train Operation-Trackside System
ATS	Automatic Train Supervision
BO	Back Office
CATO	Computer Aided Train Operation
CBTC	Communication Based Train Control
CCS	Control-Command and Signalling
CCTV	Closed Circuit Television
C-DAS	Connected Driver Advisory System
CDM	Conceptual Data Model (TMS platform-specific)
CDS	Conflict Detection System
CI	Common Interface
CM	Capacity Manager
CMS	Capacity Management System
CTC	Centralized Traffic Control
D	Deliverable
DAS	Driver Advisory System
DMPS	Digital Maintenance Planning System
DSS	Decision Support System
EIM	European Rail Infrastructure Managers
ERA	European Union Agency for Railways
ERJU	Europe's Rail Joint Undertaking
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETM	European Traffic Management
ETS	Electric Traction System
EU	European Union
EU-Rail	Europe's Rail Joint Undertaking
FFFIS	Form-Fit Functional Interface Specification
FINE2	Furthering Improvements in Integrated Mobility Management, Noise and Vibration, and Energy (Shift2Rail)

FM	Fleet Management
FP	Flagship Project
FUTURE	Delivering innovative rail services to revitalise capillary lines and regional rail services (FP6)
GoA	Grade of Automation
GDPR	General Data Protection Regulation
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HF	Human Factors
HL	High-Level
HLR	High-Level Requirement
HMI	Human Machine Interaction
IAM4RAIL	Holistic and Integrated Asset Management for Europe's RAIL System (FP3)
IAMS	Intelligent Asset Management System
ICT	Information and Communications Technology
IL	Integration Layer
IM	Infrastructure Manager
IMPACT	Indicator Monitoring for a new railway PAradigm in seamlessly integrated Cross modal Transport chains (Shift2Rail)
IN2RAIL	Innovative Intelligent Rail (Shift2Rail)
IP	Innovation Programme
IRS	International Railway Solution
IT	Information Technology
IV	Inspection Vehicle
IXL	Interlocking
JIT	Just-In-Time
JP-SP	Journey Profile-Segment Profile
KPI	Key Performance Indicators
L	Level
LINX4RAIL	System architecture and Conceptual Data Model for railway, common data dictionary and global system modelling specifications (Shift2Rail)
M	Month
MA	Movement Authority
MAWP	Multi Annual Work Plan
ML	Machine Learning
MM	Maintenance Manager
MMS	Maintenance Management System

MOTIONAL	Mobility Management Multimodal Environment And Digital Enablers (FP1)
MPS	Maintenance Planning System
MQTT	Message Queuing Telemetry Transport
OB2TS	On Board to Trackside System
OB	On Board
OBU	On Board Unit
OCC	Operation Control Center
PAS	Planning System
PE	Plan Execution
PFA	Preventive Functional Assessment
p-RTTP	Proposed Real-Time Traffic Plan
PSM	Possession Management
QoS	Quality of Services
R2DATO	Rail to Digital automated up to Autonomous Train Operation (FP2)
Rail CDM	Railway Collaborative Decision Making
RBC	Radio Block Center
RCA	Reference CCS Architecture
RFC	Rail Freight Corridor
RNE	Rail Net Europe
RTTP	Real-Time Traffic Plan, see also Operational Plan
RU	Railway Undertaking
RUD	Railway Undertaking Dispatcher
S2R	Shift2Rail
SAM	Semi-Automatic Mode
SCI-CMD	Standard Communication Interface Command
SCI-OP	Standard Communication Interface Operational Plan
S-DAS	Standalone Driver Advisory System
SFERA	Smart communications For Efficient Rail Activities (UIC)
SG	Subgroup
SMART	Smart Automation of Rail Transport (Shift2Rail)
SOTA	State-of-the-Art
SP	System Pillar
SR	Status Report
SRS	System Requirement Specification
STO	Semiautomatic Train Operation
ST	Subtask (of a Task in an EU-Rail Flagship project’s work package)
TAF/TAP	Telematics Applications for Freight/Passenger Services
T	Task (of an EU-Rail Flagship project’s work package)

TC	Traffic Controller
TCC	Traffic Control Centre
TCR	Temporary Capacity Restrictions
TCS	Traffic Control System
TD	Technical Demonstrator
TIS	Train Information System
TRANS4M-R	Transforming Europe's Rail Freight (FP5)
TSR	Temporary Speed Restrictions
TE	Technical Enabler
TM	Traffic Management
TMS	Traffic Management System
TMM	Real-time management module
TP	Timing Point
TPE	Train Path Envelope
TRL	Technical Readiness Level
TS	Trackside System
TSI	Technical Specifications for Interoperability
TT	Timetable
TTR	Timetable Redesign
UI	User Interface
UIC	International Union of Railways
UX	User Experience
VLSR	Very Large-Scale Rescheduling
WP	Work Package
WS	Workstream
X2R4	X2RAIL-4 project of the Shift2Rail programme
X2RAIL-2	Enhancing Railway Signalling Systems (Shift2Rail)
X2RAIL-4	Advanced Signalling and Automation System (Shift2Rail)
YCM	Yard Capacity Manager
YCPS	Yard Capacity Planning System
YCS	Yard Coordination System

Table 1: Abbreviation/Acronym

3. Background

This is the first delivery of WP10 “Alignment of specifications”, general WP of the specification phase of the WS1.2 “Operations”. This deliverable is based on the outcomes of Tasks 10.1 “Definition and high-level specification of technical enablers” and 10.2 “High-level specification of use cases and demonstrators”.

With focus on WS1.2 “Operations”, this can be divided into four main clusters which are:

- **WP11/WP12 – Integration cluster (Technical Integration with external TMS and other actors or systems):** this includes the developments relative to integration of TMS with other systems (asset, station/yard or crew/rolling stock/energy management systems) and with neighbouring TMS systems, including cross-border settings.

  As indicated in the FP1 Grant Agreement, before implementing operational plan changes, an appropriate alignment between TMS and other resource management systems such as asset, station/yard or crew/rolling stock/energy management systems is achieved. At the same time, the increasing dynamics in transport needs may lead to short-term changes of traffic demand to be reflected in the operational plan. For this purpose, modern integration technology needs to be used allowing dynamic exchange of latest status information at real-time scale.

- **WP13/WP14 – Disruption management cluster (Improved resilience and efficiency):** this includes the developments for a cooperative multi-actor optimisation and decision support system for incidents and disruption management, with human-in-the-loop through an advanced HMI, to increase system resilience and efficiency.

  More efficient traffic management is achieved by better consideration of human factors being enabled by new HMI design and technology as well as extended decision support featuring “what-if?” scenario evaluation with a specific focus on disruption and incident management.

- **WP15/WP16 – Operational feedback and ATO cluster (Improved automation):** This includes innovations relatives to real-time convergence with planning, including human in the loop simulation and dynamic timetables. Also, feedback loops between TMS – traffic simulation, TMS – CDAS/ATO and TMS – planning are included.

  To enable ATO or C-DAS technology to achieve energy and capacity saving objectives, a more automated way of automatically generating and implementing very short-term train control decisions from the operational plan is implemented based on accurate calculation of the traffic forecast taking into account ATO/C-DAS and ETCS2 and Hybrid Level 3 operation.

- **WP17/WP18 – Automated decisions and decision support cluster (Automated Decisions and Optimization):** this includes algorithms providing decision support and whenever possible automatic decisions for traffic management optimisation as well as to verify their suitability for different applications. This is relative to automated train control decisions and real-time optimisation.

The integration of TMS with other systems (assets, stations/yard or crew/rolling stock/energy management systems) and with neighbouring TMS systems, including cross-border ones, is one of the central topics of the FP1 project. It is expected to use the results of several Shift2Rail projects as a basis. The integration layer and the CDM data model are some of the inputs that are expected to be used. The tools, concepts under the development of RNE also play an important role. It is expected that a strong alignment with RNE and SP will be necessary.

Previous work and results from Shift2Rail projects as well as research studies will also be used for the works relative to disruption management and automated decisions and decision support.

In relation to the TMS-ATO/C-DAS link, there are already important concepts and standards that are evolving in this area, such as SFERA, ERTMS/ATO subsets and the RCA which are a good starting point. In addition, there is important knowledge about the impact on energy optimization, punctuality, capacity, workload, etc., several studies have already been done. There is also a practical basis, several countries have already carried out important implementations of C-DAS with important conclusions valid for both C-DAS and ATO operations. Also, although less, there are implementations and tests regarding ATO.

4. Objective/Aim

The objectives of the WP10 *"Alignment of specification"* are to align, prepare and deliver the high-level specification of requirements, high-level design and high-level use cases based on a state-of-the-art analysis undertaken in conjunction with Technical Enablers 8 to 17.

The deliverable (D10.1) is the first of the deliverables associated with WP10, general work package of specification phase for WS1.2 "Operations". The needs and high-level requirements associated to the technical enablers 8 to 17 are also included. Additionally, the high-level use cases for future TMS enhancements are defined and the high-level designs for each demonstration are shown. This deliverable is based on the outcomes of Task 10.1 and Task 10.2.

The content of this report is also used a basis for the continued work in WP10, Task 10.3, relative to the specification of demonstration environment/framework and identification of data structures. The outcomes of Task 10.3 are included in the following deliverable of WP10, D10.2.

The results of WP10 are expected to provide the foundation for the future developments in WP11, WP13, WP15 and WP17 and the related demonstrations in WP12, WP14, WP16 and WP18.

To be able to achieve planned results the project has maintained a good cooperation and interaction with other Flagship projects (FPx) and WPs as required. In particular for WP10 and supported by WP2, relevant requirements have been made available by other FPs in due time to allow their consideration for the demonstrator development in Workstream 1.2. An initial version of regional lines operational and functional requirements has been made available by FP6 initially at M6. Specification of dynamic dispatching requirements and constraints that are specific for last mile operations in terminals/yards have been received from FP5 at M7. All requirements being relevant for Workstream 1.2 demonstrator development have been received from other FPs latest at M12. In document "Milestone 3 - Requirements received from other FPs.docx." some requirements coming from other FPs are already collected and it is used as source.

The cooperation between the FPxs is further elaborated and established in the first phase (specification phase), in particular as part of the Tasks 10.1.3 and 10.2.2.

5. Methodology

This report is based on the input of Tasks 10.1 and 10.2, in which it is identified sources in previous international projects dealing with TMS development and integration and the trends of the market for such type of projects. Based on the needs of WPs 11, 13, 15, 17, the high-level use cases for future TMS enhancements are presented. Furthermore, high-level designs for each demonstration are also shown.

5.1. High-level specification of the technical enablers

For each technical enabler we detailed its scope and an analysis of the current state of practice is carried out taking into account previous experience and projects, identifying the existing gaps and the trends.

Based on the study of the state of the practice and the gap analysis the needs relative to future TMS development and integration are identified and collected per technical enabler. These needs come from the WPs 11, 13, 15 and 17.

Taking into account all this information the high-level requirements are identified and described.

This is the outcome of Task 10.1 and is included Chapter 6.

5.2. High-level use cases and demo definition

Based on the specification of the technical enablers performed as part of Task 10.1 the high-level use cases are identified and the demonstrations are further developed with respect to the scope included in the proposal phase. This information can be found in the Chapter 7 and Chapter 8.

The high-level use cases and demonstrations of WP11-WP18 for WS1.2 “Operations” are specified and collected based on input from WPs 11, 13, 15 and 17. This is the outcome of the works in Task 10.2.

Throughout the definition of the use cases and the description of the demonstrators, possible interactions with other WPs within FP1, other FPx or with the SP/RNE are identified. See summary in a table (see Chapter 10).

5.3. Mapping between the TEs, High-level requirements, use cases and demos

The traceability between the outcomes of Task 10.1 and Task 10.2 is established. This means we created a mapping between the technical enablers, high-level requirements, use cases and demonstration of WS1.2, which can be found in Chapter 9.

6. Definition and High-level specification of technical enablers (Task 10.1)

The technical enablers define the general capabilities that need to be developed to achieve the aim of one or multiple work package (WP) in the Europe's Rail Joint Undertaking (ERJU) project.

A total of 10 technical enablers were identified for WS1.2 "Operations". These technical enablers are linked to the different groups of specific work packages making up the WS1.2 "Operations": WP11/12 – TMS integration, WP13/14-TMS Resilience and Efficiency, WP15/16-Operational Feedback and ATO and WP17/18-Automated Decisions-Optimization. In Table 2, the technical enablers per WP are listed.

No of TE	Title	WPs
TE8	Real-time connection of rail networks as managed by TMSs and involved actors	WP11/12
TE9	Modelling and decision support for cross-border traffic management	
TE10	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	
TE11	HMI for TMS based on User Experience (UX) Design and user input	WP13/14
TE13	Cooperative planning multi-actors within rail	
TE14	Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management	
TE12	Real-time convergence between planning & feedback loop from operations	WP15/16
TE15	TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables	
TE16	Automation of very short-term train control decisions	WP17/18
TE17	Real-time conflict detection & resolution for main line and optimization	

Table 2: MOTIONAL-WS1.2 technical enablers

Figure 1 summarizes the scope of WPs forming the WS1.2 "Operations" that maps with the topics covered by the technical enablers.

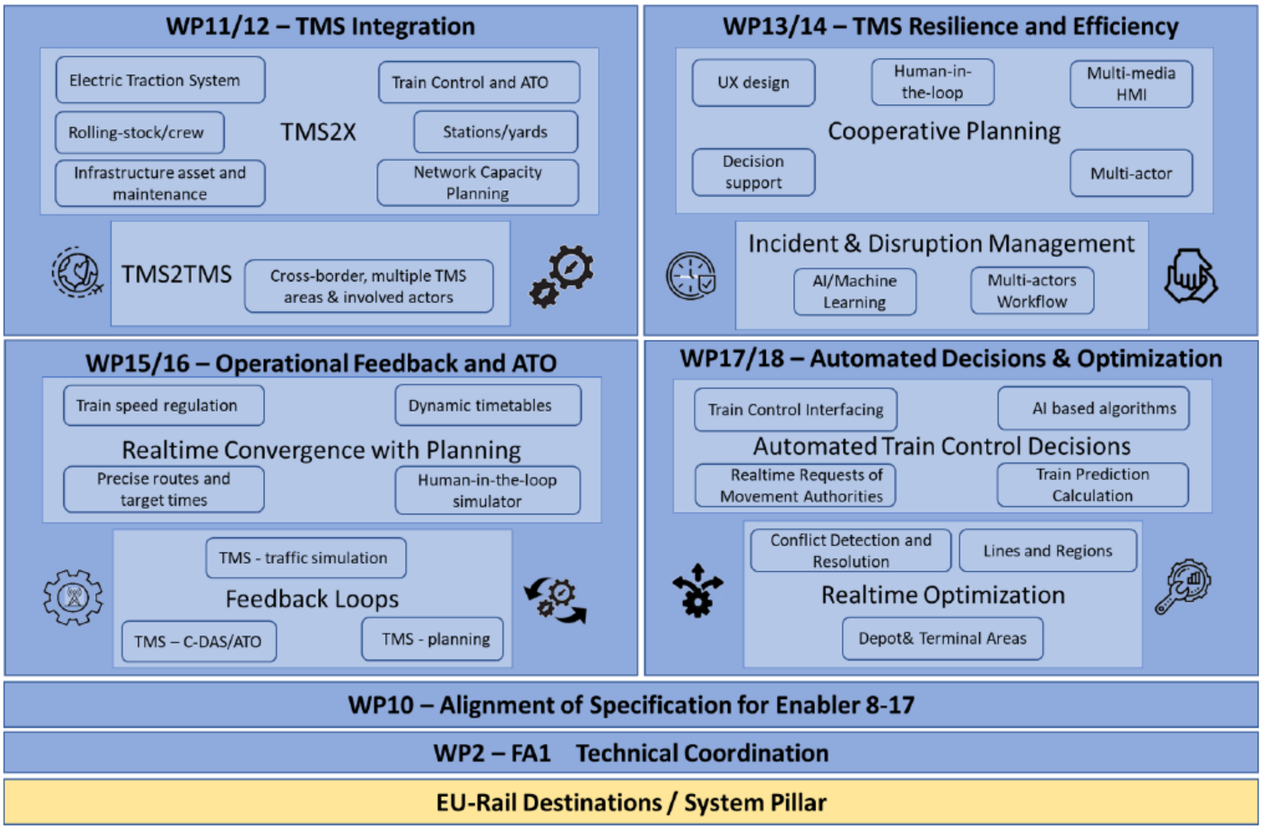


Figure 1: MOTIONAL- WS1.2 WP scope

In the following chapters of this document, the different technical enablers belonging to WS1.2 "Operations" will be described in detail, including in all of them the following structure:

A) **Short description of the TE.** Include a brief description of the technical enabler.
B) **Alignment level of this.** In this chapter, the description is to be aligned with previous results and available SP results.
C) **Current state of practice.** Identify and describe today's (SOTA) practice in conjunction with the scope of the planned demonstration and its innovative elements for this TE.
D) **Identified needs.** Identify and describe the needs in conjunction with the scope of the planned demonstration and its innovative elements for this TE.
E) **High-level requirements.** Identify and describe high-level requirements to cover the scope of demonstrations. These requirements will be further detailed as part of the specification works of the specific WPs (WP11/12, WP13/14, WP15/16 and WP17/18) and collected in the deliverables D11.1, D13.1, D15.1 and D17.1. Some of the high-level requirements are covering requirements coming from other FPs. In document "Milestone 3 - Requirements received from other FPs.docx." some requirements coming from other FPs are already collected and it is used as source.

6.1. Technical Enabler 8: Real-time connection of rail networks as managed by TMSs and involved actors

A) Short description of the TE

The Technical Enabler 8 (TE8) addresses the needs related to the real-time connection and technical integration of TMSs with

- Traffic Control Systems of the same area (TMS-TCS) including ATO/C-DAS, and
- other TMSs of the IMs managing a different area on national or international level in Europe (TMS-TMS).

For the latter, the focus is set to cross-border operations for international and cross-control area operations for national scenarios. To foster interoperability in this area, already existing standards or new/enhanced standards for information exchange are considered.

B) Alignment level of this TE description

The TE8 description has been aligned with the Integration Layer specified and developed in the EU-funded projects IN2RAIL, X2RAIL-2 and X2RAIL-4. The Integration Layer provides a standardized high-performance communication platform for data management and distribution as a platform for TMS, which includes interaction between TMS and TCS or ATO/C-DAS systems. It supports information exchange based on the TMS platform specific CDM data model established through the Technical Demonstrator TD2.9 of the Innovation Programme 2 (IP2) of Shift2Rail. Relevant documents considered for alignment:

- X2RAIL-2 D6.1 System Requirement Specification (SRS) for the Integration Layer,
- X2RAIL-4 D9.1 Amendment to the SRS of the Integration Layer.

The platform specific CDM is also considered for setting up the System Pillar's Data Model as the basis for future harmonization or standardization of technical communication and processes in Europe's railways.

For the TMS-TMS scenarios, the European IMs and especially their association Rail Net Europe (RNE) focussing on EU-wide harmonization of IM processes and communication have published the following relevant documents which, together with a number of interaction meetings, formed the basis for alignment:

- TTR FactSheets v. 2.0, section 8 (Ad hoc), section 10 (TCR),
- TTR Process v. 3.0, section 4 (TCR), section 8 (Ad hoc),
- Handbook for European Traffic Management Network,
- Framework for setting up a Freight Corridor Traffic Management System.

C) Current state of practice

This technical enabler specification addresses common needs in relation to the real-time connection and related integration between:

- TMS and Train Control sub-systems, including ATO-TS and C-DAS, and
- Two or more TMS's of one country or of different countries (cross-border).

The today's TMSs in Europe usually feature modules for handling the timetables, generating train running forecasts, a specialised graphical user interface and technical interfaces to communicate with other systems including (sub-)systems in the area of train control, including ATO-TS or C-DAS modules or systems. These interfaces are lacking mature standards although some standards have been emerging for ATO-TS and C-DAS in the meantime.

TMS systems in Europe are supporting the management of traffic in defined geographical areas with respect to the IM's network responsibility. Today, these systems do not have a notion of trains approaching the border location from the neighbouring TMS's side, especially if the train's timetable is not valid anymore due to e.g., a delay. These trains are seen only late, i.e., when the first track circuit within the local control area is occupied by the train. On the other hand, local traffic management decisions might have been taken assuming the international train is in time. These decisions could have been more effective if the delay would have been known before.

The communication between two traffic management systems is not satisfyingly standardised. Harmonized guidelines or rules for communication are missing preventing definition and development of appropriate interfaces and functionality to enable existing TMS systems or tools to support earlier notion of cross-border relevant traffic and train status providing also regularly updated speed profiles. The intention is to bridge the gap in current practices, enabling the earlier awareness of cross-border relevant traffic status.

D) Identified needs

The needs identified at a general level are:

- Allow for an enhanced standardized communication between TMS and subsystems in the area of Train Control including ATO-TS and C-DAS.
- TMS/C-DAS Train System interfaces that allow the evolution from S-DAS to C-DAS, providing updated speed profiles on a regular basis.
- Support IMs with continuous information exchange about international trains to ensure optimal alignment of trains between national networks, especially in case of short-term maintenance needs or accidental situations.
- Pre-aligned national parts of the train journeys by 'looking-behind-the-border capability'.

Today, national traffic management of an IM has no visibility about the traffic situation or restrictions behind the border. To shorten the time required for the decision alignment with the neighbouring IM, national traffic managers could pre-align their parts before handing their part over to the next neighbouring IM in sequence. This can be achieved by being able to identify conflicts with TCRs or other trains operating behind the border. The following specific needs have been identified:

- Providing transparency about the effective capacity usage and traffic management decisions, e.g., for freight corridor managers.
- Exchange of operational traffic and restriction status through international communication structures.
- Implemented train regulation concept for capacity restrictions on all RFCs with extensive European exchange of information to ensure high quality timetables and allow for automation in timetable adaptation.
- Increased customer satisfaction through improved effectiveness of cross-border traffic management.

E) High-level requirements

It shall be possible to support:

- **Req. 8.1:** An enhanced, standardized communication between TMS and subsystems in the area of Train Control including ATO-TS and C-DAS.
- **Req. 8.2:** An integrated forecast information for the IMs' TMSs for capacity production.
- **Req. 8.3:** The RFC management with a transparent view of capacity usage on track and signalling level.
- **Req. 8.4:** Input to harmonized operational rules or paradigms for integration of national traffic management systems.
- **Req. 8.5:** Visibility of TCRs behind the area border to pre-align traffic management decisions.

6.2. Technical Enabler 9: Modelling and decision support for cross-border traffic management

A) Short description of the TE

Based on the required technical interfacing enabled by TE8, the Technical Enabler 9 (TE9) focuses on the TMS processes and related functional capability of future traffic management systems required for an improved pre-alignment, decision making and coordination of cross-border traffic. For this purpose, an adequate modelling and design of the TMS software must be implemented to support further harmonization, taking existing and already agreed EU-wide approaches such as the TTR or the Rail CDM (Railway Collaborative Decision Making) concepts of the RNE into account.

B) Alignment level of this TE description

The TE9 description has been aligned with results of previous or still ongoing activities in relation to the RNE and stakeholders as e.g., Rail Freight Corridors or EU-Rail's System Pillar.

Besides others, the following documents, together with a number of interaction meetings, formed the basis for alignment:

- TTR FactSheets v. 2.0, section 8 (Ad hoc), section 10 (TCR),
- TTR Process v. 3.0, section 4 (TCR), section 8 (Ad hoc),
- Handbook for European Traffic Management Network,
- Framework for setting up a Freight Corridor Traffic Management System,
- Striving for a virtual European Traffic Management Network – Update (EIM position paper),
- Feasibility study on Railway Collaborative Decision Making (Rail-CDM; for Rhine-Alpine corridor),
- Rail CDM Development Requirements & Implementation Roadmap,
- EU-Rail System Pillar (Task 3): 3.1.1.8 ETM process Scope,
- EU-Rail System Pillar (Task 3): 3.10.4.1 Analysis of variants for European CMS & TMS (Draft),
- EU-Rail System Pillar (Task 3): 3.4.3.2 Monitoring international x-border traffic WP1 v06 (Draft).

C) Current state of practice

Today, the rail traffic management in Europe is nationally orientated without the perspective from the origin to the final destination of the train. In fact, there is no notion of trains approaching the border location from the neighbouring IM's side, especially if the train's timetable is not valid anymore due to e.g., a delay. These trains are seen only late, i.e., when the first track circuit within the local control area is occupied by the train. On the other hand, local traffic management decisions might have been taken assuming the international train is in time. These decisions could have been more effective if the delay would have been known before.

The cross-border communication between two national traffic management systems is not satisfyingly standardised. Harmonized guidelines or rules for communication are missing preventing definition and development of appropriate interfaces and functionality to enable existing TMS systems or tools to support earlier notion of cross-border relevant traffic status and negotiation of solutions for disruption situations.

D) Identified needs

The needs identified at a general level are:

- Harmonisation cross-border traffic management within the European networks and corridors.
- Capability to consider cross-border traffic and automated re-planning.
- to contribute to the integration of national TMS for international traffic coordination.
- Harmonized/integrated cross-border dispatching on track/signalling level (routing, timing, conflict

detection and resolution, TCR related train regulation).
- Capacity for pre-alignment/transparency (and thus, reactivity) for cross-border trains.
- Harmonisation of planning rules or paradigms in national Traffic Management.
- To achieve a visibility of TCRs or disruptions behind the border and capability for pre-aligned international train dispatching, esp. for freight.

E) High-level requirements

It shall be possible to support:

- **Req. 9.1:** A TM process which is compliant with international ad-hoc path (re-)planning process in line with TTR.
- **Req. 9.2:** The capability for harmonized/integrated cross-border alignment of traffic management decisions on track/signalling level (routing, timing, conflict detection and resolution, TCR related train regulation).
- **Req. 9.3:** Delivering input to harmonized operational rules or paradigms for coordination process in national traffic management systems.
- **Req. 9.4:** Capability to pre-align traffic management decisions based on TCRs or disruptions visible behind the border.

6.3. Technical Enabler 10: Integration of TMS with a) yard management system and processes, b) station management system and processes, c) energy management (Electric Traction System) and d) real-time crew/rolling stock dispatching

A) Short description of the TE

The Technical Enabler 10 (TE10) will help to improve traffic management decisions by integrating TMSs with the systems and processes mentioned in the TE10 title and being external to traffic management. This will lead to more realistic train running forecast as a basis for traffic management decisions and induced changes to the Operational Plan. As a result, the Operational Plan managed by the TMS anticipates and addresses very short term or dynamic variations of resource availability or other dependencies made available through the integrated systems in conjunction with train operation.

B) Alignment level of this TE description

Due to the lack of available interfacing standards in the TE10 area of concern, this TE description could not be aligned with any viable source. However, following the plans for the future activities in EU-Rail's System Pillar, the TE10 related integration topics will be addressed in the SP in the future. As such, the design and development work for the TE in the MOTIONAL project is expected to deliver input to the System Pillar for the respective subtasks in SP Task 3 accordingly.

C) Current state of practice

In Europe, the today's traffic management process using national TMSs is focused on freight and passenger trains as operating on the railway lines' tracks. Based on experience, timing allowances or supplements in the timetables are used to cover non-knowledge of factors influencing the timing of trains with respect to their arrival or departure at stations or handling points. Up to a certain extent, the additional time granted also covers unawareness of different activities or constraints of resource usage impacting train operation on the lines. Today, there is no transparency about how much of the additional time will effectively be used for these activities or constraints and if these would even cause delays. As a result, any already known delay in these activities will not be communicated technically to the TMS to consider it for the forecast calculation which itself leads to less realistic forecast and finally non optimum traffic management decisions. In some situations, a very short-term change of the linked activities or resource constraints and their impact could even lead to a non-compliance of operational rules in conjunction with the current operational plan. In this case, the operational plan needs to be substantially changed in terms of e.g., train cancellation or exchanges of rolling stock/crew.

In most of the above situations, the problems are due to there is no or only insufficient integration with systems and processes related to yard or station management, asset/maintenance planning and management, real-time crew/rolling stock dispatching and electric traction systems. Moreover, these systems are lacking early information about delay or operational plan changes being required for providing a high-quality information back to the TMS.

Regarding the availability of crew related information, it should be stated that for most of the IMs' today, this information is and will not be made available because of data protection regulations.

D) Identified needs

The needs identified at a general level are:

- To improve the quality of manual or automatic traffic management decisions, the train running forecast of the TMS needs to be improved by integration of TMS with systems and processes related to:
  - yard or station management;
  - asset/maintenance planning and management;
  - real-time crew / rolling stock dispatching; and
  - electric traction systems. To make it easy and efficient to integrate TMS with those systems, standardised interfaces are needed.
- Operational processes including their actors need to be identified and aligned.

E) High-level requirements

The TMS should support to:

- **Req. 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

- **Req. 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
- **Req. 10.3:** For interfacing with electric traction system components,
  - ✓ Receive from electric traction system realtime simulator
    - electric power restrictions
  - ✓ Send to electric traction system realtime simulator
    - updated train running forecast
    - updated operational plan
- **Req. 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

6.4. Technical Enabler 11: HMI for TMS based on User Experience (UX) Design and user input

A) Short description of the TE

HMI for TMS based on User Experience (UX) Design and user input is built upon methodology using scientific methods for the design of cognitive distributed systems, applied to the object in question. It will take into account, and provide sufficient design for the interaction between interfaces, external entities and actors based on usability principles, especially degree of situation awareness and mental workload of the operators.

The HMI for TMS will be developed within the project, based on a number of basic principles. The three most important principles are i) the theoretical framework, ii) the methodological approach, and iii) the combination of the theoretical framework and methodological approach.

B) Alignment level of this TE description

Previous work and results from Shift2Rail X2RAIL projects will be used, for example methods and tools to be used in field experiments. An available document is X2RAIL-4 (S2R-CFM-IP2-01-2019) 'Deliverable 8.4, Validate methods and measures for assessment of workload and situation awareness', which will be a part of the development. The work is ongoing and the objective is to use the tools when they are developed and validated.

Alignment with applicable results from SP will be included gradually, as published.

C) Current state of practice

The current state of practice is that the theoretical understanding of the processes at hand are rather satisfactory. The main problems identified are i) the instrument to be used for assessment and ii) the empirical platform for completion of the necessary investigations.

The theoretical framework suggests that the operators and roles involved in a specific task or process need to be skilled for the task at hand. To accomplish TE11 it is of utmost importance that subject matter experts are involved and studied. The methodological approach chosen for investigations "in the wild" (i.e. in reality) suggests that researchers need to develop an understanding of the task to be performed by the subject matter experts. Second, it is important to create a mutual understanding and trust between subject matter experts and researchers. The theoretical framework chosen needs to go hand a) with the data collection methods used and b) instruments to be used to obtain results.

Today, the operators in the control centers are the key players in all the critical actions, decisions, and are in charge of managing disruptions and critical situations. The standard operations are to some degree automatized, but all the alarms and critical situations are managed manually. This has a direct impact on the final results of the traffic management: in case of big disruptions or emergencies, the final result is mainly based on the operator's capabilities. Therefore, the corresponding HMI is based on real-time representations of the status of all managed assets and alerts, intended to highlight all the critical situations that needs to be managed.

The development of TE11 will focus on handling disturbed situations that would be unethical to perform in the wild, due to the safety aspects. Therefore, the current idea is to create an HMI solution for a TMS on a simulated platform. The prerequisites for the empirical platform to be used need to be further discussed and detailed.

Research on HMI solutions, especially HMI solutions for complex processes, has brought to light the multi-actor's involvement. Therefore, it is important to consider the collaboration and coordination that takes place in reality. Previous research has also shown that field research or quasi experimental studies need to consider and control several aspects to obtain reliable results (validity is often higher). However, the experimental laboratory approach has often proven to reduce validity of most research questions asked. Both the laboratory experiment and the quasi-experimental approach (in the wild) have strengths and weaknesses, higher validity but lower reliability and vice versa.

The work to develop an HMI solution for the railway sector could be supported by the knowledge gained from other traffic sectors, such as the air traffic controllers TMS.

D) Identified needs

The control rooms must contain all the displays, control workstations, communications devices and other features together with the necessary organizational resources, i.e. operational personnel to control and manage the traffic and infrastructure at its actual volumes.

The control room organization guarantees the possibility of complying with all functionalities in the different steps of the traffic management processes, including initial planning to organize the control room in terms of user capabilities and workload, tool for timetable definition and personnel management scheduling. Additionally, during daily operation, to support the operators in traffic management and after the services to analyse quality and coherence with the requested requirements.

To cover what is indicated above three different topics are identified:

- Planning and operation framework: the features necessary to use a control room.
- Run time framework: the support to the operator during the traffic management.
- Exploitation analysis framework: the tools to analyse the quality of services.

Based on previous analyses the identified needs are summarized as follows:

- Reduce the complexity in the collection and use of the information necessary for the operator,

- Consolidate the alarms management,
- Reduce the non-value-added actions that the operators need to carry out by increasing automatic handling, for example QoS,
- Prepare predefined scenarios to standardize actions by the operator.

The aim is to move to a support-based approach, which will coincide with an important transformation induced by an evolution of the interaction between systems and operators. In this evolution there are three main aspects in focus:

- What are the use cases where it is important to guarantee support to operators.
- What is the right level and kind of support to be given to whom (actor) in the different situations.
- How will this support be reflected in the HMI. What is the most efficient allocation of actions between system and the operator (grade of automation).

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 11.1:** Function allocation and task analysis-based HMI for the tasks managed by operators in disruption management.
- **Req. 11.2:** Possibility to carry out a KPI-based measurement of workload.
- **Req. 11.3:** Make it possible to evaluate identified tasks to be automated to reduce stress.

6.5. Technical Enabler 12: Real-time convergence between planning & feedback loop from operations

A) Short description of the TE

In WP15/16 the focus is on the interaction between the operative planning made in the TMS and the execution of that plan via C-DAS/ATO. This operative planning made by the traffic controller results in the Real-Time Traffic Plan (RTTP) and is the basis for the calculations made on the way to the actual movement of the trains.

The RTTP is transformed to a Train Path Envelope (TPE) that describes which limits the train must stay within to avoid interference on and by other trains. The limits can be time, speed, and limitations on power usage at specific locations. The TPE can be described as a part of a Journey Profile (JP) which may also contain other information related to the journey.

From the TPE, calculations are then made from different optimization aspects—like energy, comfort, and tear-—to have a train trajectory that describes the exact way the train should run to keep the journey within the TPE but also fulfil the defined optimization parameters. Since the calculation of the train trajectory is based on the TPE and RTTP, some of these optimizations could also be relevant to consider for the RTTP and TPE to give good conditions for the optimization. This could also be something to consider for the capacity planning.

TE12 is about how the feedback from the C-DAS/ATO-OB, i.e., the train trajectory, should be handled in the C-DAS/ATO-TS and also in the TMS. That is, if the actual calculated train trajectory in some way should be used to change the TPE and/or RTTP or not. In the same way there can also be feedback directly from the TPE calculation to the RTTP (in the TMS).

There is also a feedback loop that can be made all the way back to the planning system (capacity planning) to improve the alignment of the capacity plan to the actual operations.

The feedback loops considered are then: 1) Feedback from C-DAS/ATO-TS into TMS, 2) Feedback from C-DAS/ATO-OB into C-DAS/ATO-TS, 3) Feedback from TMS to capacity planning.

Feedback loop number 3 is outside the operative part and the real-time approach but is still important to have a faster improvement of the capacity plan. This is something that is not handled specifically in WP15/16.

B) Alignment level of this TE description

The connection between a TMS and the C-DAS/ATO-TS is an RTTP or Operational Plan that defines the routes and timing points (TPE). Related results that the System Pillar will have to consolidate and complete are ERTMS/ATO as proposed in X2RAIL-4, Smart communications for efficient rail activities (SFERA, UIC IRS 90940), the ATO part of the Reference CCS Architecture (RCA), and the Integration Layer as proposed in X2RAIL-2 and X2RAIL-4. The European Union Agency for Railways (ERA) has recently published the Technical Specifications for Interoperability for Control Command and Signalling 2023 (CCS TSI 2023) where the specifications for ATO/ERTMS GoA2 are included. They are based on the results obtained in project X2RAIL-4.

The following ERTMS/ATO Subsets are relevant, which were developed in X2RAIL-4 D3.1 for GoA2 and are included in the CCS TSI 2023 now:

- SUBSET 125-1.0.0: ERTMS/ATO System Requirements Specification,
- SUBSET-126-1.0.0: ERTMS/ATO ATO-OB / ATO-TS FFFIS Application Layer,
- SUBSET-130-1.0.0: ERTMS/ATO ATO-OB / ETCS-OB FFFIS Application Layer,
- SUBSET-139-1.0.0: ERTMS/ATO ATO-OB / ROLLING STOCK FFFIS Application Layer.

The ERTMS/ATO GoA2 Specification ATO-TMS FFFIS X-RAIL-131, as mentioned in several documents from ERTMS/ATO and the RCA is still missing and incomplete. It was not included in the new CCS TSI 2023. This specification is the core of the interface between TMS and ATO-TS, and is needed to understand and simulate the TMS-ATO processes and feedback loops, and to develop algorithms to compute and adapt RTTPs and TPEs.

Of particular importance are also the following ATO Principles: ATO Principle 1: Performance and Energy Efficiency, ATO Principle 2: Supervision and Regulation, and ATO Principle 5: Operate Train from X2RAIL project, see

- ERTMS/ATO Operational Requirements 1.15,
- ERTMS/ATO Operational Principles 1.8.
- ERTMS/ATO Operational Scenarios 1.11.

SFERA developed a standard (IRS 90940) for the data exchange between TMS and C-DAS/ATO based on SUBSET-126, with specific additions for DAS operations and also allowing class B signalling systems. This standard includes both the communication between TMS and C-DAS/ATO-TS and C-DAS/ATO-TS and C-DAS/ATO-OB. The first communication channel is defined to use the Common Interface (CI from TAF/TAP TSI) and in the airgap between trackside and onboard MQTT is defined. This standard can be central to develop functions in the TMS for C-DAS and thereby also be ready for ATO when that becomes available.

The RCA includes ATO but the TMS is considered an external system, called the Planning System (PAS) in RCA terminology. The RCA includes the subsystems ATO Execution (AE) and Plan Execution (PE), corresponding functionally to the ATO-TS and Automatic Route Setting, respectively. These subsystems are connected to the external Planning System via the bi-directional Standard Communication Interface Operational Plan (SCI-OP). Hence, the SCI-OP is located at the system border of RCA. The subsystem ATO Execution generates instructions for ATO based on the information taken from the Operational Plan, so that Train Units autonomously drive the Operational Movements as planned. ATO Execution and Plan Execution report the execution progress of the Operational Plan back to the Planning System by the Operational Plan Execution Report and the Train Unit Report. The Operational Plan is defined per train movement and includes amongst others the operational movement, consist, passage and stop events, event times, and event links (dependencies) in RCA terminology. The Operational Plan and the SCI-OP should be aligned with TE15 and TE12. The relevant RCA documents are:

- RCA: Terms and Abstract Concepts (RCA.Doc 14)
- RCA: Concept: SCI-OP (Standard Communication Interface Operational Plan) (RCA.Doc 31)
- RCA: ATO – Concept (RCA.Doc 72)
- RCA: System Concept ATO Execution (RCA.Doc 73).

The interface specification of SCI-OP is not finalized yet. SP is working on its finalization. The RCA also refers to X-RAIL-131 as a placeholder for the TMS-ATO interface but does not provide any information on it.

Another alignment must be achieved with the Integration Layer (IL) developed in the IN2RAIL, X2RAIL-2 and X2RAIL-4 projects. The IL provides a standardized high-performance communication platform for data management and distribution as a platform for TMS, which includes the interaction TMS-ATO. The SP should consolidate the Integration Layer. Regarding this, the available documents including ATO are

- X2RAIL-2 D6.1 System Requirement Specification (SRS) for the Integration Layer,
- X2RAIL-4 D9.1 Amendment to the SRS of the Integration Layer.

C) Current state of practice

Currently, there are a number of DAS applications implemented in various countries. These include stand-alone static DAS that are based on the timetable and are not connected to a TMS, but also C-DAS installations where the DAS is connected to a TMS which produces an updated operational plan. The current journey profile in the DAS onboard may be updated either at main stations or continuously via a continuous data communication with a TMS. Examples of C-DAS of the latter type are CATO originally developed in Sweden, GreenSpeed developed in Denmark, TTG Energymiser in Australia, and TimTim in the Netherlands.

ATO GoA2 (or higher level) has been implemented on many metro systems over the world. Because in metro lines/networks the track layout is simple and the trains are homogeneous, the TMS is much simpler. In metro systems it is called Automatic Train Supervision (ATS). In these cases, ATO/ATS is mostly implemented with Communication Based Train Control (CBTC).

ATO implementations on mainlines are still limited. The Czech railways have implemented GoA2 semi-automatic train operation (STO) since 1991. In the UK, Thameslink has been operating with GoA2 ATO over ETCS Level 2 since 2019, with plans to upgrade to GoA4. In Australia, the Rio Tinto iron ore railways are fully automated with GoA4 since 2020.

The basis for both C-DAS and ATO is the RTTP from the TMS and in this area improvements are still needed to get a good function as a whole when C-DAS/ATO is added to the trains. Both to produce a good operational plan that has a good quality to work well with C-DAS/ATO and provide the necessary margins for an optimized train journey and to give feedback at different levels to improve the overall function in this regard. The feedback loops mentioned above describe the different levels that can be considered to achieve a higher quality of the operational plan.

As for the functionality of the TMS when connected to C-DAS/ATO, not much has been done. In Sweden work was carried out between 2010 and 2015 with a TMS connected to the C-DAS system, CATO, that was used by LKAB, the large Swedish mining company. Regarding the C-DAS implementation, Hitachi Rail already developed a C-DAS demonstration based on ERTMS/ATO interface standards (SUBSET126) as part of X2RAIL-4 project.

Regarding the human factors, studies for heavy rail on ATO GoA2 and GoA4 have been done, mainly focused on the effects on train drivers. Very little research has been done involving the TMS and ATO design, support and impact for dispatchers and signallers, and the interaction between them and the train drivers.

Human-in-the-loop simulation as a tool/environment to conduct human factors studies has been extensively applied in the Dutch rail context.

D) Identified needs

One of the main questions to answer is in what situations, if any, should these feedback loops affect the input source and in what way.

With a perfectly executable RTTP available in the TMS and the C-DAS/ATO-TS generating perfectly executable TPEs which are sent directly to the C-DAS/ATO-OB of the various trains, each train may perfectly adhere to the provided TPE. In such a situation, there is no need for real-time adjustments of the RTTP/TPE. The human-in-the-loop is just notified of this "Normal" state.

When traffic is disturbed, the situation becomes different, and the deviations must be handled in some way. According to predefined rules it is necessary to be able to identify events which represent deviations from the RTTP or the TPE. These deviations can be identified by comparing the input with output of the feedback loops. For each predefined event some action might be needed to, for example, notify the TMS user and/or take automated measures to update the RTTP according to the set goals, which in turn will result in updated TPEs sent to the trains.

To what extent these measures should be automatically taken and how they should be presented to the user is an important aspect of human factors. This needs to be identified and specified. Human-in-the-loop simulations are needed to evaluate how the proposed measures can be handled by the user and what affects it has on the human in a real work situation. This requires a joint simulation of the various systems and actors involved.

To be able to produce high-quality RTTPs to C-DAS/ATO, good and partly automated tools and functions in the TMS are needed. Useful feedback from C-DAS/ATO-TS and C-DAS/ATO-OB should be presented and used in the TMS if it is useful for the operational planning. Within WP15/16 this will be investigated and some of the results will be demonstrated.

Another aspect to investigate is to see if the train trajectory should be used as a basis to adjust the TPE/RTTP to give more possibilities to the traffic controller and/or influence the TPEs for other trains. Should this feedback be an internal C-DAS/ATO affair, i.e., between the C-DAS/ATO-TS and OB, or should this information also be fed back to the TMS, and then how could it be used in the TMS?

To summarize the following needs were identified:

- A common view of the functionalities of TMS – C-DAS/ATO.
- Guidelines for triggering RTTP adjustments based on feedback from C-DAS/ATO-OB for efficient C-DAS/ATO operations and traffic management.
- Guidelines for triggering TPE adjustments based on feedback from C-DAS/ATO-OB for efficient C-DAS/ATO operations.
- Guidelines for dynamically optimizing RTTPs based on the feedback from C-DAS/ATO.
- Guidelines for dynamically optimizing TPEs based on feedback from C-DAS/ATO-OB information.
- Development of a simulator environment capable of simulating TMS – C-DAS/ATO operated trains for evaluation of enhanced TMS and C-DAS/ATO functionalities.

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 12.1:** TMS – C-DAS/ATO simulation environment to test and evaluate the presentation of and identified automated measures due to feedback information.
- **Req. 12.2:** Guidelines defined and partly included in the demonstrations to show the effect of the feedback loops.

6.6. Technical Enabler 13: Cooperative planning multi-actors within rail

A) Short description of the TE

WP13/14 addresses disruption management, which is critical to providing effective and efficient railway infrastructure and service and is an example where cooperative planning among multiple actors is needed. Specifically, when major disruptions occur on a railway network, the infrastructure manager, traffic controller and train operating companies may be forced to stop trains until the normal status is restored. In other situations, they are forced to appropriately identify, for each train, a location (a safe place) where the train can hold during the disruption or an alternative route that the traffic may take to avoid blocking the entire service or disconnecting the network which could cause delay propagation to the rest of the network. The requirement for quick recovery from the disruption is vitally important to keep up with the Service Level Agreements and the passenger expectations, but this should not contradict the need for safe operations and the possibility of intervention teams to reach the area and therefore, they can operate to deal with the cause of the disruption.

The main challenge lies in the need to have multiple actors who they have to cooperate to manage a disruption case. The planning between their activities implies an effective exchange of information, in addition to these actors not intervening and deciding in isolation, but rather being able to make decisions together as peers. A case of multi-actor cooperative planning is not only limited to the disruption managing within a few (e.g., three) hours after the causative event, but also involves later than the disruption management or to deal with other cases that affect the infrastructure and provided railway services. There is a need to improve timetable planning, as well as the complete operational planning, collaboratively to keep up service expectations, capacity changes and the need to welcome multiple service companies within the same infrastructures.

B) Alignment level of this TE description

Previous work and results of Shift2Rail X2RAIL projects will be used, for example, the work done relative to integration layer to have simplified, interoperable, and effective communication between all the involved actors.

All the work carried out under WP9 “Task 9.2 – Integration Layer and System Architecture” and “Task 9.3 – Development and Verification of demonstrators TRL4” will be considered, as well as IMPACT-2, WP7 and FINE2 WP11-15 and the OC OPTIMA with respect to TMS data modelling, which is a part of the data needed when managing disruptions.

Also, the work done on the evolution of TMS within X2RAIL-4 WP8 - TMS services, as well as ERJU-funded projects LinX4Rail & LinX4Rail-2 for the System Architecture and Conceptual Data Model for Railway, Common Data Dictionary and Global System Modelling Specifications will be considered.

Alignment with SP results will be gradually included, in dialogue with the SP, when modelling TMS and other data with respect to CDM.

C) Current state of practice

Most EU countries have established a centralized Operation Control Centre (OCC) to deal with significant disruptions happening across railway infrastructures and services, as well as other possible events causing re-planning of the traffic. This centralization is necessary to coordinate the different actors involved in the identification and management of an event of this type, such as the traffic controllers of the Infrastructure Manager (IM), the operations controllers of the Railway Undertakings (RU) and the delegates from the contractors. As indicated in Figure 2, they must work together making quick decisions and collaboratively exchanging information [Ghaemi et al. 2017]. Over time, this multi-actor scenario pushes towards the progressive penetration of ICT technologies within the railways. Figure 2 shows such a scenario and the workflow during a disruption. The first source of information about a severe infrastructure failure or rolling stock is usually the driver informing the back office (BO) of the OCC through the decentralized control centre by a signaller. Then, an inspector (a.k.a. general controller) is sent to the notified location of the failure to perform an on-field inspection of the current situation. At the same time, the back office publicizes an alarm on the ICT platform used as a means of data exchange, or Integration Layer, to foster interoperability and collaboration between the involved actors.

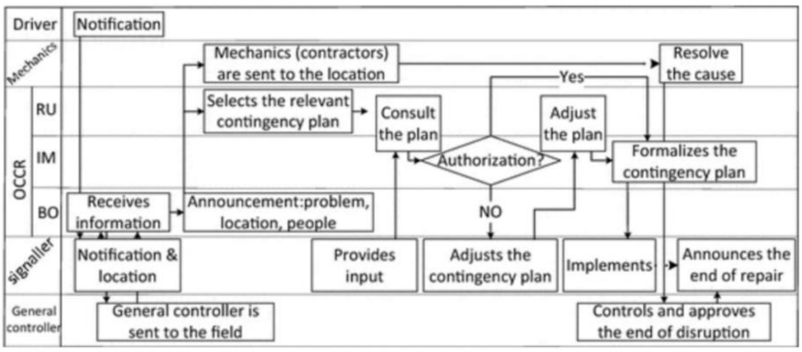


Figure 2: Workflow of disruption management [Ghaemi et al. 2017]

If necessary, contractors and/or IM staff are dispatched to the site of the disruption to repair the problem. At the same time, appropriate decisions must be made when dealing with disturbed trains that cannot proceed according to their original schedule. This is made possible by predefined contingency plans that support rail traffic controllers to determine, as early as possible, the best countermeasure to apply to reduce or minimize the impact of disruption and/or breakdowns on railway traffic. Based on the information from the field, the relevant contingency plan is selected and communicated to the traffic controllers by the infrastructure manager. All the involved actors cooperate in case of needed adjustments to the chosen contingency plan and to implement the operative instructions composing the plan. Once the faulty element is repaired or the cause of the disruption is solved, an announcement is made and traffic can be restored to the level before the interruption.

The traffic level during disruptions resembles a bathtub (Figure 3), where three distinct phases can be identified. When a disruption occurs, some trains need to be stopped at a safe point and others need to be redirected and therefore, traffic will decrease (first phase). The traffic remains low even when implementing a contingency plan that allows the intervention teams to approach the cause of the disruption and deal with it (second phase). When the team has completed their work and the disruption has been solved, the traffic will be recovered to the original timetable (third phase). The first and third phases represent operations transitions from the original timetable to the one defined in the contingency plan and vice versa. During these two phases, the traffic is different from during the regular phase, but lower, because a disruption occurs a section of the infrastructure is blocked and therefore it is impossible to maintain the same level of traffic as in the undisturbed situation.

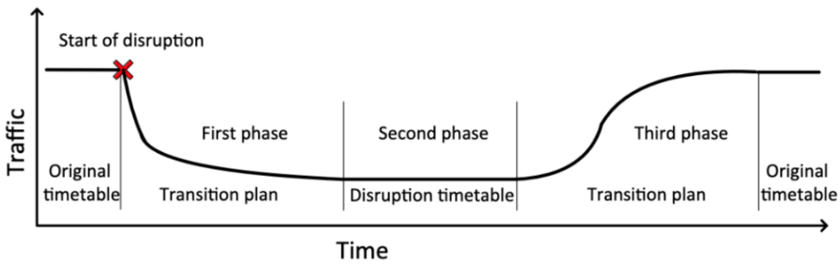


Figure 3: Bathtub model illustrating the traffic levels during a disruption [Ghaemi et al. 2017]

Experts design contingency plans and summarise the experience gained dealing with certain disruption cases. For a specific disruption scenario and considering where in the infrastructure the disruption occurred as well as the current operative conditions, the remaining capacity of the infrastructure is estimated and decided which trains should be cancelled or short-turned.

A key element of the first phase is the estimation of the exact location of the disruption and its duration, as the selection of the contingency plan depends on them. This search is based on the information received from the field, such as the exact location of the disruption and its severity. In the case of an existing suitable contingency plan, there is a problem with the implementation of these plans in the short-turning stations in the second phase of Figure 3. The solution specified in these plans cannot be precise regarding the current conditions facing by the controller, and it might not be implemented as directly as suggested in the contingency plan. Still, appropriate adjustments are always necessary to reflect the actual traffic status. Therefore, if on the one hand these plans simplify the work of the involved operators, on the other hand they cause stress as determining, communicating, and implementing these adjustments among all the involved actors as quickly as possible is troublesome. The need for these adjustments opens space for conflicts among the involved actors if two or more parties do not agree on a decision, such as cancelling a service, and have different opinions about which decision should be taken. Then, reaching an agreement might take a long time, and the final decision might not be the optimum since it depends on the experience of the involved operators and actors.

In all these three phases, it is crucial to have accurate and timely information on the current traffic status, repair activities and ongoing decision implementation. It was requested the design and implementation of the various ICT platforms for information sharing within a single organization as well as across multiple organizations (such as the different projects within the context of Shift2Rail). What is missing is adequate support for the selection and adjustment of contingency plans, as well as the ways to enable and promote effective and efficient multi-actor collaboration and coordination. In addition to proper communication means, stress on actors needs to be alleviated. Proper ICT means are needed to support the human actors in the reduction of the on-the-jobs mistakes, to have the right person (with the right competences and expertise) at the right place and to implement feedback loops between planning and operation in terms of re-enforcement learning among the actors at the two sides (making proper adjustments of the contingency plans).

D) Identified needs

The management of critical events by control room operators has significant effects on traffic regulation. Operators often have to take very quick decisions on the basis of heterogeneous information, sometimes applying complex procedures that require cooperation between several operators with different roles.

In such conditions, one of the most critical aspects of incident management is communication. Operators must be able to communicate effectively with each other and with other stakeholders, including emergency services, to ensure that the incident is handled appropriately. Communication must be clear, concise, and timely, and operators must be able to adapt their communication style to the needs of the situation.

In addition to effective communication, operators must also be skilled at problem-solving and decision-making. They must be able to analyse the situation quickly and accurately, assess the risks and benefits of various options, and make a decision based on the best available information. This requires a high-level of situational awareness and the ability to think critically under pressure.

For these reasons, the identified needs are:

- To facilitate communication and cooperation between operators.

- To reduce the risk of misunderstanding between operators in complex procedures.
- To improve comprehension by simplifying complex tasks: more complicated tasks often require a variety of different steps. This makes it increasingly difficult for employees to remember all of the steps they must carry out in order to complete a process. Typically, complex tasks require actions such as:
  - ✓ Take decisions in short-time to guarantee the regularity of the railway traffic.
  - ✓ Elaborate information coming from multiple sources or displayed in different views.
  - ✓ Coordinate personnel on site for maintenance operations.
  - ✓ Manage phone calls to assess the state of assets on site.
  - ✓ Manage multiple procedure related to different fails at the same time.
- To reduce on-the-jobs mistakes: a task analysis increases productivity, streamlines work processes, and clarifies every aspect of a task and related responsibilities. This reduces the number of errors made in the workplace.
- To identify which skills and resources are required for the process: aside from the steps that are involved, a task analysis can also identify what skills and resources are needed to complete the process.
- To improve existing processes and procedures: task analysis is helpful to create online training for current processes.
- To provide feedback loops between planning and operation.
- To develop adapters and protocols to be able to forward the right data to the right actors.
- To provide technical support for multi-acting, information sharing and negotiating among actors involved and/or affected.
- To contribute in finding an adequate level of automated decisions and decision support for traffic management optimization.

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 13.1:** The system, if several operators with different roles are involved, shall provide integrated support in the managing of traffic after a severe perturbation.
- **Req. 13.2:** The system helps to coordinate and to supervise multiple operators involved in the resolution of disruptive issues, in order to provide optimal solutions in complex scenarios.
- **Req. 13.3:** The system shall support the operator in managing critical situations. Critical situations are those in which different operators, with different roles and responsibilities, are involved in the management of critical tasks. In order to evaluate if a task is critical or not, and which is the type and the level of support to provide for each critical task, a task analysis shall be implemented.
- **Req. 13.4:** The system shall identify the level of criticality of a task on the basis of different key parameters, such as: Frequency, Operator workload, Efficiency, Reliability, Weight, Scalability (of the solution as well as the level of disruption).
- **Req. 13.5:** Once a task is identified as critical, the system shall consider which is its level of criticality, in order to define the relative level of support that has to be provided to the operators involved in the task solving procedure.
- **Req. 13.6:** Different tasks with the same level of criticality may not need the same kind of support. The type of criticality is also fundamental, in order to identify which operators to involve with proper task and how to support them.

- **Req. 13.7:** In order to support the coordination among different operators involved in the management of critical tasks, the system shall facilitate communication.
- **Req. 13.8:** The system, through the development of adapters and protocols, shall be able to forward the right data to the right actors.
- **Req. 13.9:** The system shall provide indication on tasks and action responsibilities in complex procedures, in order to reduce the risk of misunderstanding between operators that may lead to undesired decisions, which can negatively impact beneficiaries' welfare.
- **Req. 13.10:** The system shall provide information about which operator is managing a task.
- **Req. 13.11:** The system shall provide technical support for multi-acting, information sharing and negotiating among actors involved and/or affected.

6.7. Technical Enabler 14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management

A) Short description of the TE

When an unexpected event, like a broken train that blocks a track or an infrastructure failure, happens, it can cause a lot of inconvenience to passengers. It is necessary to know the exact information on the railway section affected by the disruption, such as expected passenger number or even real-time automated passenger counting. This information is an important input for managing the impact of the disruption. To achieve this aim, the integration of incident management and customer information is essential. Moreover, contingency plans to be selected and activated to deal with the event, but these plans may need adjustments and improvements to adapt them to the specific event to handle. However, these changes are not easy to do in the short-time needed to react to and manage a disruption. Currently, such a hard task is done by human operators and what to do is left to their experience, but this leaves space for inefficient decisions or even errors.

The main challenge lies in the fact that not all disruptions can be addressed with existing contingency plans. In general, disruption events are clustered in terms of features as well as solutions to be used. A contingency plan is an abstraction and summarization of all the solutions used for events in the same cluster. However, there are cases where none of these plans are applicable, leaving the controller to make decisions for different phases of a disruption, or even if a contingency plan can be selected it cannot be applied as it is. This is where a robust software solution, such as a DSS, is essential. It assists controllers from IMs and RUs in handling these unforeseen scenarios or those needing a plan to be adjusted, accelerating the plan selection process and facilitating the necessary adjustments.

A DSS can help to solve this complex problem by suggesting timetable adjustments as well as contingency plan modifications, considering multimodal alternative paths to mitigate the impact of the disruption while taking into account travel and waiting times for travellers and operational costs. The DSS can alleviate the stress on human operators by simplifying their work without substituting them, in accordance with Article 22 of the EU GDPR on Automated individual decision-making.

B) Alignment level of this TE description

Previous work and results from Shift2Rail X2RAIL projects will be used, for example, the work done on the integration layer to have simplified, interoperable, and effective communication among all the involved actors. All the work carried out under WP9 “Task 9.2 – Integration Layer and System Architecture” and “Task 9.3 – Development and Verification of demonstrators TRL4” will be considered, as well as ERJU-funded projects LinX4Rail & LinX4Rail-2 for the System Architecture and Conceptual Data Model for Railway, Common Data Dictionary and Global System Modelling Specifications.

Alignment with SP results will be included gradually, in dialogue with SP, when modelling TMS and other related data with respect to CDM.

C) Current state of practice

A railway operates as a complex, interconnected system where the infrastructure and its functions are closely intertwined. Even a small malfunction in one part of the infrastructure often causes disruptions throughout the network. Managers face immense pressure due to increasing demand for services and aging infrastructure, requiring them to ensure a secure operational network and make strategic maintenance decisions to enhance availability and prolong the lifespan of assets.

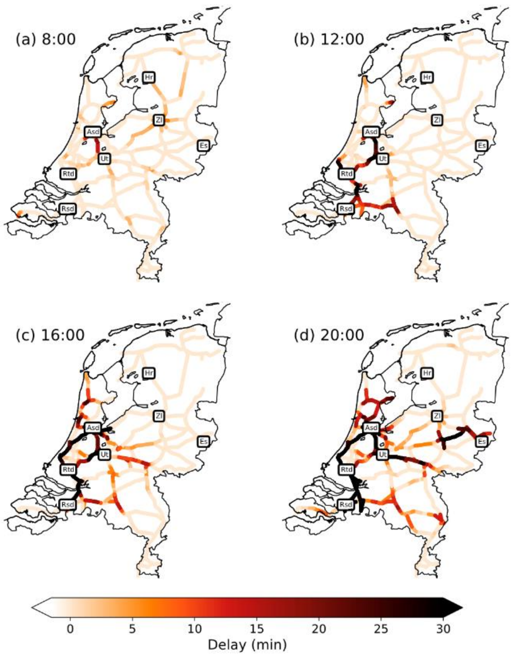


Figure 4: Average delay on the Dutch railway network, at four different times on 3 February 2012, a day with harsh winter weather [Dekker et al. 2022]

Traditionally, maintenance decisions and responses to disruptions have relied on managers' observations, experience, and available resources, including budgets, schedules, and contingency plans. However, this approach frequently results in unnecessary maintenance expenses and suboptimal disruption management, leading to decreased railway performance and passenger dissatisfaction. These situations present decision-making challenges for managers, traffic controllers, and train drivers, as they navigate conflicting priorities. As an example, it is considered the scenario in the Figure 4 where the time evolution of delays due to a disruption occurred among the passenger stations of Amsterdam and Utrecht, but later spread towards Rotterdam and Roosendaal [Dekker et al. 2022]. At the beginning of the evening, the delay even reached the far east of the Netherlands (Enschede). Unfortunately, the IM as well as the other involved actors were not able to take proper and effective decisions on how dealing with the disruption and a cascading effect lasted for the entire day with impact all over the network.

Addressing these challenges solely through expert judgment is inadequate, prompting a shift toward computer-based decision support systems (DSS) [D'Ariano 2009] [Deveci et al. 2022]. Over the past decade, advances in IT have facilitated the collection of vast amounts of data to aid decision-making. However, the complexity of data collection and management poses additional hurdles in the decision-making process.

A typical DSS comprises three primary components: a database, a decision analysis model, and a user interface. The database stores relevant data for decision analysis, focusing only on information essential to address decision queries. The decision analysis model serves as the core logic for the DSS, guiding decision-making processes and being realised by using techniques coming from artificial intelligence, machine learning, software computing, statistics or optimization theory. Finally, an intuitive user interface, often incorporating Geographic Information Systems (GIS), enables users to visualize infrastructure assets across the network and events/alarms, along with suggested decisions from the analysis model. This Human-Machine Interface (HMI) allows users to select decisions, communicate with other stakeholders, and provide feedback to improve future decision outcomes through reinforcement learning mechanisms.

Moreover, when dealing with disruptions, two key issues that need to be resolved are related to rolling stock and crew dispatching (more details are given as follows with examples to concrete and in-use examples).

On the one hand, a crew dispatcher is a professional who manages the daily operations of a company's transportation services and is responsible for scheduling and dispatching crew members, managing labor agreements, and communicating effectively with team members and customers. Within the EU railway ecosystem there are various possible solutions for crew dispatching, and let us consider one at NS, which is the CREWS-Real-time Dispatcher system (hereafter just system) provided by SISCOG, just to provide a concrete example. Within the system several advanced decision support algorithms are available to dispatchers. SAM (semi-automatic mode), based on the ideas of [Verhaegh et al. 2017], helps the dispatcher to find solutions for a single unplanned task. By using SAM an unplanned task can be rescheduled within seconds changing 1 or a few duties, if a solution within the ruleset of SAM exists. The JIT-solver (Just-in-time-solver), see [Morgado and Martins 2012], can reschedule dozens of duties at once in case of a medium sized disruption, for example when a part of the network is broken for a few hours. Finally, the VLSR (very large-scale rescheduling), see [Fioole et al. 2019], can overhaul large parts (up to the entire schedule) in case of really large unforeseen events several hours in advance, or in case of preventive measures, for example sever winter conditions. Even though these algorithms are successfully used in practice, still a lot of manual decision making and preparation before a solver run is involved in the process. This limits the use and effectiveness of these algorithms to their full potential. The aim is to add tooling and support to make the process even more automated and support dispatchers even more effectively.

On the other hand, we have that the rolling stock recovery problem is the problem of assigning train units to train departures in a disrupted rolling stock schedule so that operation returns quickly to the originally planned schedule. To give an example, rolling stock dispatching at NS is done using an in-house built system. This system provides a real-time view of all rolling stock, including all deviations from the original plan. The system has some basic conflict signaling, but no decision support tooling. Nowadays, solutions for any rolling stock conflict are invented mainly with pencil and paper. During the course of 2021 a new rolling stock dispatching tool was built, called “De Arend”, which has a more advanced conflict signaling. De Arend also includes passenger and maintenance information for conflict detection. De Arend also includes an early and very basic version of a decision support algorithm to fix rolling stock conflicts in real-time.

D) Identified needs

The control room organization guarantees the possibility to fulfill all functionalities in the different steps of the process:

- To effectively manage incidents, operators must be trained to recognize and assess the severity of the situation, and to take appropriate action in a timely manner.
- They must also be equipped with the necessary tools and resources to manage the situation effectively, including communication devices, maps, and access to real-time information. One of the most critical aspects of incident management is communication. Operators must be able to communicate effectively with each other and with other stakeholders, including emergency responders, to ensure that the incident is handled appropriately.
- Communication must be clear, concise, and timely, and operators must be able to adapt their communication style to the needs of the situation.
- In addition to effective communication, operators must be skilled in problems identification and definition. To evaluate the causes of a disruption, the related affected area, the major consequences on the line and on the traffic, is often harder than solving it. Solving a problem requires a proper diagnosis, that requires having the right information.
- After having identified problem and having collected all the useful information, problem -solving and decision-making procedures must be improved. Operators must be able to analyse the situation quickly and accurately, assess the risks and benefits of various options, and make a decision based on the best available information. This requires a high-level of situational awareness

and the ability to think critically under pressure.
- Finally, incident management in railway systems requires a strong culture of safety. Operators must be committed to following established protocols and procedures, and to continuously improving their skills and knowledge. They must also be willing to speak up if they observe unsafe behaviours or practices, and to work collaboratively with others to implement effective solutions.

In conclusion, incident management in railway systems is a complex and challenging task that requires the skills and experience of operators in control centres. By being well-trained, equipped with the necessary tools and resources, and committed to a culture of safety, these professionals can effectively manage incidents and ensure the safe and efficient operation of the railway system.

The identified needs for TMS are as follows:

- Provide adequate information, methods and tools for the operators to share and to cooperate among the actors involved and/or affected.
- Provide support in problem definition/identification (in collecting the right information).
- Provide support in decision making and to execute results of the decisions carried out.

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 14.1:** The system shall visualise all the relevant information, such as alarms and CCTV feeds, along with decision support tools and communications to help OCC operator to restore normal services quickly and safely.
- **Req. 14.2:** The system shall provide real-time information about the status of the railway system.
- **Req. 14.3:** When disruption occurs, it shall support the involved operators, providing detailed information about the disruption (such as, which is the exact problem/limitation in the network, its status, its direct consequences on the line/infrastructures and on the traffic condition...).
- **Req. 14.4:** It shall support the operator during the management of anomalies or unexpected events, providing a transparent status overview of disturbance attributes in the system and their direct impact on the infrastructures capabilities (e.g. overhead current group actions), the information on the correct actions to be taken and the support to implement them in the most effective way.
- **Req. 14.5:** The system should be able to identify the causes of a disruption.
- **Req. 14.6:** It shall support the operator in the management of a critical situation, providing the list of actions of the procedure that has to be performed (partially automatic).
- **Req. 14.7:** It shall provide recommendations, by proposing specific actions (but the actions remain in a manual mode, still in the hands of the operators).
- **Req. 14.8:** It shall inform which is the most critical alarm to act on among the alarms presented, by dynamically prioritizing them.
- **Req. 14.9:** It shall provide automatic remodelling of a views, in views, in accordance to priorities identified.
- **Req. 14.10:** In order to support the operator in solving a task, it shall extract and process all the useful information that are typically available, but difficult to be obtained and analysed by the operator himself.

- **Req. 14.11:** The system shall improve digitalization of communications between parties involved (users).
- **Req. 14.12:** It shall harmonize communications procedures pursuing a common operation (having common procedures or guidelines for common actions is therefore fundamental).
- **Req. 14.13:** It shall improve interaction of the TMS with the Maintenance System.

6.8. Technical Enabler 15: TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables

A) Short description of the TE

A main task of a railway TMS is to provide routes and times to trains for conflict-free and punctual train operation. WP15/16 is about linking TMS to ATO/C-DAS for optimized operations. As already noted in TE12, a TMS must provide an RTTP specifying the exact routes for each train as well as target times at scheduled timing points. This RTTP is the basis for both the timely route setting by the Traffic Control System and the accurate speed regulation of trains by ATO/C-DAS.

The ATO/C-DAS functions are divided into a trackside and onboard system, with the TMS connected to the trackside part. The ATO/C-DAS TS translates the RTTP in a TPE for each connected train, which specifies both targets and possibly additional time windows at Timing Points (TPs) on the train route. A TPE must give constraints to guarantee a drivable and conflict-free train trajectory, i.e., the time and speed profile over distance, while providing sufficient flexibility for energy efficient driving. In ERTMS/ATO and the SFERA C-DAS-O architecture, the TPEs are included in the Journey Profile together with the associated Segment Profiles by the ATO/C-DAS TS and are sent to the ATO/C-DAS OB of the connected trains.

The TPE is used in the train trajectory generation algorithm of the ATO/C-DAS. A C-DAS translates this train trajectory to driving advice for the driver, while ATO (from GoA 2 onwards) uses the train trajectory as reference to a train trajectory tracking algorithm to provide automated control commands to the traction and braking systems. The ATO/C-DAS OB of the connected trains report their status as feedback back to the Trackside. This feedback can be used to adjust TPEs and RTTPs.

WP15/16 develops an TMS-ATO integration platform and algorithms for TMS – ATO functions and implements them in simulation environments for ATO or C-DAS respectively. The simulation environments are used to test and evaluate the algorithms linking the TMS and ATO/C-DAS, analysing the various feedback loops between the TMS, ATO-TS and ATO-OB functions, as well as the impact on the involved human actors (traffic controllers, signallers, dispatchers, train drivers).

In TE15 the focus is on developing requirements for the TMS and ATO/C-DAS Trackside functions and their interaction. In particular, in collaboration with FP2/WP39 a TPE generator for the ATO-TS is developed, integrated and tested, as well as new TMS functions that should work smoothly together to optimize capacity, punctuality and energy efficiency.

B) Alignment level of this TE description

The connection between a TMS and the ATO-TS is an RTTP (or Operational Plan in the RCA) that defines the routes and timing points for the train traffic. Related results that the System Pillar will consolidate and complete are ERTMS/ATO as proposed in X2RAIL-4, Smart communications for efficient rail activities (SFERA), the ATO part of the Reference CCS Architecture (RCA), and the Integration Layer as proposed in X2RAIL-2 and X2RAIL-4. The European Union Agency for Railways (ERA) has recently published the Technical Specifications for Interoperability for Control Command and Signalling 2023 (CCS TSI 2023) where the specifications for ATO/ERTMS GoA2 are included. They are based on the previous results obtained in project X2RAIL-4.

The following ERTMS/ATO Subsets are relevant, which were developed in X2RAIL-4 D3.1 for GoA2 and are included in the CCS TSI 2023 now:

- SUBSET 125- 1.0.0: ERTMS/ATO System Requirements Specification
- SUBSET-126-1.0.0: ERTMS/ATO ATO-OB / ATO-TS FFFIS Application Layer
- SUBSET-130-1.0.0: ERTMS/ATO ATO-OB / ETCS-OB FFFIS Application Layer
- SUBSET-139-1.0.0: ERTMS/ATO ATO-OB / ROLLING STOCK FFFIS Application Layer.

The ERTMS/ATO GoA2 Specification ATO-TMS FFFIS X-RAIL-131, as mentioned in several documents from ERTMS/ATO and the RCA is still missing and incomplete. This specification is the core of the interface between TMS and ATO-TS, and is needed to understand and simulate the TMS-ATO processes and feedback loops. It is unclear where the specification for the potential SUBSET-131 will be developed.

Of particular importance are also the following ATO Principles: ATO Principle 1: Performance and Energy Efficiency, ATO Principle 2: Supervision and Regulation, and ATO Principle 5: Operate Train, see:

- ERTMS/ATO Operational Requirements 1.15,
- ERTMS/ATO Operational Principles 1.8,
- ERTMS/ATO Operational Scenarios 1.11.

In X2RAIL-4, an initial GoA3/4 specification has also been developed in D3.2, although here TMS is outside the scope and therefore also the interface between the TMS and the ATO Trackside. FP2/WP5 will continue with the GoA3/4 specification, in particular in task 5.3.

SFERA developed a standard for the data exchange between C-DAS TS and C-DAS OB based on SUBSET-126, with specific additions for DAS operations and also allowing class B signalling systems.

The RCA includes ATO, but the TMS is considered an external system, called the Planning System (PAS) in RCA terminology. The RCA includes the subsystems ATO Execution (AE) and Plan Execution (PE), corresponding to functionally related to the ATO-TS and Automatic Route Setting, respectively. These subsystems are connected to the external Planning System via the bi-directional Standard Communication Interface Operational Plan (SCI-OP). For additional information please check TE12.

Another alignment must be achieved with the Integration Layer (IL) developed in the IN2RAIL, LINX4RAIL, X2RAIL-2 and X2RAIL-4 projects. The Integration Layer provides a standardized high-performance communication platform for data management and distribution as a platform for TMS, which includes the interaction TMS-ATO. The SP should consolidate the Integration Layer. It is based on the Conceptual Data Model (CDM). The available documents including ATO are:

- X2RAIL-2 D6.1 System Requirement Specification (SRS) for the Integration Layer.
- X2RAIL-4 D9.1 Amendment to the SRS of the Integration Layer.
- LINX4RAIL D3.1 CDM Specification.

C) Current state of practice

See Technical Enabler 12, chapter “C) Current state of practice”.

D) Identified needs

The ATO/C-DAS is expected to contribute to increased capacity, punctuality and energy savings. Nevertheless, ATO/C-DAS performance depends on the quality of the timetable and the connection to a TMS that may adjust the timetable considering disturbances or delays. Hence, a TMS should seamlessly interact with ATO/C-DAS, which are complementary but linked systems. The TMS optimizes the adaptation of the RTTP in case of disturbances or delays focusing on integral track capacity allocation of the railway traffic on the network level.

On the other hand, ATO/C-DAS regulates the trains by computing feasible and energy-efficient train trajectories (speed profiles) over the allocated routes within the allowances contained in the real-time traffic plan and following them using speed tracking algorithms (ATO GoA2 and higher) or driver advice (ATO GoA1 with C-DAS). The time allowances must be distributed to the various trains via the TPEs, which may contain target times or time windows at timing points, to offer sufficient flexibility while guaranteeing conflict-free, punctual and energy-efficient train operation. The interaction should lead to a balanced usage of ATO train-centric optimization, complying with the network optimization of the TMS. In particular, the TPE generated by the ATO Trackside should not overlap or interfere with the network traffic optimization of the TMS and be consistent with the route setting of the Traffic Control System.

The following needs were identified:

- Guidelines to model TMS – ATO/C-DAS operated trains in timetables and simulation.
- Requirements for a Real-Time Traffic Plan (RTTP) as input to ATO/C-DAS.
- Guidelines for Train Path Envelopes (TPEs) in ATO/C-DAS, including distribution strategies for the location of timing points for dynamic and optimized capacity, punctuality and energy consumption.
- Guidelines for dynamic updating of RTTPs (dynamic timetables) to optimize ATO/C-DAS operations based on feedback from the ATO/C-DAS trains.
- Development of a simulator environment capable of simulating TMS – ATO/C-DAS operated trains

for evaluation of enhanced TMS and ATO/C-DAS functionalities.

- Development of a TMS – ATO integration platform (based on the Integration Layer/CDM) to support automated train operation.

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 15.1:** Integration platform to support TMS – ATO train operation.
- **Req. 15.2:** Method to compute optimized TPEs to connected ATO/C-DAS trains for a given RTTP.
- **Req. 15.3:** Method to dynamically adjust an RTTP based on feedback from ATO/C-DAS.
- **Req. 15.4:** Method to dynamically adjust TPEs based on dynamic RTTPs.
- **Req. 15.5:** Method to dynamically adjust TPEs based on feedback from the ATO/C-DAS Onboard.
- **Req. 15.6:** Optimal interaction of TMS, ATO Trackside and ATO Onboard functions.
- **Req. 15.7:** TMS – ATO/C-DAS simulation environment to test and evaluate TMS – ATO/C-DAS operations.

6.9. Technical Enabler 16: Automation of very short-term train control decisions

A) Short description of the TE

The goal of WP17 is the development of a system for semi-automated decisions for traffic management. To support the decision-making process, the system needs to detect situations that require an action (e.g., specific conflict situations) and propose an action to solve the situation. This WP is closely related to TE16 and TE17.

TE16 is related to the automation of very short-term train control decisions. This is expected to address non-vital functionality for the automation in making and implementing control decisions in a very short-term time window ahead of ‘0’ when no time for human based processing or decision making plus technical reaction times is left., e.g., 3mins ahead 0).

B) Alignment level of this TE description

Technical Enabler 16 (TE16) is identified as the automated execution level for operational plans. Within the SP architecture this functionality is related to the “Plan Execution” module, called PE.

PE is connected via SCI-OP bidirectional interface to the TMS. Through this interface, PE receives operational plans from the TMS. Operational plans contain trip data relevant to execution, such as: planned train route, timing point locations, schedule including arrival and departure times.

SCI-OP interface is used by PE to send back status information about requested/granted/rejected ETCS Level 3 movement authorities.

The specification of SCI-OP interface is not finalized yet. SP is reusing the already advanced proposal from SMART Rail4 project and is working on its finalization.

On the other hand, PE is connected to vital APS by bidirectional SCI-CMD interface. This interface is used to send MA requests to APS and to receive status feedback such as MA granted/rejected.

The specification of this SCI-CMD interface is not yet finalized either. SP is reusing the basic proposal from SMART Rail4 and is working on its finalization.

Further open topics are if PE shall use SCI-OP to send back status information about requested/granted/rejected ETCS L3 movement authorities to ATO execution module directly. This can be used to adapt speed profiles in almost real-time. The current SP architecture foresees the feedback loop running via TMS to ATO-execution exclusively.

Regarding the level of intelligence implemented in PE:

One idea is to keep PE limited to non-vital simulation and requesting of ETCS L3 Movement Authorities.

An enhanced concept foresees to implement advanced functionalities for very short-term automated decision making as part of the TMS. This should at least provide the functionality of ETCS L2 route setting systems as described in current state of practice below. This ETCS L2 functionality should be enhanced by impact driven decision levels, used to decide which kind of actions PE is allowed to be executed automatically or sent back to TMS operators.

To make best usage of ETCS L3 flexibility, more intelligence is needed for real-time execution.

C) Current state of practice

In the current ETCS L1 – 2 operations, this functionality is implemented in automated route setting systems. Here automated decisions are taken, when/if and to which extend route settings will be requested for execution by interlocking system.

This process is called “availability check” or “Vorverfügbarkeitsprüfung” in German language. This considers train, block and field element status/setting times.

In enhanced implementations precise speed profile and breaking distance calculation are used to optimize route setting time. Leveraging between requesting route setting as late as possible, but early enough, that trains can continue without breaking, has huge impact on track capacity.

Further functionality implemented in automated route setting is basic conflict detection. Conflict types depend on national operational rules.

For example, deadlock conflicts can be detected which are caused by disturbances beyond the next routes to be set. In this case, the automated route setting avoids the train departing from platform. This does not solve the conflict but helps to minimize impact of unplanned disturbance.

Automated route setting systems do not change operational plans. Its scope is limited to execute operational plans, given by TMS, best possible and minimize impact of unplanned disturbances.

D) Identified needs

Technical Enabler 16 addresses non-vital functionality for the automation in making and implementing control decisions in a very short-term time window ahead of '0' when no time for human based processing or decision making plus technical reaction times is left., e.g., 3mins ahead 0).

This is especially important in larger nodes or switching areas with higher route complexity. This requires highly accurate forecast calculations based on the real-time status and automated updating of operational plan leading to real-time MA requesting for ETCS L3 hybrid and L3 full moving block operation.

E) High-level requirements

The solution to the Technical Enabler shall be able to support:

- **Req. 16.1:** Precise train running forecast calculation providing accurate times/TPEs and track level routing.
- **Req. 16.2:** Detection of deviations and deriving operational mitigating actions.
- **Req. 16.3:** Automated impact analysis with adjustable thresholds deciding on automated putting in operation or feeding back proposals.
- **Req. 16.4:** A modern technology avoidance of deadlock conflicts, high impact emergency stops or reversing actions.
- **Req. 16.5:** A modern technology avoidance of sequencing conflicts, causing high impact on schedule for higher priority trains.
- **Req. 16.6:** Highly accurate forecast calculations based on the real-time status and automated updating of operational plan (RTTP) leading to real-time MA requesting for ETCS L3 hybrid and L3 full moving block operation.

6.10. Technical Enabler 17: Real-time conflict detection & resolution for main line and optimization

A) Short description of the TE

The goal of WP17 is the development of a system for semi-automated decisions for traffic management. To support the decision-making process, the system needs to detect situations that require an action (e.g., specific conflict situations) and propose an action to solve the situation. This WP is closely related to TE16 and TE17.

TE17 is concerned with developing a methodology that detects conflicts from the current traffic situation in the network and determines actions to solve the conflict. Conflict situations and their resolutions can be multifaceted, and their effects can range from minor delays of individual trains to a disruption of the entire network (due to, e.g., infrastructure restrictions).

Different approaches and methods are available for the TE implementation. On the one hand, real-time operations simulations offer the possibility to diagnose timetable deviations and disruptions, as well as forecasting the near future and conflict situations that may arise at that time. A simulation can also be the basis for analysing recommended conflict solutions and their subsequent effects on the railway network. On the other hand, methods such as mathematical optimization or reinforcement learning can be used to generate conflict solutions that optimize traffic based on the current traffic situation in the network and possibly also on historical data. Depending on the technology chosen for implementation, optimization or reinforcement learning, processes may have a close link with simulations. For example, in reinforcement learning, past conflict scenarios may be mapped into simulations so that, the method can learn from these situations (and their resolutions) and then apply this knowledge to the current traffic situation. This might have performance advantages compared to solving optimizations problems in real-time.

The selection of suitable technologies for implementing the requirements described in this document is part of the implementation phase of WP17 (i.e., Task 17.2). The developments related to TE17 that are achieved within WP17 are designed to reach a technical readiness level of 4 (TRL4) – defining the required maturity of a developed technology. In WP18, demonstrators with maturity level TRL5 of the TE17 are developed. To facilitate the future selection of the appropriate technologies for implementation, functional and non-functional requirements in the next chapters have been formulated in a technology-open manner.

B) Alignment level of this TE description

Solving conflicts largely depends on human agents' skills to understand and analyse the scenario and provide solutions to resolve these conflicts. A traffic management system facilitates this manual process through means such as visual representation of both scheduled and anticipated train routes, along with options for manual intervention. The capability to detect and resolve conflicts is a critical feature of any traffic management system. When conflicts cause a deviation in planned operations, they need to be addressed to restore the seamless operation.

"WP6 - Traffic Management evolution" of X2RAIL2 has provided a description of Use-Cases for new TMS Principles and a general description of these conflict resolution use cases. This work has been further developed in "Task 8.2 - Use cases for advanced TMS principles" within "WP08 - TMS services" of X2RAIL4. In addition to the review and update of the described use cases in X2RAIL2, functional specifications for TMS for the selected use cases have been developed. Additionally, "Task 8.3 - Automated conflict handling solution" proposes a conflict resolution system designed to automatically generate a new plan following a significant disruption, such as a railway line closure within a densely populated network. It considers various factors, including the current positions of trains, re-routing options that take into account train characteristics, the scheduling of maintenance for units, and the management of crew cycles or passenger movements. The system offers multiple solutions, each accompanied by clear performance indicators (KPIs) and all the necessary information, enabling the operator to choose the most suitable solution. "Task 8.4 - Large scale optimisation method" of WP8, applying strategies from Operations Research and Artificial Intelligence, identified advanced mathematical methods that can enhance automation and optimization on a larger scale and relax the imposed limitations in terms of number of trains, network complexity, and the range KPIs.

Within EU-Rail, Specifically, TE 17 must adhere to the guidelines and specifications established by the System Pillar. The objective of the System Pillar is to realize the vision of a seamlessly integrated railway system by the year 2031. It establishes applicable standards for the systems within the ERJU. Given the dynamic interaction between the System and Innovation Pillars, the outcomes from WP 17 (including those pertaining to TE 17) are shared with the System Pillar.

C) Current state of practice

With increasing demand on the European railways, higher frequencies and the need for higher capacities, the number of conflict situations during operation is expected to increase. Currently, adverse downstream effects of conflict situations are limited by the quick and manual intervention of dispatchers. Driven by digitalization and new data streams, for instance through the development and implementation of advanced ETCS levels, new digitalisation and automation potentials are emerging. The multitude of data that is currently (or projected to be) available combined with state-of-the-art algorithms offer the possibility to automatically identify conflicts in real-time, and to support dispatchers with proposed conflict resolution actions.

Currently, monitoring of the network and intervention in conflict situations is still largely carried out by dispatchers of the Infrastructure Managers (IMs) in collaboration with the Railway Undertaking (RU) side. Together, these stakeholders monitor the information from several systems in parallel and take part in the event of train delays, infrastructure disruptions, or other unforeseeable deviations in the timetable. Due to the complexity of the network, the effects of conflict resolutions are difficult to predict, and decisions are usually taken based on the personal experience of decision-makers or pre-defined operational rules. Of course, decisions made by the dispatchers also have a large impact on the other actors in the rail operation. Therefore, to avoid creating new conflicts, decisions are made in close consultation with the other involved parties. For example, before taking a conflict resolution decision an IM dispatcher coordinates their changes with the RU, in many cases verbally via telephone.

With the continuous development of fields such as artificial intelligence (AI) and machine learning (ML), there are already initial pilot projects in Europe aimed at exploiting the potential of generated operations data. In particular, techniques such as mathematical optimization, supervised learning and reinforcement learning are in the beginning stages of being phased-in for the optimization of traffic flow – even in real-time. By mapping the current situation on the railway infrastructure in a digital twin, forecasts can be generated and deviations in the operation can be detected – if conflicts arise, resolutions to these can be suggested. While there is great intention to incorporate these new technologies to support daily operations (and also for support in timetable planning), developments in this direction are still in their beginnings. In addition, various players in railway operations are developing their own systems for optimizing their operations. All approaches have in common, that high quality of data and an appropriate simulation approach are required in order to monitor the current state of the network and simulate future states over the next minutes and hours.

Similar to these on-going pilot projects, WP17 focuses on decision support for traffic management optimization and is intended to facilitate and support the work of dispatchers. Throughout the processing of WP17, the goal is to apply state-of-the-art machine learning techniques to gain insights into rail operations in real-time and generate solution proposals for any conflicts that may be detected. In this sense and in contrast to the currently on-going pilot projects, innovation is generated by the following aspects:

- **Integration into the development of a European Traffic Management**

This creates a holistic view of rail operations – Europe-wide and cross-industry – and breaks down the silo thinking of RU, IM and other players. A key benefit here is the generation of non-discriminatory proposals and the integration of cross-border operations.

- **Alignment with other innovations in the railway sector**

The alignment of the WP with other subprojects in the ERJU project creates a demonstrator with a view to other innovations in the railway sector. Examples of such subprojects are demand-based utilisation optimization and the integration of multi-modal solutions.

- **Digitalisation of train control decision process**

While the dispatcher still needs to be in charge of accepting or declining the system's recommendations, the communication between RU and IM can be supported by digital systems and semi-automized – thereby reducing the number of consultations that the dispatcher must have with other stakeholders. Automation of communication also has the potential to eliminate errors that may occur due to miscommunication amongst the various parties.

All developments will have a European-wide focus and will support the standardization of conflict detection, semi-automated decision making, and communication between dispatchers within the European rail network.

D) Identified needs

Needs identified regarding the following topics:

- Solvers and optimizers used in TMS for decision making: Optimizers based on different approaches such as AI, ML as a decision support tool in different scenarios in an automatic, semi-automatic or supervised manner.

- AI and optimization: Optimization to predict, identify and resolve conflicts and to ensure that the network in question is conflict-free. Different approaches can be used, including Neural Networks, (Deep) Reinforcement Learning, other suitable self-learning (backpropagation) methods as well as what-if and impact analysis.
- Micro-level modelling: to represent the behaviour of individual and/or a limited number of trains, as well as specific conflicts involving a limited number of trains, and how they interact with each other and with the larger system. The coherence with network level traffic management must be ensured.
- Line based as well as yard and station/depot specific operations.
- Multi-Solution evaluation and selection: to assess the effectiveness of possible solutions, each representing a different set of conditions, assumptions and pros/cons. The evaluation then examines the performance of the possible solutions under each scenario to determine how well it would perform under different conditions. Based on some criteria, the evaluation results can be ranked and presented.
- Integration/use in forecast calculation: Using the forecast calculation, it is possible to predict the future state of the system under consideration within a given time frame and proactively react to undesirable situations as conflicts before they happen.

E) High-level requirements

The high-level requirements for the scope of demonstrations are:

- **Req. 17.1:** Identification of potential conflict (in the connected traffic) in a defined time/geographical scope.
- **Req. 17.2:** Proposal of ranked/prioritized solutions based on different approaches such as What-if and impact analysis to human agents.
- **Req. 17.3:** Configurability at run-time.
- **Req. 17.4:** Parametrization of the algorithms and the configurability of the parameters.
- **Req. 17.5:** Metadata about the proposed optimization (used method, level of certainty, etc).
- **Req. 17.6:** Enabling indication of the satisfaction with the solutions by human agents.
- **Req. 17.7:** Enabling different levels of automation.

7. High-level use cases (Task 10.2)

In this chapter of the document, the high-level use cases identified for MOTIONAL WS1.2 "Operations" are listed in Table 3. Each use case is mapped with the group of WPs (development + demonstration) relative to the topic they address and also with the demo(s) that are expected to cover it. As additional information, the responsible partner for the creation of that use case is reported.

Use case Id	Use case Title	Responsible partners	WP	Demo
UC-FP1-WP10-01	Information exchange for Automatic Route Setting (ARS)	ATSA	11/12	1
UC-FP1-WP10-02	Information exchange for Monitor & Control Train	ATSA	11/12	1
UC-FP1-WP10-03	Monitor & Control the field elements	ATSA	11/12	1
UC-FP1-WP10-04	Support for trans-border travel related decisions for station operator	PKP	11/12	2
UC-FP1-WP10-05	Detail train timetable for energy saving, ATO-TS	STS	11/12	3
UC-FP1-WP10-06	Information exchange between TMS and C-DAS TS	INDRA	11/12	4
UC-FP1-WP10-07	Cooperative conflict resolution (Two TMSs)	MERMEC	11/12	5
UC-FP1-WP10-08	Exchanging real-time train data regarding the border stations	MERMEC	11/12	5
UC-FP1-WP10-09	Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts	ADIF	11/12	6
UC-FP1-WP10-10	Sending and Receiving train running forecast information	HACON	11/12	6
UC-FP1-WP10-11	Pre-aligned decisions cross-border	HACON	11/12	6
UC-FP1-WP10-12	Consider constraints or needs of integrated processes and related systems integrated	HACON	11/12	7
UC-FP1-WP10-13	Train running forecast of the TMS improved by integration of TMS with systems and processes related to yards, stations and so on.	ADIF	11/12	7
UC-FP1-WP10-14	Planning and/or management of systems and processes using information received from the TMS	ADIF	11/12	7
UC-FP1-WP10-15	Sending and Receiving track allocation information between TMS and YCS	TRV	11/12	8
UC-FP1-WP10-16	Notifying TMS and YCS operators about disruptions and requests	TRV	11/12	8
UC-FP1-WP10-17	IAMS interface	CEIT	11/12	9
UC-FP1-WP10-18	Involving multi-actors in decision making	HACON	13/14	10
UC-FP1-WP10-19	Critical alarm management	STS	13/14	10/11
UC-FP1-WP10-20	Short-term management of a possible asset failure	STS	13/14	10/11
UC-FP1-WP10-21	Preventive functional assessment (PFA)	STS	13/14	10/11
UC-FP1-WP10-22	Disruption management and activation of emergency services.	ADIF	13/14	10
UC-FP1-WP10-23	Disruption management and activation of a	ADIF	13/14	10

	maintenance intervention			
UC-FP1-WP10-24	Solving of Rolling stock dispatching conflicts using reserves and swaps	NSR	13/14	10
UC-FP1-WP10-25	Proactive solving of macro tasks for crew dispatching	NSR	13/14	10
UC-FP1-WP10-26	Trespassing	TRV/VTI	13/14	11
UC-FP1-WP10-27	-	-	-	-
UC-FP1-WP10-28	Infrastructure problems detected by railway staff	TRV/VTI	13/14	11
UC-FP1-WP10-29	-	-	-	-
UC-FP1-WP10-30	Train Path Envelope calculation	PR	15/16	12/14
UC-FP1-WP10-31	TMS-ATO feedback loop	PR	15/16	12/14
UC-FP1-WP10-32	TMS-ATO operation interactions between human actors in different conditions	PR	15/16	12/14
UC-FP1-WP10-33	TMS enhancements to support C-DAS operations	INDRA	15/16	13
UC-FP1-WP10-34	C-DAS simulator	CEIT	15/16	13
UC-FP1-WP10-35	RTTP-updates to increase C-DAS efficiency	TRV	15/16	13
UC-FP1-WP10-36	Traffic regulation based on the time of the day	CAF	15/16	15
UC-FP1-WP10-37	Traffic regulation based in track areas	CAF	15/16	15
UC-FP1-WP10-38	Traffic regulation considering adhesion factors	CAF	15/16	15
UC-FP1-WP10-39	ATO-TMS integration	AZD	15/16	15
UC-FP1-WP10-40	Performances comparison between C-DAS and C-DAS-O architectures	STS	15/16	15
UC-FP1-WP10-41	Notification of conflict	ÖBB-INFRA	17/18	16
UC-FP1-WP10-42	Presentation of notification	ÖBB-INFRA	17/18	16
UC-FP1-WP10-43	Presentation of additional information on conflict	ÖBB-INFRA	17/18	16
UC-FP1-WP10-44	Resolution of conflict	ÖBB-INFRA	17/18	16
UC-FP1-WP10-45	Automatic Conflict Detection and Resolution using AI applied to Depots and Terminal Stations environment	ENYSE	17/18	17
UC-FP1-WP10-46	Optimized conflict resolution based on realistic forecast calculation	HACON	17/18	18
UC-FP1-WP10-47	Automated very short-term decision making for real-time operation for departing train	GTSD	17/18	19
UC-FP1-WP10-48	Automated very short-term decision making for real-time operation to keep sequence	GTSD	17/18	19
UC-FP1-WP10-49	Operator notification in case of automated very short-term decision making	GTSD	17/18	19
UC-FP1-WP10-50	For real-time operation system must request movement authorities	GTSD	17/18	19
UC-FP1-WP10-51	Optimized conflict detection and resolution	STS	17/18	20
UC-FP1-WP10-52	Train that cannot continue on its route	FS	17/18	20/23
UC-FP1-WP10-53	Dispatcher constraints entry	FS	17/18	20/23
UC-FP1-WP10-54	Ability to provide multiple solutions	AZD	17/18	21
UC-FP1-WP10-55	Real-time operation of algorithm	AZD	17/18	21
UC-FP1-WP10-56	Automatic Conflict detection and resolution	INDRA	17/18	22
UC-FP1-WP10-57	Decision support system for different conflicts	INDRA	17/18	22

UC-FP1-WP10-58	Conflict detection and resolution	MERMEC	17/18	23
UC-FP1-WP10-59	Very short-term decision	MERMEC	17/18	23
UC-FP1-WP10-60	Evaluation platform	SNCF	17/18	25
UC-FP1-WP10-61	Test bed for local TMS evaluation	SNCF	17/18	25
UC-FP1-WP10-62	Operational Plan update through TMS and ATO-TS interaction	MERMEC	15/16	15

Table 3: MOTIONAL WS1.2 high-level use cases list

Note: Some use cases were removed from the original numbering. Since the original numbering had already been used in other tasks and WPs, it was decided to keep the original numbering (with the 27 and 29 gap).

The high-level use cases have been defined using the use case template created in WP2, but only taking into account the high-level fields. The detailed use cases are expected to be carried out as part of the activities of the specific WPs of the development and demonstration phases (WP11/12, WP13/14, WP15/16 and WP17/18. The specific template used to provide the information is as follows (see Table 4):

Name	*Descriptive Name of the use case*
ID	*ID of the use case "UC-FP1-WPx-number"*
Partner	*Who develops this use case*
Demo associated	*Indicate demo(s) associated to this use case*
Description	*Short description of the use case*
Related to WP(s)	*WP(s) that this use case relates to*
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)*
Sequence	*List steps of the use case (to be filled during specification phase)* 1. *Step x* 2. *Step y* 3. *Step z*
Notes	*Additional notes for the use case* *Note: Please include any relevant information from the use cases (clarification, aspects to be considered, etc).*

Table 4: High-level use case template based on WP2 use cases template

To improve the readability of this document, the complete definition of the high-level use cases for WS1.2 can be found in Appendix A.

The high-level use cases in the Appendix A Defined High-level use cases of WS1.2. collected are also transferred to WP2 for the preparation of D2.3 (report with the collection of all the high-level use cases of WP1.1, WS1.2 and WS1.3).

8. Demonstrations (Task 10.2)

In chapter 8, all demonstrations associated with WS1.2 “Operations” are introduced and described. In the proposal phase, 25 demonstrations were identified which are related to WP11/12, WP13/14, WP15/16 and WP17/WP18. They are listed in Table 5 including the partner(s) in charge and their mapping against TEs and TRL levels.

For some demonstrations, there are several beneficiaries involved. In some of these cases, the demonstrations are divided into sub-demonstrations since different approaches are covered. This is the case of demo 10, demo 13 and demo 15.

Demonstrations for WS1.2							
No	**Partner**	**Task**	**Description of Demonstration**	**Timeframe**	**TRL**	**TE**	**Chapter in D10.1**
WP11/12							
1	ATSA	12.2.1	Interfaces TRL5 from the communication Platform to the Timetable Management Applications and to the Traffic Control (RBC, Interlocking).	M40-M46	5/6	8,10	Demo 1: Task 12.2.1
2	PKP	12.2.2	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.	M40-M46	6	9	Demo 2: Task 12.2.2
3	STS	12.2.3	Interface from TMS Planning system to ATO-TS control module to maximise the energy efficiency of the train operation in a short-term action.	M40-M46	6	8	Demo 3: Task 12.2.3
4	INDRA	12.2.4	Interfaces from the communication Platform to wayside C-DAS operation system, focusing on speed profiles functionalities.	M40-M46	5/6	8	Demo 4: Task 12.2.4
5	MERMEC	12.2.5	Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between neighbouring TMSs and IMs) to provide a TMS and IM real-time connection of rail networks focused on cross border traffic management.	M40-M46	5/6	8,9	Demo 5: Task 12.2.5
6	HACON	12.2.6	TRL6 interfaces and TRL5 decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border operations (supporting FP5 activities).	M40-M46	6	8,9	Demo 6: Task 12.2.6
7	HACON	12.2.7	Interfaces for integration of TMS with other services such as station and yard management systems (supporting FP5 activities), digital maintenance systems (supporting FP3 activities), Passenger Information Services (supporting FP6) as well as electric traction systems and crew/ rolling stock management systems.	M40-M46	6	10	Demo 7: Task 12.2.7
8	TRV	12.2.8	Interface of TMS to Yard Coordination System 2.0 in Malmö node. Work connects to WP4.	M40-M46	6	10	Demo 8: Task 12.2.8

9	CEIT	12.2.9	Interface in view of the future autonomous inspection vehicle for the infrastructure (FP3) 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.	M40-M46	6	10	Demo 9: Task 12.2.9
			WP13/14				
10	STS, TRV, NSR, HACON,	14.1	Collaborative DSS for efficient and effective disruption management	M40-M43	4/5	11,13,14	Demo 10: Task 14.1
10.1	STS, TRV	14.1	Collaborative DSS	M40-M43	4/5	11,13,14	Demo 10: Task 14.1
10.2	NSR	14.1	Decision support for rolling stock dispatching	M40-M43	4	13,14	Demo 10: Task 14.1
10.3	HACON	14.1	Collaborative DSS for efficient and effective disruption management	M40-M43	4/5	13,14	Demo 10: Task 14.1
11	TRV, STS, INDRA	14.2	HMI for TMS based on User Experience (UX) Design and user input	M40-M43	8	11	Demo 11: Task 14.2
			WP15/16				
12	PR, TRV, NSR, KB, ADIF, CAF	16.2	Linking TMS to ATO/C-DAS for optimised operations "Live" demonstration for the public (or by video) of future TMS-ATO operations, including human factors: [...]	M40-M44	4/5	12, 15	Demo 12: Task 16.2
13	TRV, PR, NSR, INDRA, CEIT, STS	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective.	M40-M44	4/5	12, 15	Demo 13: Task 16.3
13.1	TRV, PR, NSR, STS	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective	M40-M44	4/5	12, 15	Demo 13: Task 16.3
13.2	INDRA	16.3	Improvement of forecast calculation through TMS and C-DAS integration	M40-M44	4/5	12, 15	Demo 13: Task 16.3
13.3	CEIT	16.3	Improved C-DAS operations	M40-M44	4/5	15	Demo 13: Task 16.3
13.4	STS	16.3	Performances comparison between C-DAS-C and C-DAS-O architectures (STS)	M40-M44	4/5	12, 15	Demo 13: Task 16.3
14	PR, TRV, NSR, KB	16.4	Human-in-the-loop simulations test the ATO operational concept in emulated active practice and using tailor-made TMS/ ATO/C-DAS algorithms.	M40-M44	4/5	12, 15	Demo 14: Task 16.4
15	AZD, PR, ADIF, CAF, STS	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based on FA2&System Pillar specifications regarding ATO [...]	M40-M44	4/5	15	Demo 15: Task 16.5
15.1	AZD, PR, STS	16.5	ATO – TMS integration platform developed in subtask 15.4.4, implementing possible new requirements and architecture based on FA2&System Pillar specifications regarding ATO / TMS to support the autonomous train	M40-M44	4/5	15	Demo 15: Task 16.5

			operations.				
15.2	CAF, ADIF	16.5	Testing and demonstrating the modelling for future operation of traffic regulation strategies (Operational Concept) for improved global behaviour of the traffic under minor timetable disturbances (delays and unfulfilled headways), based on different criteria and taking into account the global situations of the line through TMS – ATO interaction.	M40-M44	4/5	15	Demo 15: Task 16.5
15.3	MERMEC	16.5	Improvement of traffic forecast and operational plan update through TMS and ATO-TS integration	M40-M44	4/5	12	Demo 15: Task 16.5
			WP17/18				
16	ENYSE, ÖBB-INFRA, PR, NRD	18.2.1	Demonstrator for Real-Time Conflict Identification & Resolution.	M40-M46	5	17	Demo 16: Task 18.2.1
17	ENYSE	18.2.2	Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection and Resolution using AI.	M40-M46	5	17	Demo 17: Task 18.2.2
18	HACON	18.2.3	Demonstrator for Improved Decision Support	M40-M46	5	17	Demo 18: Task 18.2.3
19	GTSD	18.2.4	Demonstrator for Advanced Automation of Real-time Operation	M40-M46	5	16	Demo 19: Task 18.2.4
20	STS and FS	18.2.5	Demonstrator for Advanced Decision Support for Real-time Operation	M40-M46	5	17	Demo 20: Task 18.2.5
21	AZD	18.2.6	Demonstrator for Advanced Conflict Decision Support and Route Setting	M40-M46	5	16, 17	Demo 21: Task 18.2.6
22	INDRA	18.2.7	Decision Support for improved traffic management operation	M40-M46	5	17	Demo 22: Task 18.2.7
23	MERMEC, FS	18.2.8	Demonstrator for Automation of Real-time Operation	M40-M46	5	16, 17	Demo 23: Task 18.2.8
24	ÖBB-INFRA, PR, NSR, ENYSE, NRD	18.3.1	Simulation of real-time conflict identification and resolution	M40-M46	5	17	Demo 24: Task 18.3.1
25	SNCF	18.3.2	Performance evaluation of optimisation algorithms for local level traffic management in a single region	M40-M46	5	17	Demo 25: Task 18.3.2

Table 5: MOTIONAL WS1.2 demonstrations

Note: In subsequent deliverables of FP1-[MOTIONAL] the demonstration numbering was decided to be changed. In the Appendix C of this deliverable the traceability between the existing numbering of D10.1 and the new demo numbering can be found.

The purpose of the prototypes is to verify the planned goals, using already existing architecture. For most of the demonstrations, the architecture is based on the Shift2Rail TD2.9 demonstrators which are not necessarily compliant with the SP architecture provided only after start of SG2 (TMS) activities in the FP1-MOTIONAL project.

In the following subchapters, all demonstrations and sub-demonstrations are described, providing information about their objectives, scope, inputs, outputs, interactions and so on. For that the following template is used (see Table 6).

Task XX.Y.Z- Title of the demonstration (Partner(s) involved)
1) Given is: *(To indicate the preconditions, the starting point)*
2) Actors: *(Involved actors (active and passive ones), not necessarily human actors).* *Guidelines:* • *Identify the key actors or entities that will interact with the system, such as passengers, train operators, maintenance personnel or other external systems.* • *Describe the roles and responsibilities of each actor or entity.*
3) System: *(Description of the system).* *Guidelines:* • *Describe the overall purpose of the system, including its intended benefits and outcomes.* • *Define the boundaries of the system, including any interfaces with other systems or processes.*
4) Goals: *(to include briefly the goal(s) of the demonstration, for example to test some specifications, so on*
5) Forecast window: *(forecast window considered, if necessary)*
6) Objectives: *(to detail the objectives associated with the demonstration)*
7) Inputs: (*Required input(s) for the demonstration to be carried out)*
8) Outputs: *(What will be the expected result(s))*
9) Demo scenarios to be covered: *(To include the scenarios associated with the demo)*
10) Methodology (how): *(Methodology to be followed indicating how the demo will be done and considerations to take into account)*
11) Interactions with other WPs: *(To indicate when applicable the interactions with other WPs from FP1)*
12) Interactions with other FPx or SP: *(To indicate when applicable the interactions with the System Pillar or other Flagship Projects)*
13) Physical: YES/NO *(To include if the demo is physical or not, and the location)*
14) How to evaluate the demo

15) Diagram with the interaction: *Including:* • *Actor involved* • *External systems (part not development in the FP1 project but necessary for input/output exchange (for example transmitting data)* • *Part development as part of the FP1* • *Actions* • *Functions that are activated* • *To identify with parts are real and part of the demo and which parts are simulated (datas)*

Table 6: Demonstration description template

8.1. Description of the demonstrations associated with WP11/12

The overall objectives of WP11 (development) and WP12 (demonstration) are linked to TEs 8, 9 and 10. With the WP11/12 group it is pursued 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 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 is expected to support an aligned re-planning and management of platform track/parking/facility track allocation of trains including graphical visualisation, conflict detection and resolution.

A) Demo 1 (Task 12.2.1)- Interfaces from the communication Platform to the Timetable Management Applications and to the Traffic Control (ATSA)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
1	ATSA	12	12.2.1	Interfaces TRL 5 from the communication Platform to the Timetable Management Applications and to the Traffic Control (RBC, Interlocking).	M40-M46	5/6	8,10

Table 7: Demo 1 (ATSA) summary

Task 12.2.1- Interfaces TRL 5 from the communication Platform to the Timetable Management Applications and to the Traffic Control (ATSA)

1) Given is:

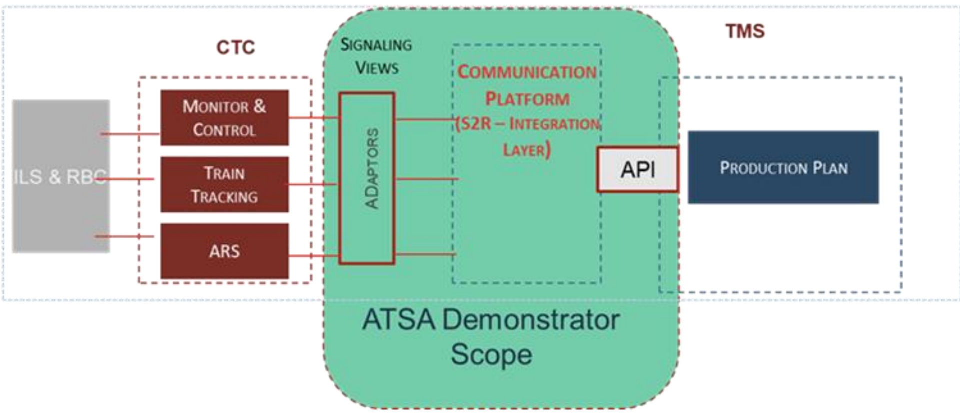
- TMS, CTC system and the prototype of communication platform – Integration Layer (IL) developed within S2R X2R4 project.
- Data scope planned to be used in demonstration:
  - Topology and infrastructure data: the topology test data needs to be aligned between connected systems in order to operate the train on them, provide train running states or exchange other topology-related information.
  - Timetable: to exchange operational timetable between systems.
  - Dynamic states: to exchange train operation status including train position.
  - Infrastructure restrictions: to exchange temporary constraints on the network.

2) Actors:

- TMS/TMS operator that can request the production timetable update.
- The CTC system that can provide status information of the train movement like position and time based on received Interlocking (IXL) or RBC information (depends on its availability).
  - IXL that sets, locks and releases routes,
  - RBC that generates the MA for the trains.
- Systems publishing infrastructure restrictions, limitations to communication platform (optional).

3) System:

- The demonstration is focused around designing the integration between Timetable Management Application (TMS system) and Traffic Control (CTC system) over communication platform.



- 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 which will be used to design the integration between Timetable Management Application (TMS system) and Traffic Control (CTC system).

4) Goals:
To design the integration over communication platform of the Timetable Management Application (TMS system) and Traffic Control (CTC system).

5) Forecast window:
24h.

6) Objectives:

- To test the complete (End to End) communication.
- Possibility to operate together different TMS and CTC systems.
- Possibility for TMS and CTC system to exchange information with other systems connected to communication platform.

7) Inputs:

- Prototype of communication platform – Integration Layer developed within S2R X2R4 project.
- Available CDM definitions to support interoperability of the demonstration.
- Internal ATSA railway real line data to be used (topology, timetable, train status).

8) Outputs:

- Interfaces/API from the Communication Platform to the Timetable Management Applications and to the Traffic Control.
- Interfaces/API for the Communication Platform allowing to exchange restrictions/ limitations.
- Dedicated adaptors allowing already existing CTC/TMS systems to communicate via the Communication Platform. The adaptors are responsible for translations individual system Specific API into Communication Platform generic API.

9) Demo scenarios to be covered:
The integration will involve 3 class scenarios:

- TMS Production Plan delivery as the input for CTC class system operations. (UC-FP1-WP10-01).
- Real-time information from CTC (including interlocking & RBC info) to TMS influencing planning and decision support. (UC-FP1-WP10-02).

• Information about restrictions, limitations, maintenance activities available on Integration Layer are provided to CTC and TMS systems. (UC-FP1-WP10-03).
10) Methodology (how): • The prototype of the designed API will be implemented including necessary adaptors allowing existing TMS and CTC system to communicate with communication platform. • The existing interoperable data model (CDM) will be analysed to be used for the information exchange purposes.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: SP interaction regarding evolution of CDM.
13) Physical: No. Laboratory based demonstration.
14) How to evaluate the demo: Successful test of the use cases and requirements related to the demo scope.
15) Diagram with the interaction:

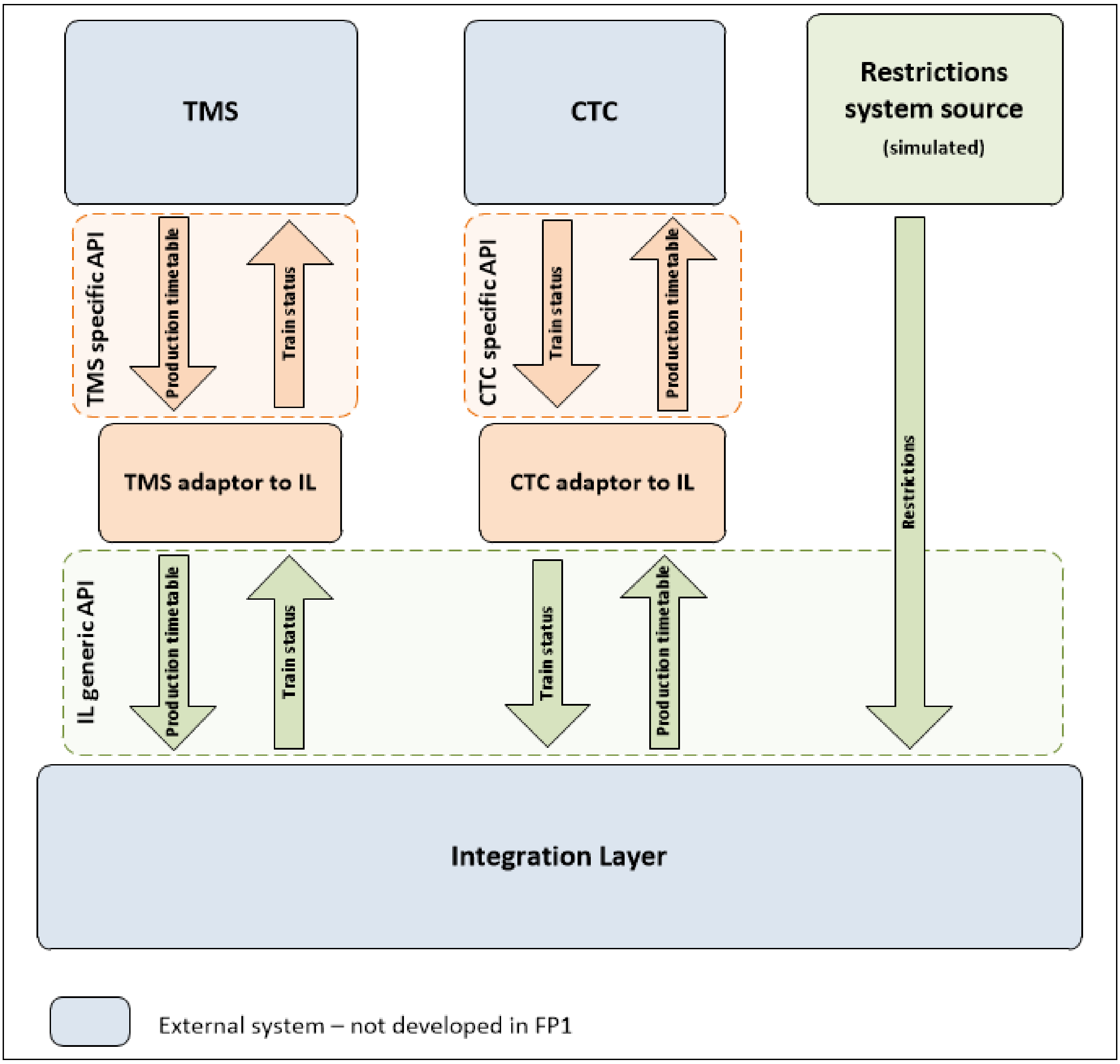


Table 8: Demo 1 (ATSA) description

8.1. Demo 2 (Task 12.2.2)- Integration solution for the data exchange and storage system (data lake) (PKP)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
2	PKP	12	12.2.2	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.	M40-M46	6	9

Table 9: Demo 2 (PKP) summary

Task 12.2.2- 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. (PKP)

1) Given is:
• TMS system, Prototype of DataLake system, Dashboarding system.
• Data scope planned to be used in demonstration:
  o Test data for train transborder connections,
  o Geographical data of railway stations,
• Static train timetable.

2) Actors: • Station operator: decision maker with respect to marketability of station. • Data Lake: information storage and organization system. • Decision support system: system for computing necessary statistics for decision making. • Dashboarding system: visualization platform allowing presentation and configuration of necessary decision-making activities.
3) System: • Decision support system based on data lake information necessary for an appropriate valuation and marketing of real estate. • Overall purpose – decision support system will provide decision maker (station operator) with information about trans-border reach of individual station, including accessibility and timing of connection to selected destinations. • Decision support system will interface with data lake solution containing necessary information for decision support, including relevant data from TMS.

4) Goals: Integrate trans-border travel data streams (including TMS) with a Data Lake providing data for municipal level decision support.
5) Forecast window: N/A.
6) Objectives: Improve efficiency of valuation of railway station real estate in context of trans border travel visibility.
7) Inputs: Data retrieved from the data lake residing therein following the organization's business policies. The data used to perform the process is: static timetable obtained from TMS and information about the operator's trains.
8) Outputs: Dashboard containing visualization of trans border travel availability and popularity for the station. Trans border travel direction selection for visualization will be done by decision support.
9) Demo scenarios to be covered: Station operator requires support in decision for station effective usage in the context of the relevant for that station trans-border travel availability. (UC-FP1-WP10-04).
10) Methodology (how): Computer system will be implemented including layers such as: • Interfacing with data lake, • Computation of necessary decision-making statistics, • Visualization of the results to the operator.
11) Interactions with other WPs: FP1/(WP21): Results should be consistent with respect to user interface demonstration realized in WP21 (Demonstration: Integration Rail with other transport modes).
12) Interactions with other FPx or SP: No interactions were identified.
13) Physical: No. Logically located in Lodz.
14) How to evaluate the demo During development a catalogue of test scenarios for acceptance tests will be created. System will have to pass all of those marked “essential” and at least 75% of those marked “desired”.

15) Diagram with the interaction:

Note: TMS integration is realised by Data Lake.

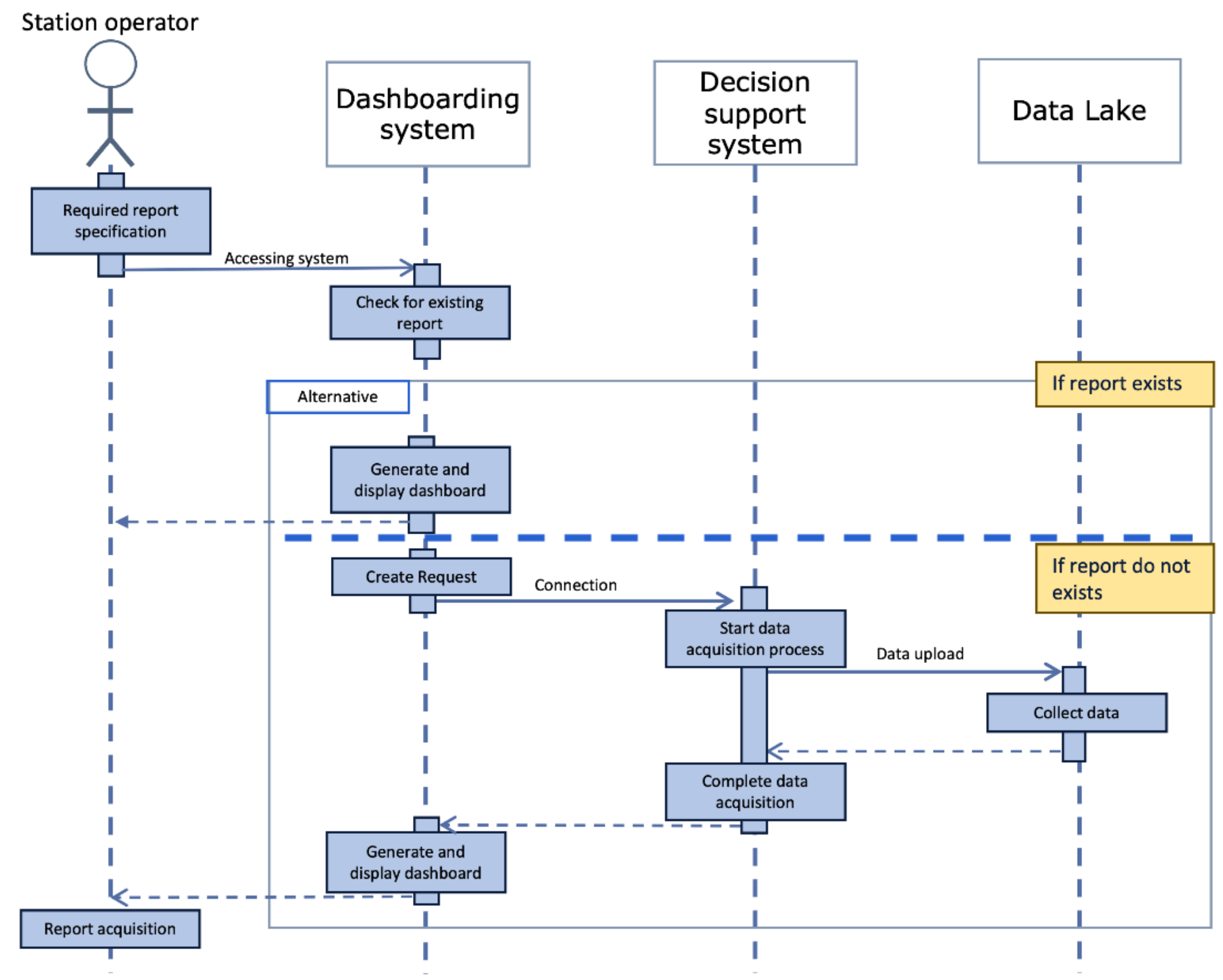


Table 10: Demo 2 (PKP) description

B) Demo 3 (Task 12.2.3)- Interface from TMS Planning system to ATO-TS control module (STS)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
3	STS	12	12.2.3	Interface from TMS Planning system to ATO-TS control module to maximise the energy efficiency of the train operation in a short-term action.	M40-M46	6	8

Table 11: Demo 3 (STS) summary

Task 12.2.3- Interface from TMS Planning system to ATO-TS control module (STS)

1) Given is:

- An operational production plan with a single- or multi-regional national scope with mixed freight and passenger trains.
- Conceptual Data Model (X2Rail4 CDM) with TMS and ATO-TS.
- Link to the development of a TMS-ATO integration platform (i.e., the Integration Layer developed in Task 15.4.4).

2) Actors:

- TMS, that provides the initial timetable for a given train to be sent to the TMS module ECO-DRIVE, updates train position and whenever a conflict is solved, applies dynamic headway for energy saving and generates a new timetable to be sent to ECO-DRIVE.
- 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.

3) System:

The aim of this prototype is to develop a low-cost evolution of TMS – ATO-TS interface that, starting from a TMS predicted timetable, generates a detailed predicted timetable by adding additional timing points intended solely for optimising energy savings. The purpose of this demonstration is twofold:

- To define a Detailed Timetable to save energy without compromising punctuality.
- To be able to update the Detailed Timetable whenever necessary (e.g. in case of resolution of conflicts by TMS involving the considered train).

The innovation lies in the use of the train position at different granularities to identify the optimal number of extra timing points to be added into the Detailed Timetable to reach a compromise between energy savings, driver's workload and onboard installations adding substantial recurrent engineering costs.

4) Goals:

Improve energy efficiency.

5) Forecast window:

3-4 hours.

6) Objectives:

The objective is to achieve a sufficient energy efficiency, by assessing the minimum train accuracy and number of additional timing points, and, consequently, the minimal number of directives to the driver (an excess of driving directives may create work overload to the driver and therefore these impacts in safety).

7) Inputs: Operational production plan, detailed train timetable (to ATO-TS).
8) Outputs: Driving strategy provided by C-DAS module(s).
9) Demo scenarios to be covered: TMS sends the train timetable as input to ECO-DRIVE and then ECO-DRIVE generates the detailed timetable to be sent to ATO-TS (UC-FP1-WP10-05).

10) Methodology (how):
• TMS generates the initial timetable for a given train and sends it to the ATO-TS using IL.
• Until the train reaches its final destination:
    o TMS sends to the ATO-TS updates of the timetable for a given train (including those generated by conflict resolutions for energy saving) using IL.
    o ECO-DRIVE calculates the detailed timetable for energy savings and sends it to C-DAS C through ATO-TS.

11) Interactions with other WPs: • FP1/(WP10, Task 10.3): (T10.3 "Specification of Demonstrator environment/framework and identification of data structures"), • FP1/(WP11, Task 11.3, Subtask 11.3.3): (T11.3 "Development of prototypes TRL 4" and ST11.3.3 "STS develops an interface from TMS Planning system to ATO-TS control module"), • FP1/(WP15, Task 15.4, Subtask 15.4.4): (T15.4 "Development of specific TMS-C-DAS/ATO planning & simulation environment, including human factors" and ST15.4.4 "Development of TMS- ATO integration platform based on the updated requirements & specifications, following the possible new needs supporting autonomous train operations").
12) Interactions with other FPx or SP: FP2-R2DATO – dependencies on ATO subset/functionalities evolution.
13) Physical: No. Simulation.
14) How to evaluate the demo: The demo is evaluated by integrating this demonstration into the WP15 Task 15.4.4 developments and compare energy consumptions with and without detailed timetable during the WP16 Task 16.5 demonstration.
15) Diagram with the interaction:

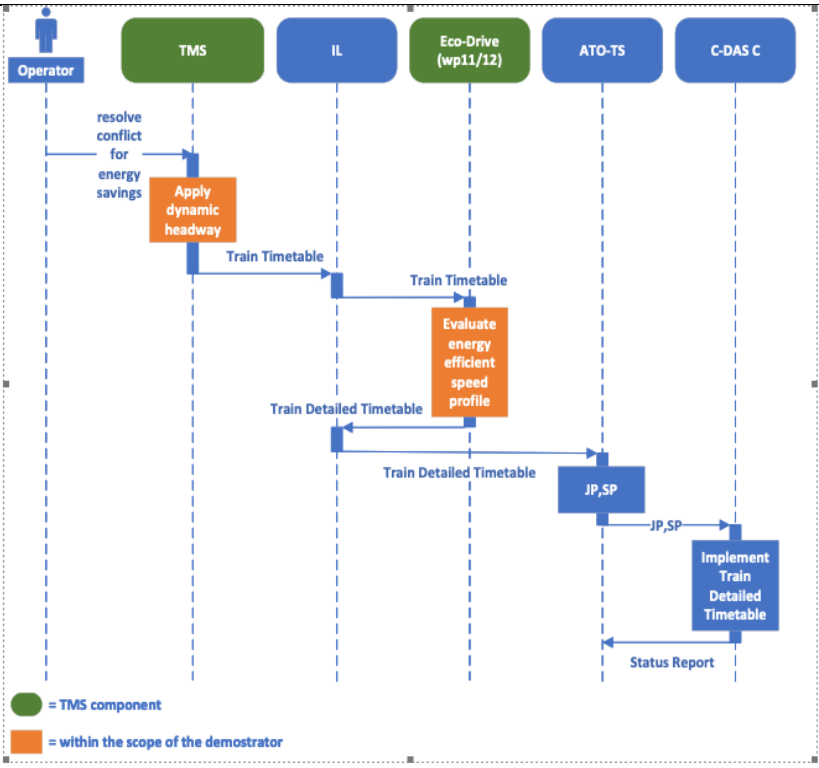


Table 12: Demo 3 (STS) description

C) Demo 4 (Task 12.2.4)- Interfaces from the communication Platform to wayside C-DAS operation system (INDRA)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
4	INDRA	12	12.2.4	Interfaces from the communication Platform to wayside C-DAS operation system, focusing on speed profiles functionalities.	M40-M46	5/6	8

Table 13: Demo 4 (INDRA) summary

Task 12.2.4- Interfaces from the communication Platform to wayside C-DAS operation system (INDRA)
1) Given is: • An operational production plan including scheduled-target-forecasted timetables of involved trains. • Topology elements of the infrastructure. • Train characteristics (weight, max. speed, length...).

- Temporary Speed restrictions (TSR).
- C-DAS TS system.

2) Actors:

- The C-DAS TS gathers real-time data about the train's status from onboard sensors and systems, including GPS for position, speed, temperature sensors, etc. It receives this data from Indra's own train simulator, ensuring accurate and up-to-date information. This data is used to create the status report (SR) sent to the TMS for analysis and management of train operations. It then sends the status report (SR) containing this information to the TMS.
- The TMS receives the status report from the C-DAS TS but it may also send the set of control measures that is planned to be taken in a given time period ahead which is called the Real-Time Traffic Plan (RTTP), which includes the planning and timing information for all stations along the route to the C-DAS TS or other onboard systems for optimizing train operations and analyses it to monitor and manage train operations effectively.
- This bidirectional transmission of data ensures that both systems have up-to-date information during the journey, contributing to overall efficiency.

3) System:

The aim of this prototype is to develop TMS/C-DAS TS interfaces. These interfaces allow the evolution from S-DAS to C-DAS providing updated speed profiles on a regular basis.

4) Goals:

- Develop the interface between TMS and C-DAS TS for real-time data adjustment to accomplish with the planning.
- Reception of data in real-time by C-DAS TS to take into account during the journey.
- Reception of data in real-time by TMS with status information from the C-DAS TS (speed and position of the train).

5) Forecast window:

3 hours.

6) Objectives:

The objective is to develop and deploy the interfaces for the data exchange between TMS and C-DAS TS and the evolution from S-DAS to C-DAS.

The data transferred are based on the CDM (S2R) and the planned train schedule with its modifications, which includes the arrival and departure times at stations and control points, as well as the routes affected by this schedule. The schedule data must be provided by the real-time part (TMM) of the TMS. The routes must be provided by the TMS (either through the Router (ARS), the CTC, or the real-time management module (TMM)).

7) Inputs:

• Operational production plan (existing timetable), • Topology and TSR's data, • Train characteristics.
8) Outputs: • Interfaces for the data exchange between TMS and C-DAS TS. • Integration layer and data protocol implementation between TMS and C-DAS based on previous S2R projects.
9) Demo scenarios to be covered: • TMS sends the RTTP (production plan delivery) as the input for the C-DAS TS, • C-DAS TS reception of data according to UC-FP1-WP10-06 communication from TMS that provides the trip information. • TMS receives status report from the C-DAS TS including speed and position.

10) Methodology (how):
• Scenario preparation to achieve the communication between TMS and C-DAS TS composed by:
  o Initial production plan (RTTP) , sent by TMS using IL.
  o Reception of the RTTP by the C-DAS TS.
  o C-DAS TS sends info to the C-DAS OB (to support WP15 the C-DAS TS part is made with C-DAS OB) (expected to be performed in the future, not in Demo 5 scope).
  o C-DAS OB calculates speed profile and advice and is transmitted to the train simulator (expected to be performed in the future, not in Demo 5 scope).
  o C-DAS OB sends SR (speed and position) to the C-DAS TS (expected to be performed in the future, not in Demo 5 scope)
  o C-DAS TS sends to the TMS train status (position, speed, ...).
  o TMS receives the C-DAS TS information related to speed and position.
  o Modification of the timetable by the TMS (expected to be performed in the future, not in Demo 5 scope).
  o New plan (RTTP) sent by TMS (expected to be performed in the future, not in Demo 5 scope).

11) Interactions with other WPs: • FP1/(WP8/9) is based on the TMS/C-DAS communication performed in WP11/WP12 focuses on different C-DAS driver modes. • FP1/(WP15/16) in which a modular architecture is expected to manage the distribution of functionalities between C-DAS TS and C-DAS OB testing how the information of C-DAS (basically the train status reports received by the TMS) can improve the forecast calculation of the TMS.

12) Interactions with other FPx or SP:

SP interaction, to align architecture in TMS/ C-DAS communication.

13) Physical:

Partially.

- C-DAS (OB and TS) will be a physical one.
- On the other hand, TMS, infrastructure and trains will be simulated.

14) How to evaluate the demo

Using simulation of trains and infrastructure, testing the correct communication between TMS and C-DAS TS.

15) Diagram with the interaction:

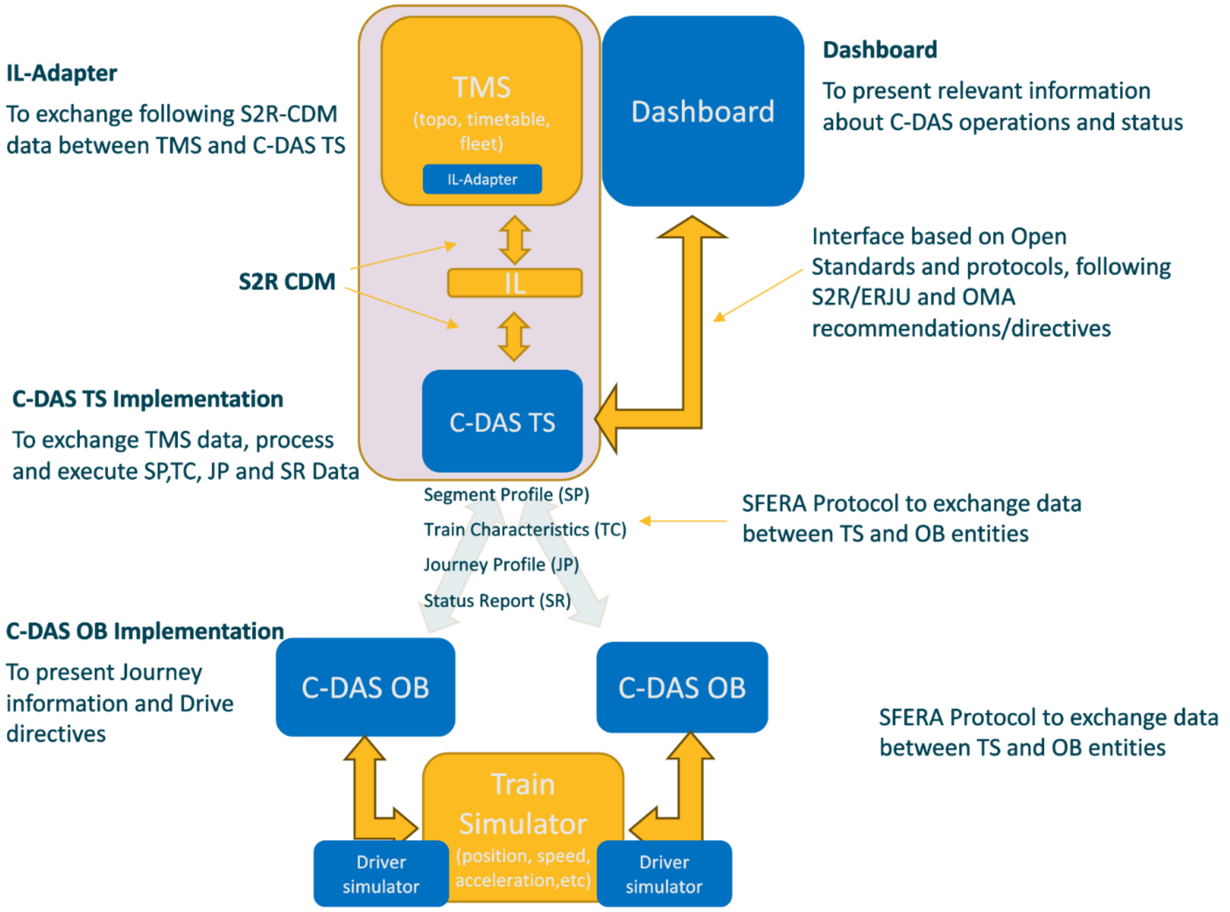


Table 14: Demo 4 (INDRA) description

D) Demo 5 (Task 12.2.5)- Interfaces between neighbouring TMSs and IMs (MERMEC)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
5	MERMEC	12	12.2.5	Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between neighbouring TMSs and IMs) to provide a TMS and IM real-time connection of rail networks focused on cross border traffic management.	M40-M46	5/6	8,9

Table 15: Demo 5 (MERMEC) summary

Task 12.2.5- Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between neighbouring TMSs and IMs) to provide a TMS and IM real-time connection of rail networks focused on cross border traffic management. (MERMEC)
1) Given is: • Two nearby regional (or national) TMS instances, TMS1 (controlling station A) and TMS2 (controlling station B) with their border station A1. • Two capacity plans containing a train scheduled with an A->A1 timetable for TMS1 and an A1->B timetable for TMS2. • Possible resolutions of conflicts impacting the given train that can be aligned between the two TMSs to share the final decision.
2) Actors: • TMS1 that controls the line 1 and sends the forecast/deviations of trains that go to line 2. • TMS2 that controls the line 2 and receives the forecast/deviations of trains from TMS1 and evaluates its forecast and conflicts eventually.
3) System: Nowadays TMSs 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 through two national line cross-area, TMS1, which owns station A, evaluates conflicts and delays, while TMS2 evaluates them when the train leaves the border station. If the communication is performed with the aim of harmonizing rail traffic between two neighbouring TMSs, then TMS2 could evaluate conflicts and delays of the given train as soon as TMS1 starts sending data.
4) Goals:

Harmonize the management of railway traffic between two neighbouring TMSs.
5) Forecast window: 3-4 hours.
6) Objectives: Aligning TMSs for cross-border or cross-area trains by data exchanging.
7) Inputs: • Baseline data: capacity plan, track topology and eventually train related data. • Relevant operational rules as available.
8) Outputs: Aligned decisions implemented.
9) Demo scenarios to be covered: • Station A to Station B (cross area, two TMSs and one or two CMSs). (UC-FP1-WP10-07, UC-FP1-WP10-08).
10) Methodology (how): • 'Looking-behind-the-border' capability, inbound and outbound train effects. • Exchange of train running forecast between TMSs. • Exchange of train characteristic. • Exchange of possible forecast scenarios derived from different conflict solutions. • Creation of a test bed. • Comparing non-aligned decision scenarios with aligned ones. • Making use of TSI TAF/TAP focused on TAP between neighbouring TMSs.
11) Interactions with other WPs: FP1/(WP17/18) (Development/Demonstration - Automated decisions and decision support for traffic management optimisation). The Conflicts detection and conflict resolution TMS module coming from WP17/18 is used to evaluate conflicts into TMS2 by using exchanged train forecasts/deviations.
12) Interactions with other FPx or SP: SP and RNE cross border topics.
13) Physical: No.
14) How to evaluate the demo From WP17-18 algorithm: • Comparing forecast of the border train with and without data exchanged by the two TMS.

- Comparing the conflicts detected with and without data exchanged by the two TMS.

15) Diagram with the interaction:

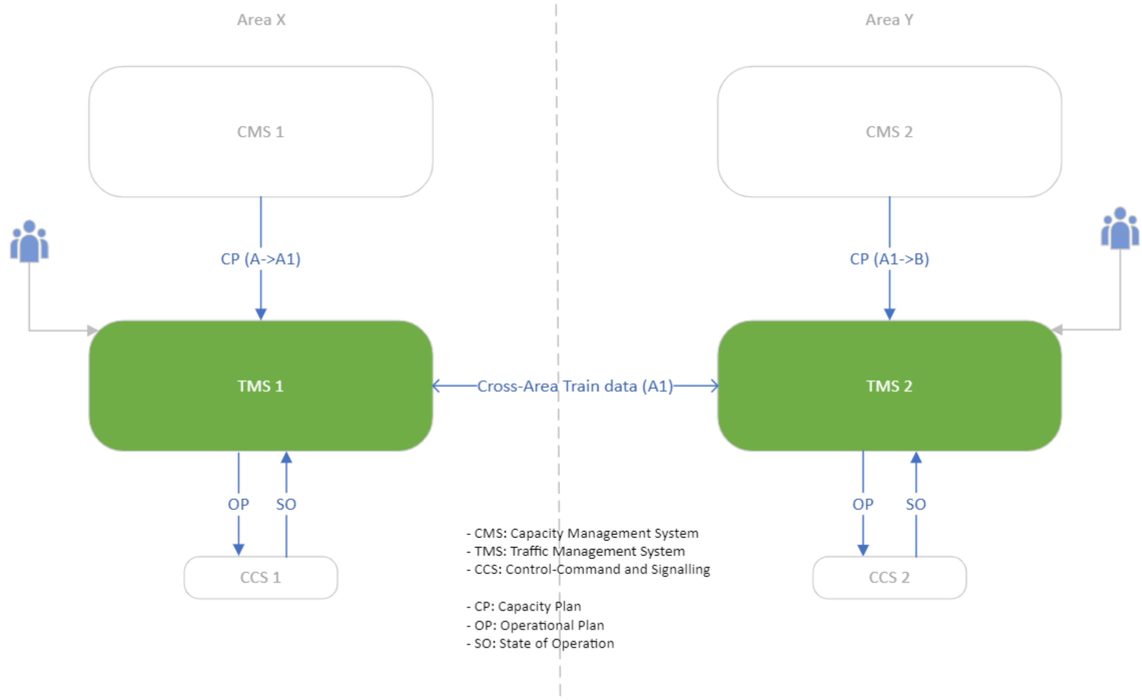


Table 16: Demo 5 (MERMEC) description

E) Demo 6 (Task 12.2.6)- Interfaces and TRL 5 decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border (HACON)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
6	HACON	12	12.2.6	TRL 6 interfaces and TRL 5 decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border operations (supporting FP5 activities).	M40-M46	6	8,9

Table 17: Demo 6 (HACON) summary

Task 12.2.6 - Interfaces and TRL 5 decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border (HACON)
1) Given is: • An operational plan including mixed freight and passenger trains and capacity restrictions for a smaller national or regional scope with cross-border situation and at least two national TMS areas. • One or more conflict scenarios identified from the train running forecast calculation in a minor or major disruption situation and requiring decision alignment between the involved TMS's. • Two national TMS instances A, B1 and another IM's TMS instance B2 in the same country as B1.
2) Actors: • TMS A: TMS System A (country A) used for managing the railway traffic in country A. • TC A: Train/Traffic Controller using TMS System A for taking and implementing decisions leading to updates of the operational plan managed by the TMS A. • TMS B1: TMS System B1 (country B) with cross-border line between control areas of A and B1 used for managing the railway traffic in area B1. • TC B1: Train/Traffic Controller using TMS System B1 for taking and implementing decisions leading to updates of the operational plan managed by the TMS B1. • TMS B2: TMS System B2 (country B) adjacent to TMS B1 without cross-border line in its control area used for managing the railway traffic in area B2. • TC B2: Train/Traffic Controller using TMS System B2 for taking and implementing decisions leading to updates of the operational plan managed by the TMS B2.
3) System: The demonstration provides the technical basis for demonstrating interactions between two TMS's allowing for cross-border (international) use cases as well as cross-area (national) use cases. This set up allows a variety of different show cases under various constrained network conditions and resulting effects. The graphical user interface will feature Train Graphs, network views as well as train schedule details views.
4) Goals: To test and demonstrate use cases related to aligned decision making of Train/Traffic Controllers in cross-border (international) or cross-area (national) situations.
5) Forecast window:

3-4 hours.
6) Objectives: Aligned traffic and network status view and TM decisions for cross-border or cross-area trains based on: • Realistic forecast calculation, • Multiple solution scenarios and • Considering constraints/needs of both involved IMs or area TCs.
7) Inputs: • Baseline data: operational plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR), train consist related data. • Relevant operational rules as available.
8) Outputs: • Aligned traffic and network status view. • Aligned TM decisions implemented.
9) Demo scenarios to be covered: • A-B1 cross border (international), i.e., cross TMSs of two different, neighbouring IMs A and B1; according to FP5-TRANS4M-R Seamless workstream (UC-FP1-WP10-10, UC-FP1-WP10-11). • B1-B2 cross area (national) two TMSs of different, neighbouring IMs of the same country (UC-FP1-WP10-10). • B1x-B1y cross control areas x and y of TMS B1 (UC-FP1-WP10-10).
10) Methodology (how): • 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. • It is planned to make use of TSI TAF/TAP based communication between neighbouring TMSs and between TMS and the centralized applications to cover forecast time horizons longer than 4 hours ahead of crossing the border. In these cases, centralized pan-European forecasting tools are expected to deliver more appropriate results.
11) Interactions with other WPs:

FP1/(WP4/5), (Development/Demonstration - Integration of planning systems and processes including cross-border planning): Alignment of demonstration set-up to allow cross-border CMS (WP4/5) and cross-border TMS (WP11/12) demo cases on the same cross-border line(s).
12) Interactions with other FPx or SP: • FP5-TRANS4M-R (Seamless workstream): Joint discussion and input for development and preparation of demonstrations; joint demonstrations. • SP/RNE: Joint discussion and existing RNE documents (e.g., Handbooks) as input for the development and preparation of demonstrations.
13) Physical: No. Cloud based demonstration.
14) How to evaluate the demo • Successful test of the use cases and requirements related to the demo scope. • The forecast/decision results are compared with results based on non-availability of the integrated information. • The results of non-aligned decision scenarios are compared with the results of aligned ones.
15) Diagram with the interaction:

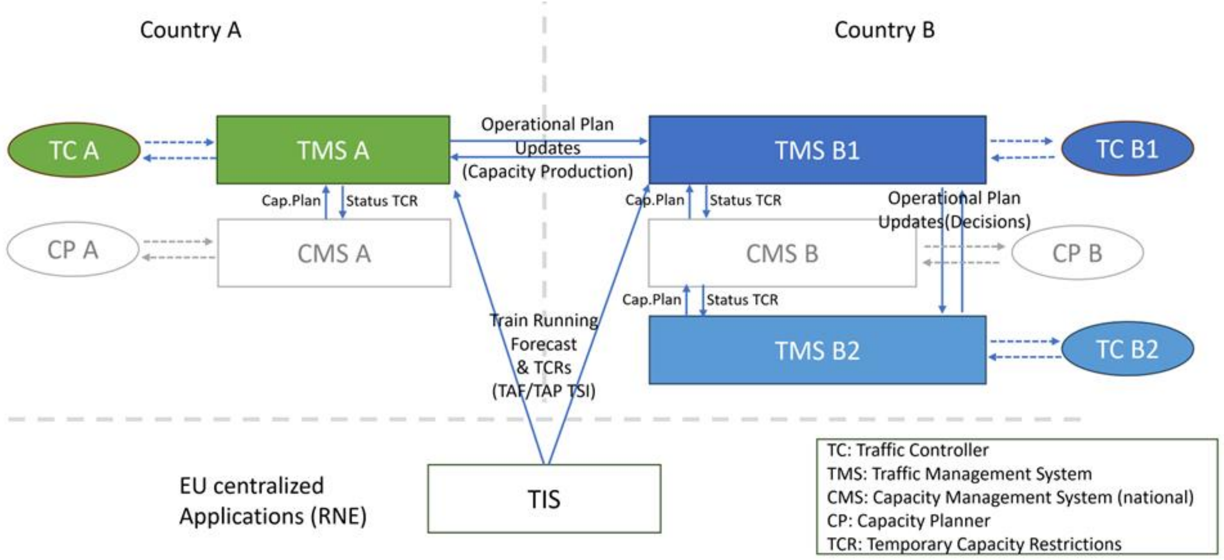


Table 18: Demo 6 (HACON) description

F) Demo 7 (Task 12.2.7)- Interfaces for integration of TMS with other services such as station and yard management systems, etc (HACON)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
7	HACON	12	12.2.7	Interfaces for integration of TMS with other services such as station and yard management systems (supporting FP5 activities), digital maintenance systems (supporting FP3 activities), Passenger Information Services (supporting FP6) as well as electric traction systems and crew/ rolling stock management systems.	M40-M46	6	10

Table 19: Demo 7 (HACON) summary

Task 12.2.7- Interfaces for integration of TMS with other services such as station and yard management systems, etc. (HACON)
1) Given is: • An operational plan including mixed freight and passenger trains and capacity restrictions for a smaller national or regional scope. • One or more conflict scenarios identified from the train running forecast calculation in a minor or major disruption situation and involving input from the integrated processes/systems. • One national TMS instance and integrated systems for yard/station planning, digital maintenance planning, ETS simulation, crew/rolling stock assignment (interface emulation only).
2) Actors: • TMS: TMS System used for managing the railway traffic in a defined area or on one or multiple defined lines. • TC: Train/Traffic Controller using the TMS for taking and implementing decisions leading to updates of the operational plan managed by the TMS. • YCPS: yard/station capacity planning system used for (re-)planning of track reservations used for operational activities. • YCM: yard/station capacity manager using the YCPS for (re-)planning of track reservations. • MPS: infrastructure maintenance planning system used for planning track maintenance& repair and disseminating technical descriptions of resulting capacity restrictions.

• MM: infrastructure maintenance manager using the MPS for planning track maintenance& repair. • RUD: crew/rolling stock dispatcher of a Railway Undertaking responsible for involved crew/stock resources and deciding on the resource assignment to trains leading to new or changes of train links. • ETS: Electric Traction System simulator simulating the behaviour and resulting KPIs of a physical Electric Traction System based on real-time information about actual power demand of running trains. The simulation is performing calculations in cycles forecasting power restrictions, KPI threshold violations or system failures like e.g., triggering of electrical fuses of substation areas. It provides forecasted restrictions and train control suggestions for addressing forecasted power conflicts.
3) System: The demonstration 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 and train control suggestions 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 RUD will make use specific views emulating such a system to reflect the required changes of resource links as assigned to trains.
4) Goals: To test and demonstrate use cases related to aligned decision making of Train/Traffic Controllers taking into account the up-to-date characteristics, needs and constraints of involved track, energy availability, rolling stock and crew resources. As a consequence, better TC decisions based on a higher 'reality' of the train running forecast can be expected.
5) Forecast window: 3-4 hours.
6) Objectives: Better forecast quality due to considered constraints or needs of integrated processes/systems.
7) Inputs: Baseline data: operational plan and microscopic infrastructure model including ETS configuration and a set of planned maintenance activities, one or more detailed yard/station areas and train consist related data.
8) Outputs:

• Calculated forecast considering characteristics, forecasted energy restrictions and train control suggestions addressing power conflicts, involved track, rolling stock and crew resources communicated by other systems or related processes. • Aligned TM decisions implemented.
9) Demo scenarios to be covered: • Maintenance plan updates impacting the forecast result or triggering re-planning in TMS, e.g., due to results of measurement runs and re-prioritization of maintenance (FP3-IAM4RAIL WP8/9) (UC-FP1-WP10-12). • Yard/station track capacity re-planning impacting the forecast result or triggering re-planning in TMS (UC-FP1-WP10-12, UC-FP1-WP10-13, UC-FP1-WP10-14). • ETS power restrictions caused by multiple trains accelerating at the same time in a substation area impacting the forecast result (UC-FP1-WP10-12). • Crew/Rolling Stock assignment changes impacting the forecast result or triggering re-planning in TMS (UC-FP1-WP10-12).
10) Methodology (how): • Scenario preparation in the integrated systems for triggering different impact quality (changes of forecast timing, routing, non-compliance with rules, conflicts). • Comparing forecast/decision results with results based on non-availability of integrated information.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: • FP3-IAM4RAIL/(WP8/9): input for development and preparation of demonstrations; joint demonstrations. • FP5-TRANS4M-R/(WP25/26): alignment of requirements and use cases resulting in input for development and preparation of demonstrations. • FP6-FUTURE/(WP6): alignment of requirements and use cases resulting in input for development and preparation of demonstrations. • SP interaction: Interaction with Task 3 focusing on TMS interfaces resulting in input for development and preparation of demonstrations.
13) Physical: No. Cloud based demonstration.
14) How to evaluate the demo • Successful test of the use cases and requirements related to the demo scope. Expert judgement based on performed demonstrations.

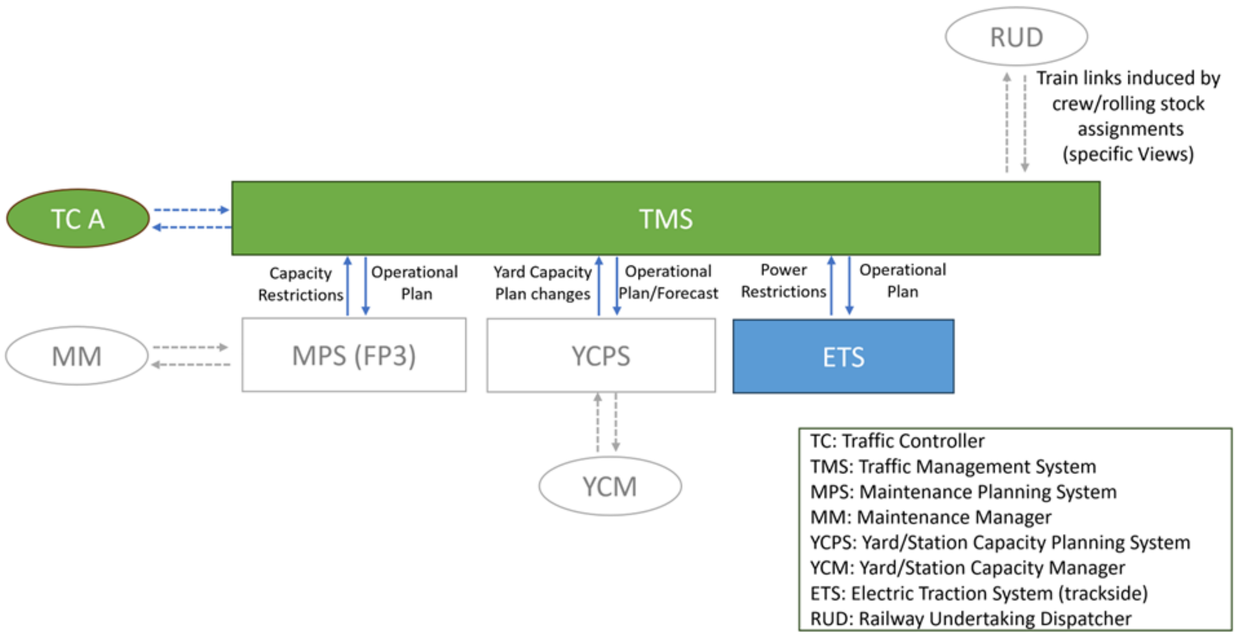
• Comparing forecast/decision results with results based on non-availability of integrated information.
15) Diagram with the interaction: 

Table 20: Demo 7 (HACON) description

G) Demo 8 (Task 12.2.8)- Interface of TMS to Yard Coordination System 2.0 (TRV)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
8	TRV	12	12.2.8	Interface of TMS to Yard Coordination System 2.0 in Malmö node. Work connects to WP4.	M40-M46	6	10

Table 21: Demo 8 (TRV) summary

Task 12.2.8- Interface of TMS to Yard Coordination System 2.0 in Malmö node (TRV)
1) Given is: • An operational plan for trains (RTTP) for a neighbouring area of a marshalling yard. The RTTP is handled in a TMS system. • A plan for track allocation for an arrival/departure yard that connects to the neighbouring TMS area. The track allocation plan is handled in YCS. • An integration platform for exchange of information between the TMS and YCS.

2) Actors: • Traffic Controller for the line (person responsible for traffic activities on the tracks that connects to the neighbouring yards). • Traffic Controller for the yard (person responsible for making capacity allocations at the arrival/departure yard). • Yard Manager (responsible for internal yard marshalling operations). • Terminal Manager (responsible for operations at a multimodal terminal).
3) System: • Coordination of line capacity management and yard capacity management. • Coordination of yard track allocation between the actors at the marshalling yard (including multimodal terminal).
4) Goals: Efficient interaction between TMS and YCS users, that will contribute to smooth and easy control and supervision of traffic in the border area between YCS and TMS.
5) Forecast window: Primary forecast window: nearest 24 hours.
6) Objectives: Assessing the TMS-YCS integration and operations on performance, capacity, track allocation, punctuality and human factors.
7) Inputs: Test environment and workplaces for users to interact with the systems, realistic operational data and operational scenarios.
8) Outputs: • Validated integration of TMS and YCS, functions, robustness, performance. • Human factors assessment of functions and GUI.
9) Demo scenarios to be covered: • Sending and Receiving track allocation information between TMS and YCS, UC-FP1-WP10-15. • Notifying TMS and YCS operators about disruptions, requests about plans and track allocations, and updated arrival and departure times, UC-FP1-WP10-16.
10) Methodology (how): 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.
11) Interactions with other WPs:

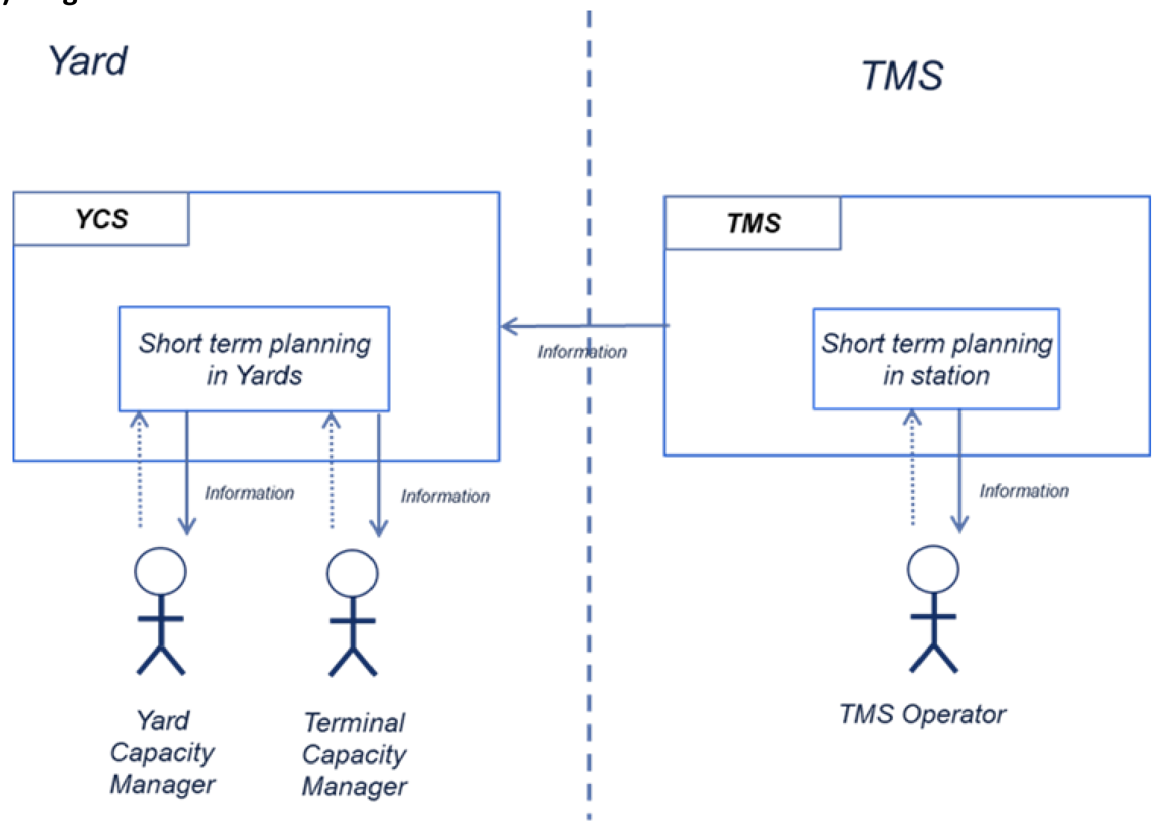
FP1/(WP4/5): (Development/Demonstration - Integration of planning systems and processes including cross-border planning), works in the area of long-term capacity planning on conceptual level. WP4 will develop methods and tools for track allocation planning, which will contribute in development of TMS-YCS demonstrations.
12) Interactions with other FPx or SP: FP5-TRANS4M-R/(WP32): WP11/12 will utilize data sharing provided by FP5 WP32.
13) Physical: Yes, in a test bed environment.
14) How to evaluate the demo By executing operational scenarios in cooperation with end users to evaluate and validate the integration of TMS and YCS.
15) Diagram with the interaction: 

Table 22: Demo 8 (TRV) description

H) Demo 9 (Task 12.2.9)- Interface in view of the future autonomous inspection vehicle for the infrastructure and its integration with the Intelligent Asset Management System (IAMS)(CEIT)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
9	CEIT	12	12.2.9	Interface in view of the future autonomous inspection vehicle for the infrastructure (FP3) 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.	M40-M46	6	10

Table 23: Demo 9 (CEIT) summary

Task 12.2.9 - Interface in view of the future autonomous inspection vehicle for the infrastructure (FP3) 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 (CEIT).
1) Given is: • Planned infrastructure maintenance operations. • An IAMS system to interact with a TMS and a TMS to interact with the inspection Vehicle (in absence of TMS, IAMS interacts directly with the inspection vehicle).
2) Actors: • TMS: Traffic Management System, for managing the railway traffic. • IAMS: Intelligent Asset Management System, to send alert messages to TMS or inspection vehicle about required inspection intervention status of assets. • IV: Inspection Vehicle, to receive the allocated path for inspection.
3) System: The demonstration provides the technical basis for demonstrating improved interactions between an inspection vehicle, an IAMS and a TMS.
4) Goals: To test and demonstrate integrations and communication requirements between TMS, IAMS and inspection vehicle.
5) Forecast window:

Not applicable.
6) Objectives: Definition and exchange of information that will allow optimized inspection activities by means of the interaction of IAMS, TMs and an inspection vehicle.
7) Inputs: • Required inspection intervention. • Infrastructure asset alerts with warnings or recommendations (e.g. apply temporary speed restrictions, alerts about assets reaching critical status, etc…). • Inspection Vehicle location. • Allocated path for inspection vehicle based on asset status and planned interventions.
8) Outputs: • IAMS to TMS interface. • TMS to Inspection vehicle interface.
9) Demo scenarios to be covered: • Sending and receiving track allocation information between TMS and inspection vehicle [UC-FP1-WP10-17]. • Sending alert messages from IAMS to TMS (or inspection vehicle in case of no TMS) about required inspection intervention status of assets [UC-FP1-WP10-17]. • Sending alert messages from IAMS to TMS about critical status of assets [UC-FP1-WP10-17]
10) Methodology (how): • Define and develop an interface and message structure for communications between IAMS and TMS. • Define and develop an interface and message structure for communications between TMS and Inspection vehicle related to the inspection intervention. • Define and exchange between IAMS and TMS warning or recommendations based on infrastructure status (e.g. apply temporary speed restrictions, alerts about assets close to reaching critical status, etc…).
11) Interactions with other WPs: Not applicable.
12) Interactions with other FPx or SP: FP3-IAM4RAIL: interaction with FP3 to define the inspection details and asset alerts or warnings to be transmitted to the inspection vehicle.
13) Physical: No, virtual demonstration.

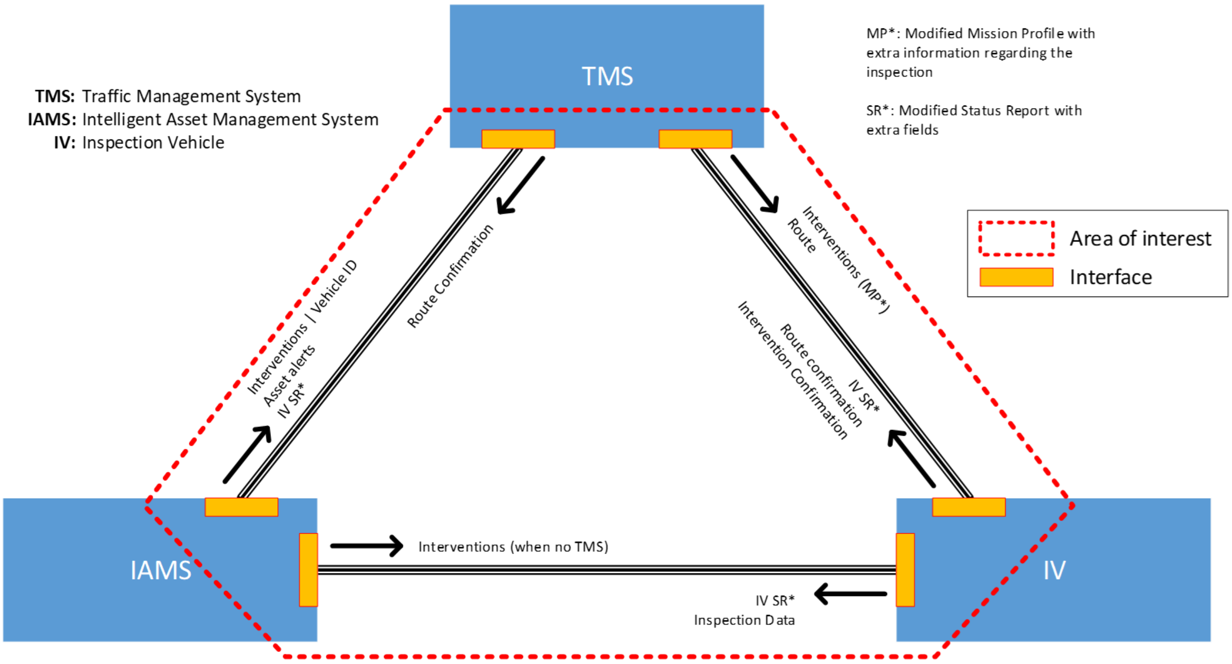
14) How to evaluate the demo Successful test of the requirements related to the demo scope.
15) Diagram with the interaction: 

Table 24: Demo 9 (CEIT) description

8.2. Description of the demonstrations associated with WP13/14

The overall objectives of WP13 (development) and WP14 (demonstration) are linked to TEs 11, 13 and 14. With the WP15/16 group it is pursued to develop prototypes for a cooperative multi-actor optimisation and decision support system for incidents and disruption management, with human-in-the-loop through an advanced HMI, to increase system resilience and efficiency.

The following will be designed and developed as part of the scope of this WPs:

- Innovative rail multi-actor network management processes and methods for incidents and disruption management, through an advanced high-grade automation for TMS and the ability to interact with railway asset maintenance systems and other possible actors, able to improve the railway resiliency and performance.
- Decision Support Systems (DSS) integrating the above network management processes/methods with optimisation means.
- An advanced multi-media HMI, based on web technology stack, for the DSS enhancing user interaction and allowing risk- and context-aware decisions, exploiting AI and Machine-Learning and user-centred design approaches.

A) Demo 10 (Task 14.1)- Collaborative DSS for efficient and effective disruption management (STS, TRV, NSR, HACON)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
10	STS, TRV, NSR, HACON,	14	14.1	Collaborative DSS for efficient and effective disruption management	M40-M43	4/5	11,13,14

Table 25: Demo 10 (STS, TRV, NSR, HACON) summary

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
10.1	STS, TRV	14	14.1	Collaborative DSS	M40-M43	4/5	11,13,14

Table 26: Demo 10.1 (STS, TRV) summary

Task 14.1- Collaborative DSS for efficient and effective disruption management (STS with TRV contribution) - Demo 10.1

1) Given is:

- An operational plan (7 days) for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions, calculated forecast for 3-4 hours.
- Updates about predictive maintenance by IAMS of IAMS4RAIL (FP3), WP3/WP4.
- Updates about critical systems alarms, requiring special procedures involving multiple actors, received via interface.

2) Actors:

- TMS, for managing the railway traffic.
- IAMS, to collect alarms and events from assets being monitored and/or human operators and send them to the system for analysis; to send messages to TMS for traffic reschedule or send messages to HMIs of human operators for the implementation of disruption management.
- Train/Traffic Controller, to send alarms/events to IAMS and to receive messages from IAMS about how managing a disruption.
- Infra maintenance manager, to receive messages from IAMS about how managing a disruption.
- RU dispatcher, to receive messages from IAMS about how to manage disruptions.
- Train driver, to send alarms/events to IAMS and to receive messages from IAMS about how to manage disruptions.

3) System: • From the control room, railway operators (IM) control and directly manage the railway traffic, ensuring the highest standards of safety, regularity and punctuality, and an effective intervention in case of disruptions or breakdowns. In the management of alarms and scenarios of particular interest, an operating Decision Support System (DSS) can help the involved operators in reducing complexity of their tasks by automating data integration, repetitive and time-consuming tasks, by recommending specific actions or providing list of actions that have to be implemented. • Mostly, the operators need to be supported every time a disruption occurs. Unplanned events generally lead to a first chaotic phase in which the operator involved has to take recovery decisions in a very short-time with limited information. In this context, a DSS can help the operator by reducing the effort and stress required.
4) Goals: • Multi-actor coordination and decision support for implementation of aligned decisions (TE13). • Support the operators when performing complex procedures, to reduce the workload and the fatigue in critical scenarios and to remain in a high degree of situational awareness. • Provides suggestions to optimize maintenance, using information coming from IAMS, with the respect of current traffic status.
5) Forecast window: 1 working day.
6) Objectives: • Improve the prompt and effective management of critical events and failures occurring at entities within a railway infrastructure by reducing possible issues on the railway traffic and keeping high-level of safety. • Support operators in the management of critical events and failures by presenting the best possible remediation actions and allowing multi-actor coordination and cooperation via computer-based communications. • Ensure an efficient interaction between actors involved (including technical systems), interfaces and external entities.
7) Inputs: • Operational plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR). • Prediction of faults of specific devices provided by IAMS. • Critical alarms and/or events of specific devices, wayside or on board, provided by monitored assets.

• Current traffic scheduling provided by TMS • Suggestion of specific maintenance procedure by IAMS. • Usability principles and HMI methodology
8) Outputs: • Multi-actor scenario that highlights the interactions and exchange of data occurring among these actors. • Suggest changes and optimization to maintenance plan.
9) Demo scenarios to be covered: • Management of a critical alarm symptomatic of a failure of an asset within the railway infrastructure able to cause a disruption by means of a collaboration among actors and a support of a DSS for the effective and efficient selection of the best resolution strategy (UC-FP1-WP10-19) • Preventive management of a possible failure of an asset within the railway infrastructure able to cause a disruption by leveraging on a DSS to find out preferable time window in which to plan intervention and the kind of intervention (UC-FP1-WP10-20) • Implementation of Preventive Functional Assessment with a DSS determining if an intervention is needed and when to conduct it (UC-FP1-WP10-21)
10) Methodology (how): • Scenario preparation with respect to a representative disruption, modelling the possible state of the infrastructure and data instances to be exchanged among the identified interactive systems. • Model of the reference scenario by using emulation, sand-boxes and multi-user access. • Measure the KPI for proper, prompt and efficient disruption management during the emulated scenario handling, and compare what achieved with respect to the state of the art. • Measure the KPI for mental workload and situation awareness.
11) Interactions with other WPs: N/A.
12) Interactions with other FPx or SP: FP3- IAMS4RAIL/(WP3, WP4): • WP3 on the definition of requirements for DSS-IAMS interfaces (protocols, CDM, visualization, …). • WP4 Integration of DSS result and interfaces into IAMS platform.
13) Physical: No, the system will be remotely accessible and will work in a simulated environment.
14) How to evaluate the demo KPIs measures on the quality of the disruption management, mental workload and situation

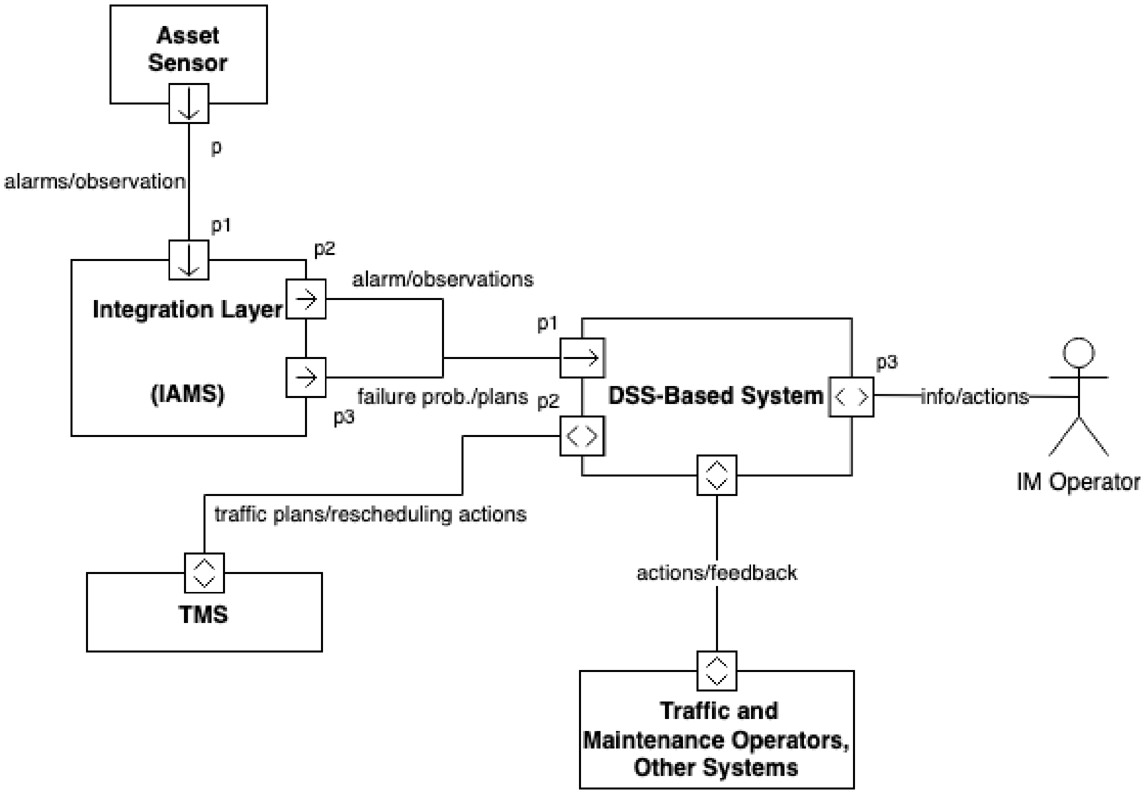
awareness in comparison with the state-of-the-art and KPIs from existing solutions. Conformity with usability principles and HMI methodology
15) Diagram with the interaction: 

Table 27: Demo 10.1 (STS, TRV) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
10.2	NSR	14	14.1	Decision support for rolling stock dispatching	M40-M43	4	13,14

Table 28: Demo 10.2 (NSR) summary

Task 14.1- Decision support for rolling stock dispatching (NSR) - Demo 10.2
1) Given is: • A real-time rolling stock schedule for 3 days. • Real-time information on disruptions. • Passenger crowding information.
2) Actors: Rolling stock dispatcher.

3) System: From the Operational control centre rail, the rolling stock dispatchers monitors the rolling stock circulation and solves conflicts in this circulation when they occur. Conflicts can occur in real-time or several hours ahead of time.
4) Goals: Solve conflicts in rolling stock circulation minimizing impact on the operator side as well as on the passenger side.
5) Forecast window: 48-72 hours.
6) Objectives: Demonstrate added value for the rolling stock dispatchers by providing them an impact analysis and prioritisation for individual conflicts and propose solutions when possible.
7) Inputs: • Real-time rolling stock schedule. • Real-time delay information. • Real-time disruption information.
8) Outputs: • Conflict based prioritisation using a single currency evaluator.
9) Demo scenarios to be covered: Solving of rolling stock dispatching conflicts using reserves and swaps. (UC-FP1-WP10-24, UC-FP1-WP10-25)
10) Methodology (how): This is tested the algorithm described and developed in WP13 on several historical data instances mimicking a real-time setting.
11) Interactions with other WPs: No.
12) Interactions with other FPx or SP: No.
13) Physical: No.
14) How to evaluate the demo Expert judgment based.
15) Diagram with the interaction:

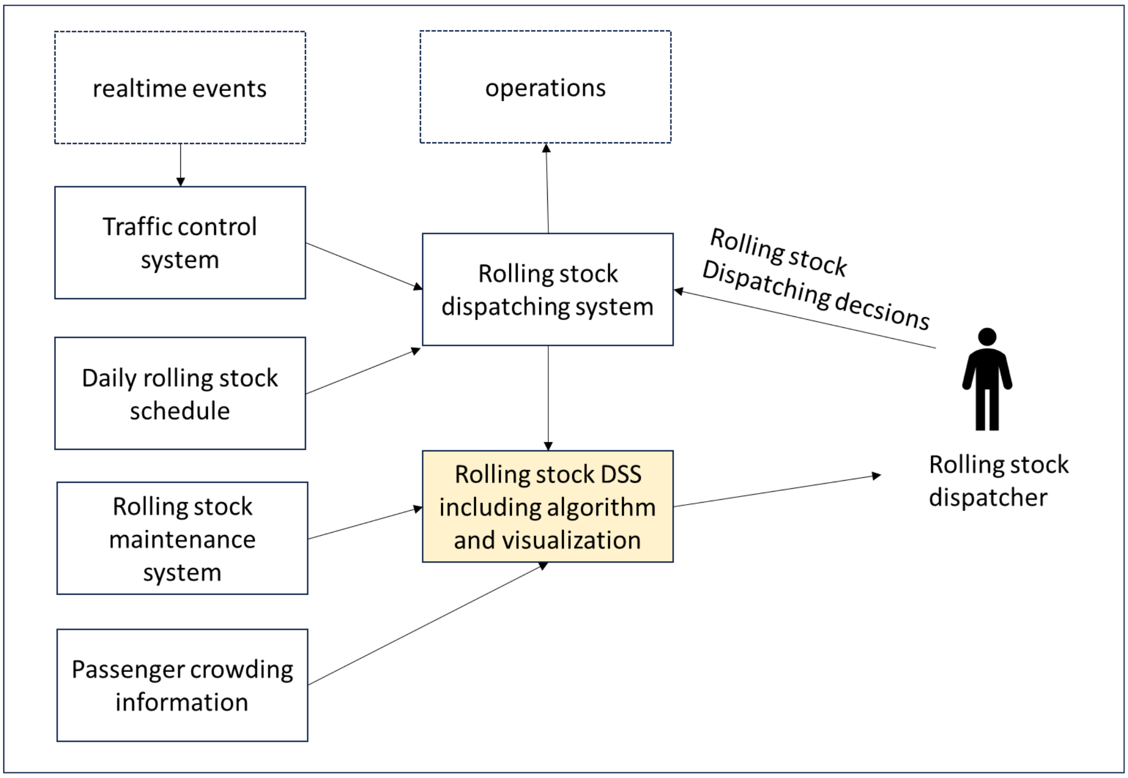


Table 29: Demo 10.2 (NSR) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
10.3	HACON	14	14.1	Collaborative DSS for efficient and effective disruption management	M40-M43	4/5	13,14

Table 30: Demo 10.3 (HACON) summary

Task 14.1- Collaborative DSS for efficient and effective disruption management (HACON) – Demo 10.3
1) Given is: • An operational plan (7 days) for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions, calculated forecast for 3-4 hours. • Updates of planned infrastructure maintenance by IAMS(DMPS) of IAM4RAIL (FP3), WP8/WP9 received via interface. • A set of active Control Rules reflecting earlier control decisions. • Conflict(s) identified from the train running forecast calculation in conjunction with updated maintenance plan.

2) Actors: • TMS: TMS System used for managing the railway traffic in a defined area or on one or multiple defined lines. • TC: Train/Traffic Controller using the TMS for taking and implementing decisions leading to updates of the operational plan managed by the TMS. • CMS: Capacity management and planning system used for (re-)planning of train paths. • CM: Capacity planner using the CMS for (re-)planning of train paths. • MPS: infrastructure maintenance planning system used for planning track maintenance& repair and disseminating technical descriptions of resulting capacity restrictions. • MM: infrastructure maintenance manager using the MPS for planning track maintenance& repair. • RUD: crew/rolling stock dispatcher of a Railway Undertaking responsible for involved crew/stock resources and deciding on the resource assignment to trains.
3) System: The demonstration provides the technical basis for demonstrating how collaborative decisions can be taken into account as resulting from decision support modules of TMS. A specific focus is set with respect to collaborative track maintenance decision making supported by interfaces with the IAMS/DMPS subsystem as implemented in FP3-IAMS4RAIL WP8/9. 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 RUD will make use specific views emulating such a system to reflect the required changes of resource links as assigned to trains. The system also comprises an integration with capacity planning system demonstration of FP1-MOTIONAL WP4/5 for feedback of operational data to improve the timetable / track capacity planning.
4) Goals: To test and demonstrate use cases related to: • Multi-actor coordination and decision support for implementation of aligned decisions (TE13). • Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management (TE14). • Interaction of TMS with the Maintenance Planning System for improved and cooperative traffic optimisation and regulation. • Give operational feedback to planning services to allow for improved timetable planning, as complementary activities to WP4/5.
5) Forecast window: 3-4 hours; operational plans available for the next 7 days.
6) Objectives:

• Improve forecast calculation quality due to considered (collaborative) decisions based on constraints or needs of integrated processes/systems. • Optimize cost/benefit ratio of effective train operations resulting from aligned and fast decisions and improved timetables.
7) Inputs: Baseline data: operational plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR).
8) Outputs: • Adjusted timetable suggested in DSS subsystem for implementation. • Adjusted or new active Control Rules and updated operational plan. • Multi-actor scenario that highlights the exchange of data occurring among these actors. • Operational feedback sent to capacity planning / management system. • Plans received from capacity planning / management being better adapted to operational needs. • Collaborative TM decisions implemented. • Calculated forecast considering collaborative decisions.
9) Demo scenarios to be covered: • Maintenance plan updates requiring train regulation changes impacting the forecast result or triggering re-planning in TMS, e.g., due to results of measurement runs and re-prioritization of maintenance (FP3-IAM4RAIL WP8/9, UC-FP1-WP10-18). • Providing timetable information to maintenance planning (FP3-IAM4RAIL WP8/9) for aligned decision making for minimized impact of maintenance plans (UC-FP1-WP10-18). • Changes of Crew/Rolling Stock links impacting the forecast result or triggering re-planning in TMS (UC-FP1-WP10-18). • Feeding back TMS operational information to CMS (required for integration with WP5 CMS demos).
10) Methodology (how): • Scenario preparation in the integrated systems for triggering different impact quality (changes of forecast timing, routing, non-compliance with rules, conflicts). • Comparing forecast/decision results with results based on non-availability of integrated information or non-aligned integrated information. • Making use of sand-boxes and multi-user access.
11) Interactions with other WPs: FP1/(WP4/5): give operational status and feedback to CMS planning services to allow for improved timetable planning, as complementary activities to WP4/5.
12) Interactions with other FPx or SP:

- FP3-IAM4RAIL WP8/9 (Task 8.4): delivering input to Task 14.1 about TCR specification and handling for development and preparation of this demonstration; receiving specification of timetable data to be sent to the DMPS system delivered by FP3-IAM4RAIL Task 8.4; joint demonstrations.
- SP interaction: providing input about interface specifications in support of development and preparation of this demonstration.

13) Physical:
No. Cloud based demonstration.

14) How to evaluate the demo
- Successful test of the use cases and requirements related to the demo scope.
- Assessment of decision results against results based on non-availability of integrated information or non-aligned integrated information.
- Expert judgement based on performed demonstrations.

15) Diagram with the interaction:

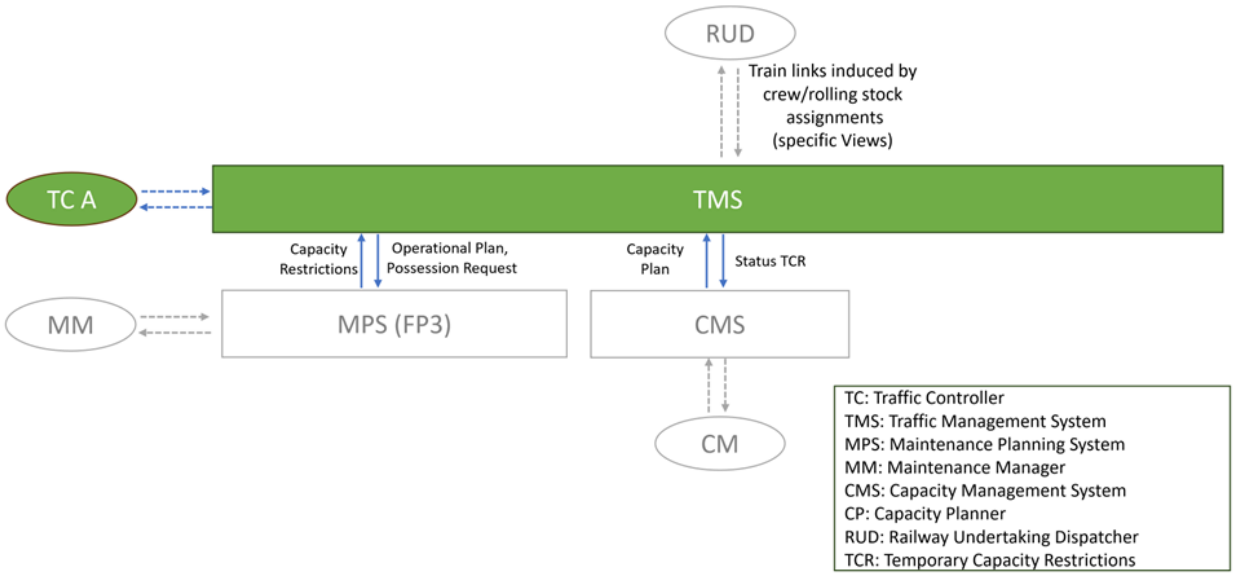


Table 31: Demo 10.3 (HACON) description

B) Demo 11 (Task 14.2)- HMI for TMS based on User Experience (UX) Design and user input (TRV, STS, INDRA)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
11	TRV, STS, INDRA	14	14.2	HMI for TMS based on User Experience (UX) Design and user input	M40-M43	8	11

Table 32: Demo 11 (TRV, STS, INDRA) summary

Task 14.2 - HMI for TMS based on User Experience (UX) Design and user input (TRV, STS, INDRA).

1) Given is:
• An Operational Plan for trains (RTTP). The RTTP is handled in a TMS.
• A simulator platform representing an authentic TMS including functions and tools for needed for
    ○ exchange of information between the TMS operator and other actors involved.
    ○ executing commands and monitor their effects on the traffic, in real time.
• Access to subject matter experts.

2) Actors: • TMS operators, • Train drivers, • Service/rescue team, • Maintenance team, • Back-office planning support.
3) System: In the operation control centre (OCC), TMS operators control and manage the railway traffic, ensuring the highest standards of safety, regularity and punctuality, and an effective intervention in case of different levels of deviations from the operational plan. An understanding of the situation, situation awareness, is essential for the TMS operator to make the decisions that will reach these high standards of safety, regularity and punctuality and must therefore be supported by the TMS. The demonstration provides a proof of the concept developed within task 13.3, based on HMI design principles for traffic management. The main objective is to create a situation with the optimal prerequisites possible for the TMS operator.
4) Goals: The goal is to test how well the concept developed supports increased situation awareness and the measurement of mental workload compared to the state-of -art for an efficient TMS.
5) Forecast window: N/A
6) Objectives: • Improve TMS operators' understanding of the situation due to considered (and where applicable; collaborative) decisions based on the developed proof of concept. • Improved understanding of the relevant information shared by the other actors involved.

• Decrease the workload for TMS operator.
7) Inputs: • A simulator platform. • One or several scenario(s) with a realistic situation. • A functional TMS to demonstrate a valid work situation.
8) Outputs: Actions taken by the train driver and actions taken by the TMS operator/dispatcher in a realistic scenario in a simulator-based situation.
9) Demo scenarios to be covered: Trespassing and/or Infrastructure problems detected by railway staff. (UC-FP1-WP10-26, UC-FP1-WP10-28)
10) Methodology (how): 1. The TMS operator (subject matter expert) will be educated on how to use the simulated TMS. 2. Scenario preparation in the simulator platform for triggering events. 3. Comparing decision results with results based on the scenarios demonstrated and todays working procedure. 4. Evaluate changes in workload and situation awareness. 5. Conclusions and recommendations for traffic management efficiency based on measurement of workload and situation awareness. STS will support the Demo by applying the methodology for UX HMI within the context of Demo 10 and the collaborative DSS to provide to TRV KPI results and operator's stress evaluation in dealing with critical events and multi-actor resolution. STS will provide remote access to its internal simulator-based environment to conduct the demo activities. INDRA provides KPI for measuring the workload of the dispatcher including them in a view of the HMI developed. These KPI will allow to know when work peaks take place and how they affect to the dispatchers, being the measures easily accessible to the operator. These KPI will be based on the uses cases to study, in order to provide an accurate result of the demonstrator.
11) Interactions with other WPs: FP1/(WP15/16), in the Human factors perspective.
12) Interactions with other FPx or SP: N/A.
13) Physical: No. Simulation-based environment.

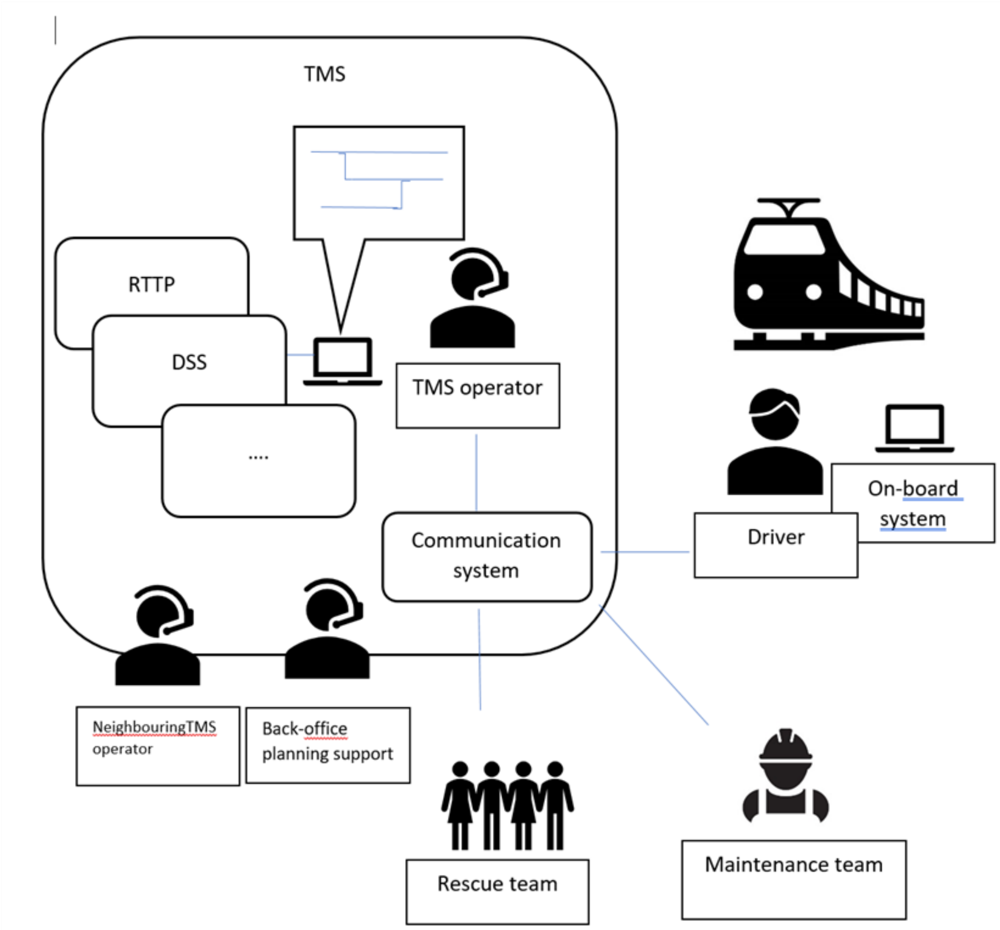
14) How to evaluate the demo • Assessment of performances, of all involved actors. • Conformity with usability principles and HMI methodology • KPIs measures on mental workload and situation awareness for TMS operator/dispatcher in comparison with the state-of-the-art.
15) Diagram with the interaction: 

Table 33: Demo 11 (TRV, STS, INDRA) description

8.3. Description of the demonstrations associated with WP15/16

The overall objectives of WP15 (development) and WP16 (demonstration) are linked to TEs 12 and 15. Within WP15/16, it is pursued to reach seamless integration between TMS and ATO/C-DAS. The combination TMS and ATO/C-DAS is expected to provide significant advantages such us increase network capacity, robustness, punctuality, energy consumption, among other things.

The TMS optimises the adaptation of the trains' schedule in case of delays and disturbances, focusing on integral network optimisation. The ATO/C-DAS optimises the trains' trajectory through the network within the margins of the "timetable envelope", the bandwidth wherein the train may operate in each section of the trajectory. The combination of both leads to balanced usage of ATO's/C-DAS's train centric optimisation, which complies with the network optimisation of the TMS.

Future TMS and ATO functionality must be tested by simulation before it is tested in a live environment. Simulation tools and methodologies are already at hand to make a realistic depiction of their future performance and human-in-the-loop. This also include to develop a system that support human factors in the interaction with ATO/C-DAS.

These WPs are expected to deliver modelling advice guidelines for future modelling of ATO timetables. Differences between the two technologies will be indicated.

This includes:

- Feedback-loop with traffic simulation verifying the algorithms relatives to TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables to test the linkage of TMS to ATO/C-Das and being a test-bench to check the algorithms.
- Testing the future applicability in operations, including human-factors research, by "real-world" emulation with a human the loop simulation environment which contains connected simulators of loco drivers, signallers and traffic managers linked to dynamic however, in regard of the interlocking, de-coupled traffic management system and ATO on-board modules.

A) Demo 12 (Task 16.2)- Linking TMS to ATO/C-DAS for optimised operations "Live" demonstration for the public (or by video) of future TMS-ATO operations (PR, TRV, NSR, KB, ADIF, CAF)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
12	**PR, TRV,** NSR, KB, ADIF, **CAF**	16	16.2	Linking TMS to ATO/C-DAS for optimised operations "Live" demonstration for the public (or by video) of future TMS-ATO operations, including human factors: • In alignment with FP2 "Mainline demonstration preparation"- a project of a complex network use case including very short headways, disruption, and conflict resolution where TMS and ATO together show	M40-M44	4/5	12, 15

				their added value, also indicating how this new kind of operation will impact the involved operational actors (train drivers and signallers HF research) by ProRail/NSR. • Testing HF impact when applying in FP2 developed new optimised braking functionality. • In alignment with FP6 test bench demonstration simulation.			

Table 34: Demo 12 (PR, TRV, NSR, KB, ADIF, CAF) summary

Task 16.2- TMS – ATO simulations and demonstrations (PR, TRV, NSR, KB, ADIF, CAF)
1) Given is: • Operational plan for a mainline railway with mixed passenger trains, • Corresponding infrastructure data and train data, • Scenarios for normal and disturbed conditions.

2) Actors:
• TMS: provides Operational Plan to ATO-TS,
• ATO-TS: provides and sends Journey Profile and Segment Profiles to ATO-OB of all connected trains, including Train Path Envelope according to Operational Plan,
• ATO-OB: provides train trajectory within Train Path Envelope and the corresponding traction and brake control commands,
• Train: follows commands from ATO-OB under supervision of ETCS,
• TMS/CTC Operator combined in one actor:
  ○ CTC System Operator responsible for safe route setting both in normal and degraded conditions,
  ○ TMS Operator (local): responsible for a feasible route plan according to Operational Plan.
• TMS Operator (global): coordinates network traffic (or large traffic control area),
• Simulation leader: responsible for start/stop/pause simulation or introduction disturbances,
• Train driver: responsible for driving a train safe, punctual and economical (GoA1 and GoA2).

3) System: • Human-in-the-loop chain simulator environment including TMS-ATO functions and human roles in the traffic control centre (local TMS/CTC Operator and global TMS Operator) and train driver. • The TMS – ATO linkage provides each train with a Train path Envelope according to the Operational Plan from the TMS such that each train is able to operate conflict-free, energy-efficiently and respecting the targets at Timing Points from the Operational Plan.

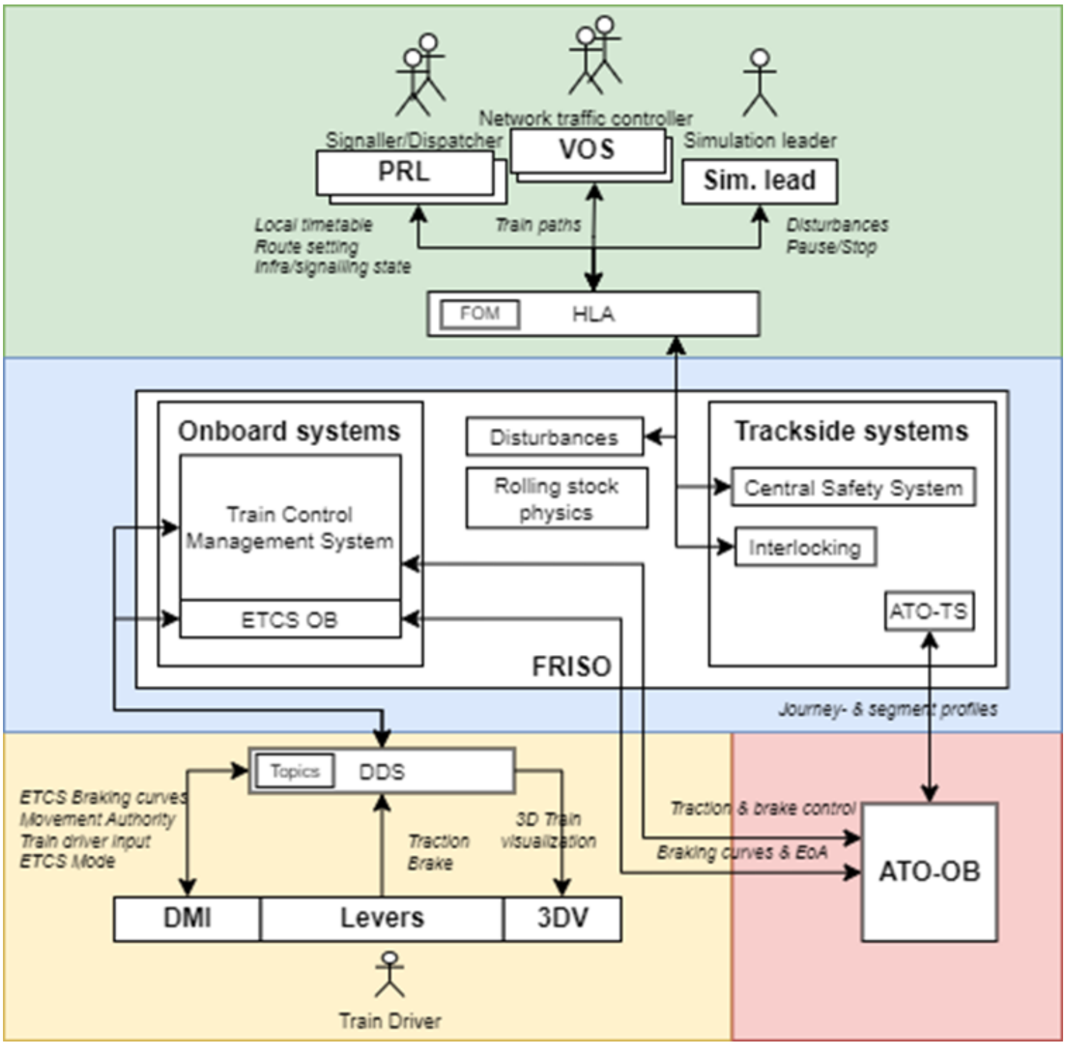
• The interface between the ATO-TS and the ATO-OB is included in the CCS TSI 2023, and the ATO-OB train trajectory generation and tracking algorithms are assumed available (or at least beyond the scope of the assessment).
4) Goals: • "Mainline demonstration preparation" in alignment with the FP2/WP39. • 'Live' demonstration for the public of future TMS-ATO operations, including human factors.
5) Forecast window: None.
6) Objectives: TMS and ATO together show their added value, also indicating how this new kind of operation will impact the involved operational actors (train drivers, CTC/TMS Operator, TMS Operator) in HF research.
7) Inputs: • Baseline data: operational plan, microscopic infrastructure model, train characteristics, • Scenarios for operating the real-world human-in-the-loop demonstration defined in Task 16.1.2 in close alignment with FP2/WP39.
8) Outputs: • Simulation of feedback loops between TMS and ATO-TS, between the ATO-TS and ATO-OB, and the roles of human actors, • 'Live' simulator demonstration of TMS-ATO operation including impact on the operational human actors.
9) Demo scenarios to be covered: • Mainline with high-density heterogeneous traffic involving TMS - ATO interface, including timing points, train path envelopes and energy-efficient driving for various normal and disturbed scenarios. (UC-FP1-WP10-30, UC-FP1-WP10-31, UC-FP1-WP10-32)
10) Methodology (how): Human-in-the-loop chain simulator capable of simulating real traffic situations with TMS-ATO operated trains and various actors. Evaluation of enhanced TMS-ATO functionality and human-in-the-loop aspects.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP:

- FP2-R2DATP/(WP39): This demo is done in close alignment with FP2 Task 39.1 'Preparatory work to demonstrate ATO-solutions for main line bottlenecks. In particular, the test specification definition and finetuning of the TMS-ATO interaction and DATO functionalities.
- FP2-R2DATO/(WP17): This demo will also test the HF impact when applying the new optimised braking functionality developed in FP2/WP17.
- FP6-FUTURE, under discussion with FP6 lead.

13) Physical:
Yes, Utrecht, the Netherlands.

14) How to evaluate the demo
Questionnaire for demo participants + Debriefing the participants.

15) Diagram with the interaction:



PRL: Dutch TMS, VOS: Dutch traffic control system, HLA: High-Level Architecture, DDS: Data Distribution Service, FRISO: Dutch microscopic railway simulation tool

Table 35: Demo 12 (PR, TRV, NSR, KB, ADIF, CAF) description

B) Demo 13 (Task 16.3)- Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective (TRV, PR, NSR, INDRA, CEIT, STS)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
13	**TRV, PR,** NSR, INDRA, CEIT, STS	16	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective	M40-M44	4/5	12, 15

Table 36: Demo 13 (TRV, PR, NSR, INDRA, CEIT, STS) summary

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
13.1	**TRV, PR, NSR, STS**	16	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective	M40-M44	4/5	12, 15

Table 37: Demo 13.1 (TRV, PR, NSR, STS) summary

Task 16.3- Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management perspective (TRV, PR, NSR, STS) - Demo 13.1
1) Given is: • Operational plan for a mainline railway with mixed trains in TMS, • Corresponding infrastructure data and train data, • Data exchange according to SFERA (IRS 90940), • C-DAS OB functionality, existing C-DAS system or a simulation.
2) Actors: • TMS Operator, • Train driver, • TMS, • C-DAS TS, • C-DAS OB.
3) System: Demonstration shows improved (extended) functionality of TMS.

4) Goals: Show functionality of tools that assist TMS Operator in creating better RTTP and creates better prerequisites for C-DAS operations.
5) Forecast window: 1-2 hours.
6) Objectives: To evaluate if proposed concepts for improved TMS functionality that can assist TMS Operator in better handling C-DAS trains and improve performance of the C-DAS system.
7) Inputs: RTTP in TMS. Train operations (real or simulated) that deviate from RTTP.
8) Outputs: Updated, proposed RTTP (p-RTTP) that is better adapted to efficient operations for C-DAS trains.
9) Demo scenarios to be covered: Mainline with traffic consisting of both C-DAS and non-C-DAS trains, including small daily deviations from RTTP (no disruptions or large disturbances). (UC-FP1-WP10-35)
10) Methodology (how): New concepts based on AI and/or optimization techniques will be implemented in a TMS test environment and an external module to TMS. In the future this external module could be an integrated part of TMS.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: SP interaction.
13) Physical: Yes, Malmö, Sweden.
14) How to evaluate the demo: • Concept evaluation: Evaluate if TMS Operators perceive any positive value of having this kind of decision support tools in TMS. • Design evaluation: What are the pros and cons of the demonstrated tools and in what ways should they be further enhanced.
15) Diagram with the interaction: JP – Journey Profile, SP – Segment Profile, SR – Status Report, p-RTTP – Proposed Real-Time Traffic Plan

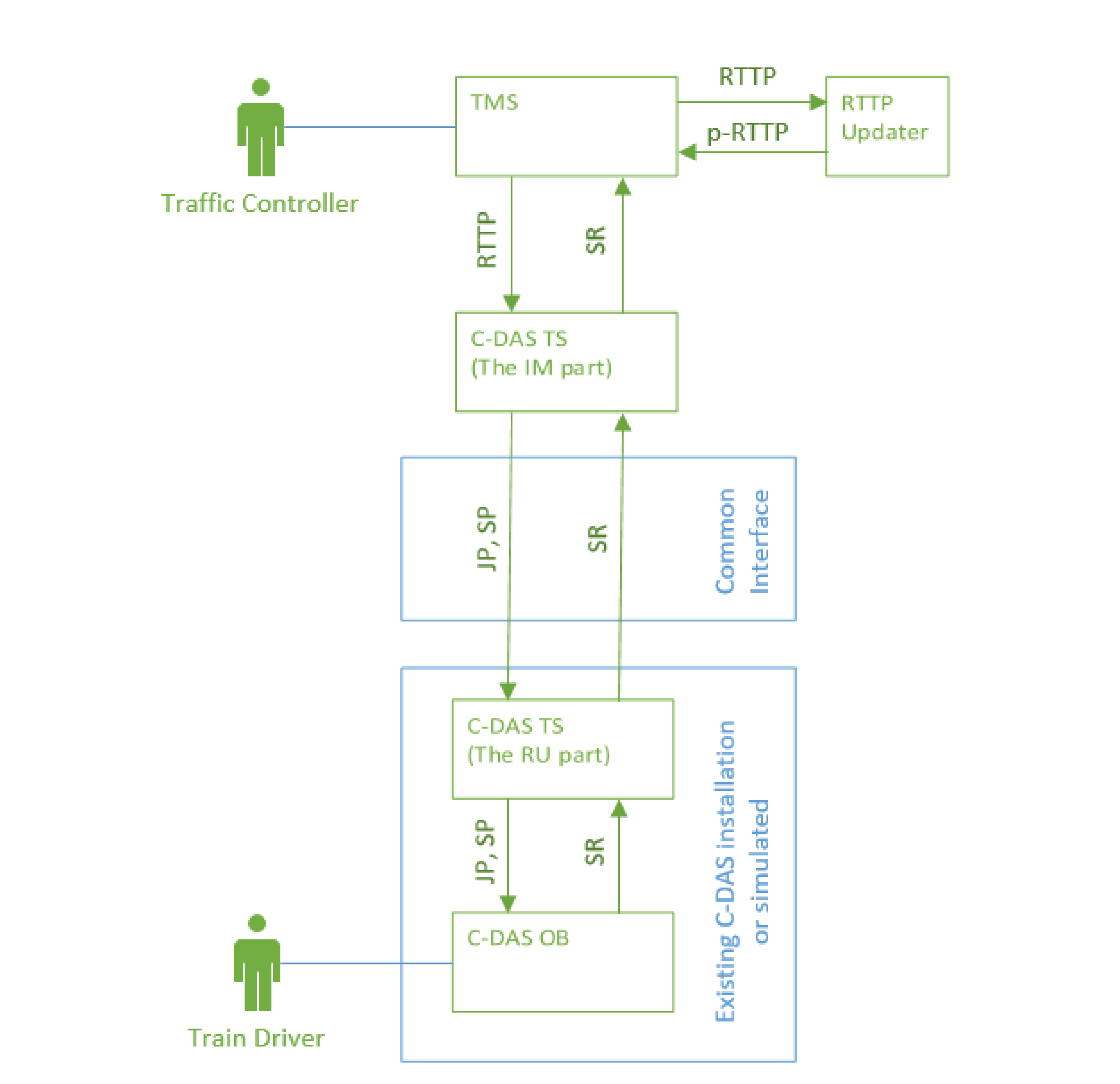


Table 38: Demo 13.1 (TRV, PR, NSR, STS) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
13.2	**INDRA**	16	16.3	Improvement of forecast calculation through TMS and C-DAS integration	M40-M44	4/5	12, 15

Table 39: Demo 13.2 (INDRA) summary

Task 16.3- Improvement of forecast calculation through TMS and C-DAS integration (INDRA) - Demo 13.2

1) Given is: • Operational plan for a mainline railway. • Corresponding infrastructure data and train data. • C-DAS OB and C-DAS TS functionality. • Forecast calculation.
2) Actors: • Operator, • Train driver, • Dispatcher, • Signaller, • TMS, • C-DAS TS, C-DAS OB.
3) System: This functionality allows the regulation operator to obtain the time forecast for the points of the route that have not been completely audited.
4) Goals: Improve TMS operational efficiency by enhancing forecast calculation and provide improved tools for dispatcher decision-making.
5) Forecast window: TBD.
6) Objectives: Obtain train positions through Status Reports (SP) to optimize the operation module in TMS enhancing forecast calculation.
7) Inputs: • Status Report (SP) from C-DAS. • RTTP in TMS. • Train route and timetable. • Train operations (real or simulated) that deviate from RTTP.
8) Outputs: • Updated RTTP. • Early detection of potential conflicts.
9) Demo scenarios to be covered: • Train position and speed updates. • Comparison of forecast with planned route.

• Mainline with traffic consisting of both C-DAS and non-C-DAS trains, including small daily deviations from RTTP (no disruptions or large disturbances). (UC-FP1-WP10-33)
10) Methodology (how): • Optimize the operation module in TMS updating train positions via Status Reports (SP). • Exchange real-time data and arrival time predictions between C-DAS and TMS.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None.
13) Physical: No.
14) How to evaluate the demo: • Concept evaluation: Comparison of forecast accuracy with and without enhancement. Evaluation of TMS operational efficiency before and after implementation. • Design evaluation: What are the pros and cons of the demonstrated tools and in what ways should they be further enhanced.
15) Diagram with the interaction:

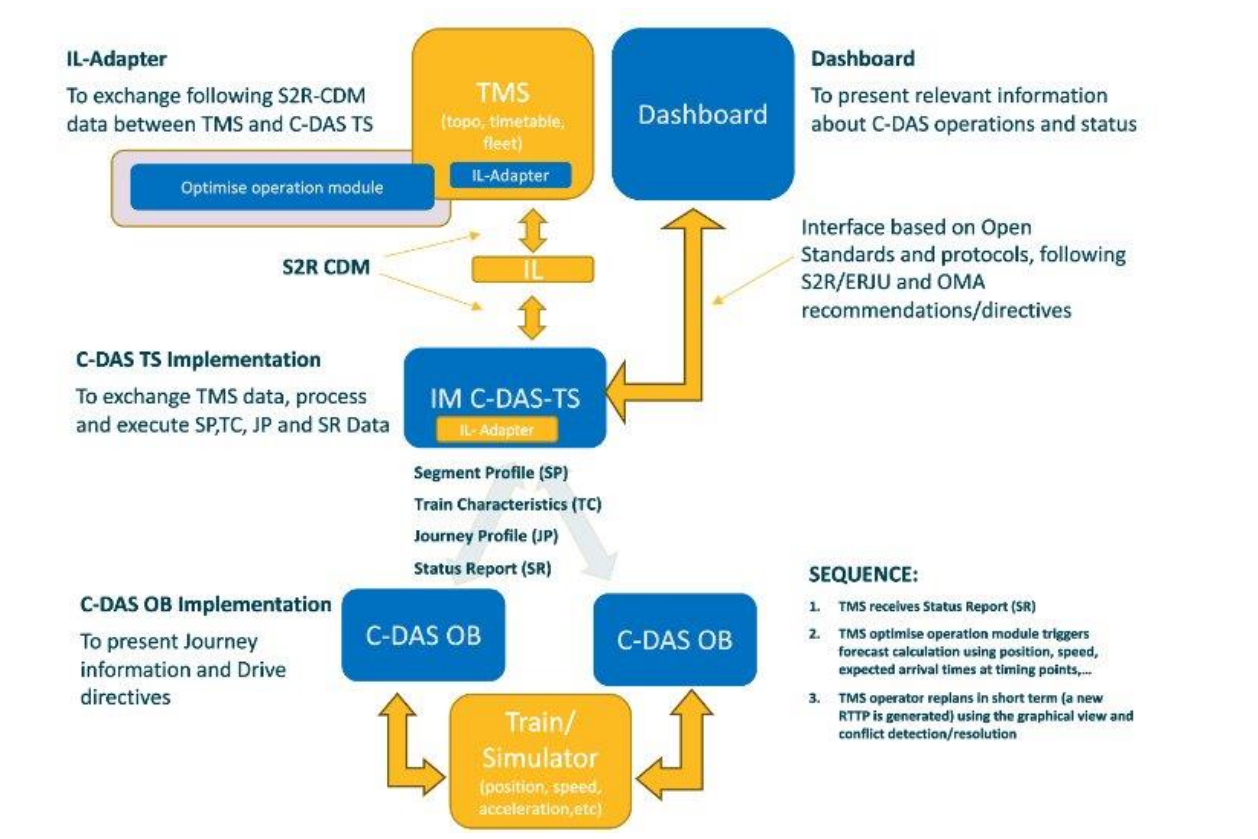


Table 40: Demo 13.2 (INDRA) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
13.3	**CEIT**	16	16.3	Improved C-DAS operations	M40-M44	4/5	15

Table 41: Demo 13.3 (CEIT) summary

Task 16.3- Improved C-DAS operations (CEIT) - Demo 13.3
1) Given is: • Operational plan for a mainline railway line. • Corresponding rolling stock and infrastructure data. • C-DAS OB and C-DAS TS simulated functionalities.
2) Actors: • Train driver, • TMS Operator, • CTC Operator, • TMS,

• C-DAS TS, C-DAS OB.
3) System: Improved behaviour of C-DAS.
4) Goals: Improve C-DAS operational efficiency through more realistic characterization of some key aspects.
5) Forecast window: 1-2h.
6) Objectives: Evaluate how different aspects of C-DAS (e.g. comms and positioning) can affect the behaviour of C-DAS systems.
7) Inputs: • RTTP from TMS. • Real or simulated communication and positioning characteristics.
8) Outputs: Updated RTTP.
9) Demo scenarios to be covered: • Mainline with traffic with C-DAS and including small deviations from RTTP (no disruptions or large disturbances) • Ideal scenario (in terms of comms. and positioning) and realistic or degraded conditions. (UC-FP1-WP10-34)
10) Methodology (how): Analyse C-DAS performance through comparison of ideal and real characterization of comms and positioning modules.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None
13) Physical: No
14) How to evaluate the demo: • Concept evaluation: Evaluation of C-DAS behaviour in different scenarios of communication and positioning conditions. • Design evaluation: What are the pros and cons of the demonstrated tools and in what ways should they be further enhanced.
15) Diagram with the interaction:

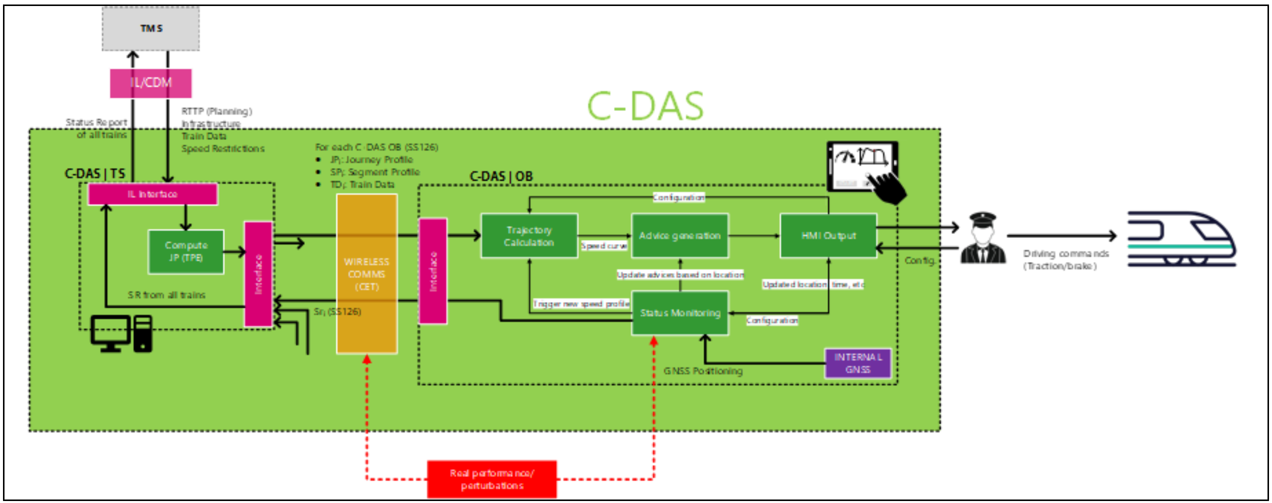


Table 42: Demo 13.3 (CEIT) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
13.4	**STS**	16	16.3	Performances comparison between C-DAS-C and C-DAS-O architectures (STS)	M40-M44	4/5	12, 15

Table 43: Demo 13.4 (STS) summary

Task 16.3- Performances comparison between C-DAS-C and C-DAS-O architectures (STS) - Demo 13.4
1) Given is: • Two different C-DAS architecture will be tested to compare their performances in term of energy efficiency. • C-DAS-C architecture: the C-DAS is at trackside, with no connection with the on board odometry. It can retrieve positioning and speed information of the train through the TMS with a dedicated module. • C-DAS-O architecture: the C-DAS is on-board and it can retrieve positioning and speed information of the train through a GPS.
2) Actors: • Integration Platform (IL/CDM) able to interface TMS with ATO-TS. • TMS (Timetable Simulator) able to manage and generate data useful to ATO/C-DAS for energy efficiency driving. • ATO-TS able to interface TMS with C-DAS on board and trackside. • C-DAS on board and C-DAS trackside able to use TMS data in order to drive the train in energy efficiency way.

• Driver/DMI able to apply energy efficiency driving strategy.
3) System: Demonstration of two C-DAS architecture, C-DAS-C (according to D15.1) and C-DAS-O (according to D15.1), and the comparison between their performances in terms of energy saving using algorithms from WP12. The innovation of the approach lies in comparing two architectures: • The C-DAS-C that calculates trackside train positions and therefore the energy saving profiles thus avoiding the integration with onboard odometry to collect train positions, thus limiting onboard installations to drastically reduce recurrent engineering costs. • The C-DAS-O that makes onboard all energy saving calculations thus requiring the onboard installation of a GPS sensor.
4) Goals: Compare the performances of two different C-DAS architectures to define pros and cons of each of them.
5) Forecast window: 3-4 hours.
6) Objectives: Development and test two C-DAS architectures to compare their performances in term of energy efficiency.
7) Inputs: Data exchanged between actors according to CDM data structures.
7) Outputs: Energy efficiency of the driving strategies of the two C-DAS architectures
8) Demo scenarios to be covered: Different conditions of traffic (under minor timetables disturbances and no timetables disturbances) for both the proposed architectures. (UC-FP1-WP10-40)
9) Methodology (how): Testing on real trains on Italian railways.
10) Interactions with other WPs: FP1/(WP12, Task 12.2.3), FP1/(WP10, Task 10.3) and FP1/(WP30, Tasks 30.4 and 30.5).
11) Interactions with other FPx or SP: None

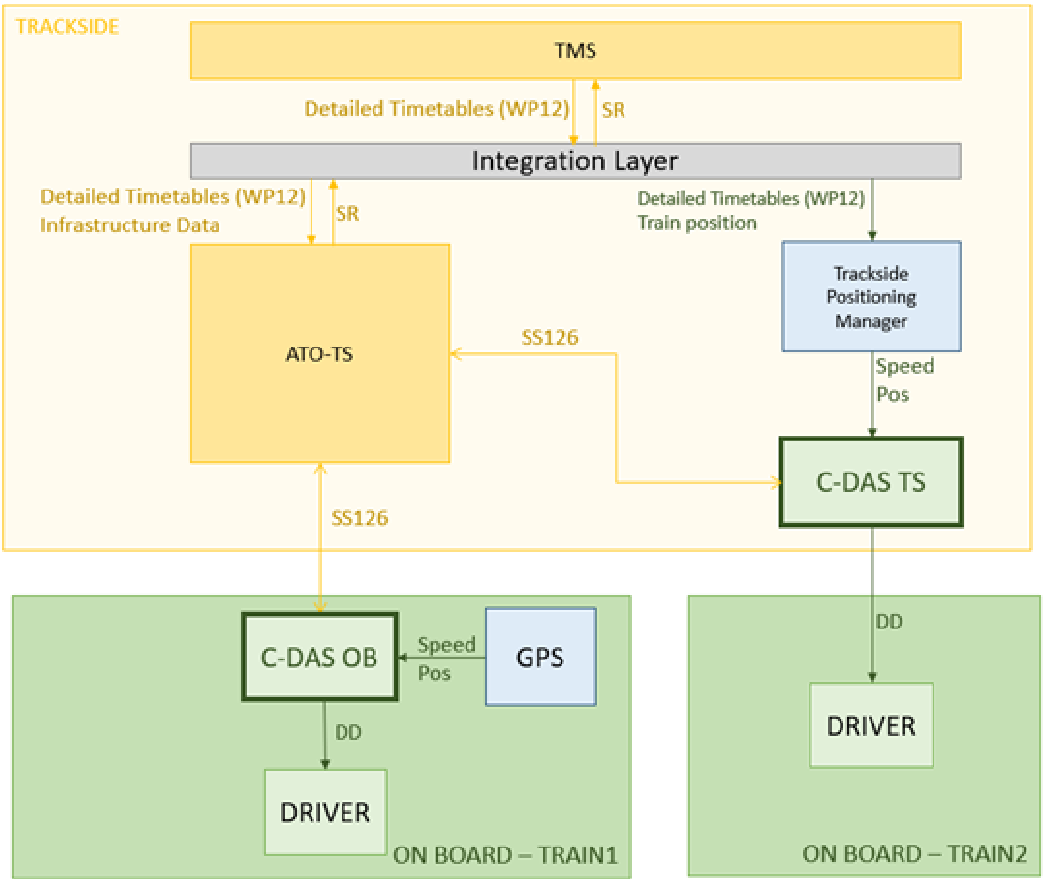
13) Physical: Yes.
14) How to evaluate the demo Comparison in term of energy efficiency of the driving strategies produced by the two C-DAS architectures.
15) Diagram with the interaction: 

Table 44: Demo 13.4 (STS) description

C) Demo 14 (Task 16.4)- Human-in-the-loop simulations test the ATO operational concept in emulated active practice and using tailor-made TMS/ ATO/C-DAS algorithm (PR, TRV, NSR, KB)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
14	**PR, TRV,** NSR, KB	16	16.4	Human-in-the-loop simulations test the ATO operational concept in	M40-M44	4/5	12, 15

				emulated active practice and using tailor-made TMS/ ATO/C-DAS algorithms.			

Table 45: Demo 14 (PR, TRV, NSR, KB) summary

Task 16.4- TMS – ATO human factors assessment (PR, TRV, NSR, KB)
1) Given is: • Operational Plan for a mainline railway with mixed passenger trains, • Corresponding infrastructure data and train data, • Scenarios for normal and disturbed conditions.

2) Actors:
• TMS: provides Operational Plan to ATO-TS.
• ATO-TS: provides and sends Journey Profile and Segment Profiles to ATO-OB of all connected trains, including Train Path Envelope according to Operational Plan.
• ATO-OB: provides train trajectory within Train Path Envelope and the corresponding traction and brake control commands.
• Train: follows commands from ATO-OB under supervision of ETCS.
• TMS/CTC Operator combined in one actor:
    o CTC System Operator: responsible for safe route setting both in normal and degraded conditions.
    o TMS Operator (local): responsible for a feasible route plan according to Operational Plan.
• TMS Operator (global): coordinates network traffic (or large traffic control area).
• Simulation leader: responsible for start/stop/pause simulation or introduction disturbances.
• Train driver: responsible for driving a train safe, punctual and economical (GoA1 and GoA2).

3) System: • Human-in-the-loop chain simulator environment including TMS-ATO functions and human roles in the traffic control centre (local TMS/CTC Operator, global TMS Operator) and train driver. • The TMS – ATO linkage provides each train with a Train path Envelope according to the Operational Plan from the TMS such that each train is able to operate conflict-free, energy-efficiently and respecting the targets at Timing Points from the Operational Plan. • The interface between the ATO-TS and the ATO-OB is included in the CCS TSI 2023, and the ATO-OB train trajectory generation and tracking algorithms are assumed available (or at least beyond the scope of the assessment).
4) Goals:

Test the TMS-ATO operational concept in emulated active (human-in-the-loop) practice and using tailor-made TMS/ATO algorithms.
5) Forecast window: None.
6) Objectives: Assessing human factors. In particular, the changed roles and interactions between the various operators with the increased automation.
7) Inputs: • Baseline data: operational plan, microscopic infrastructure model, train characteristics. • Pre-experimental (individual) and experimental (Team) scenarios. • Human factors metrics from a technological point of view. • Team human factors metrics that measure the interaction between train drivers and traffic controllers/operators.
8) Outputs: Human factors assessment of all human actors with TMS, ATO-TS and ATO-OB functions.
9) Demo scenarios to be covered: • Low-density traffic with large buffer times between trains (focus on punctuality and energy efficiency; no issues with conflicting TPEs). • Hight-density traffic with short headway times between trains such that unconstrained driving strategies may deviate from the assumed train behaviour in the TMS and generate train path conflicts during journeys between scheduled stops (focus on conflict-free TPE generation with optimal Timing Points). (UC-FP1-WP10-30, UC-FP1-WP10-31, UC-FP1-WP10-32)
10) Methodology (how): Human-in-the-loop chain simulator capable of simulating real traffic situations with TMS-ATO operated trains and various actors. Evaluation of enhanced TMS-ATO functionality and human-in-the-loop metrics from a technological point of view (usability, accessibility etc.) and human point of view (cognitive workload, fatigue, attention etc.). Final metrics will be selected as part of task 15.4.2.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: FP2-R2DATO/ (WP32, task 32.2): This demo has a close interaction with FP2 Task 32.2 'DATO Operational assessment including HF', which will provide the test requirements, while this

demo delivers recommendations for TMS -ATO implementation, based on human factors research.

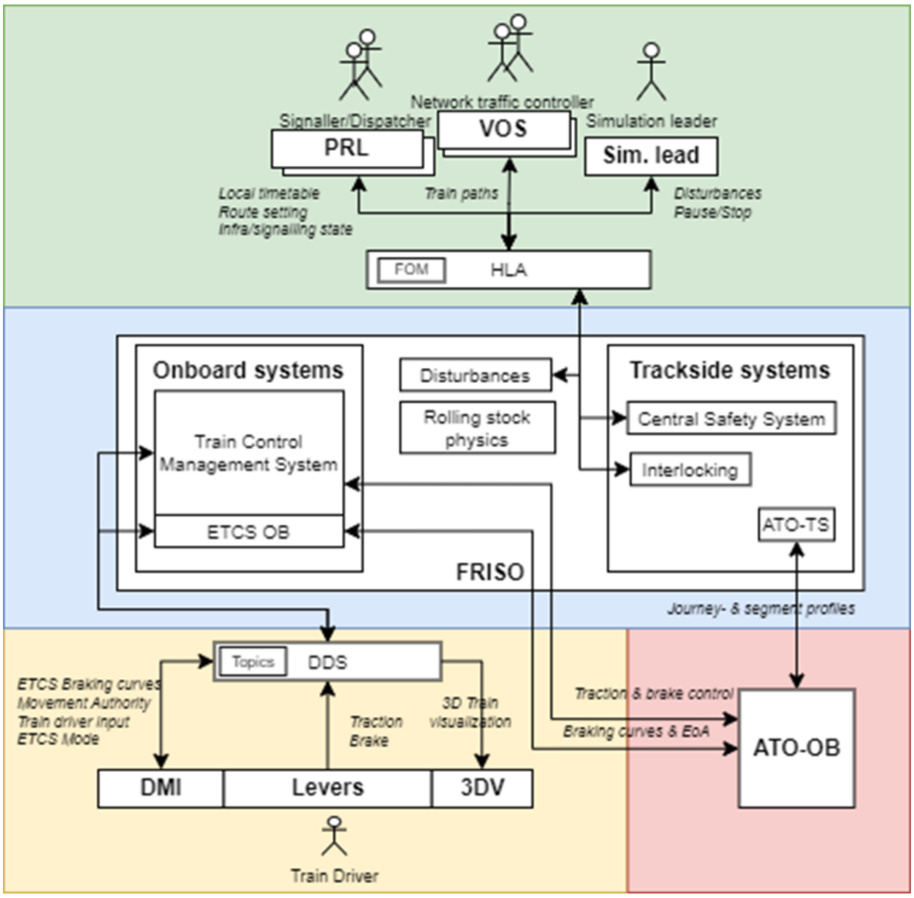
13) Physical:
Yes, Utrecht, the Netherlands.

14) How to evaluate the demo
Human factors measurement tools, such as:

- Questionnaire,
- (Video) observation,
- Debriefing,
- Simulation data.

Final tools will be determined as part of task 15.4.2.

15) Diagram with the interaction:



PRL: Dutch TMS, VOS: Dutch traffic control system, HLA: High-Level Architecture, DDS: Data Distribution Service, FRISO: Dutch microscopic railway simulation tool

Table 46: Demo 14 (PR, TRV, NSR, KB) description

D) Demo 15 (Task 16.5)- ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based on FP2&System Pillar specifications (AZD, PR, ADIF, CAF, STS)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
15	AZD, PR, ADIF, CAF, STS	16	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based on FP2&System Pillar specifications regarding ATO / TMS to support the autonomous train operations. Also, testing and demonstrating results the modelling for future operation of traffic regulation strategies (Operational Concept) for improved global behaviour of the traffic under minor timetable disturbances (delays and unfulfilled headways), based on different criteria and taking into account the global situations of the line through TMS – ATO interaction.	M40-M44	4/5	15

Table 47: Demo 15 (AZD, PR, ADIF, CAF, STS) summary

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
15.1	AZD, PR, STS	16	16.5	ATO – TMS integration platform developed in subtask 15.4.4, implementing possible new requirements and architecture based on FA2&System Pillar specifications regarding ATO / TMS to support the autonomous train operations.	M40-M44	4/5	15

Table 48: Demo 15.1 (AZD, PR, STS) summary

Task 16.5- ATO-TMS integration (AZD, STS, PR) - Demo 15.1
1) Given is: • Data exchanged between actors according to CDM data structures,

• To allow the integration between TMS with ATO/C-DAS Task 15.4.4 will make available a demonstrational platform, based on the Integration Layer (IL) to guarantee data transfer between all the technologies/subsystems involved in WP15, • Necessary to collect data and interfaces requirements for all the technologies/subsystems that will be connected to the platform, • The IL designed and developed, starting from the data structure CDM.
2) Actors: • Integration Platform (IL/CDM), able to interface TMS with ATO-TS, • TMS, able to manage and generate data useful to ATO/C-DAS, • ATO-TS, able to interface TMS with ATO/C-DAS OB, • C-DAS/ATO-OB, able to use TMS data in order to drive the train following the timetable (Journey Profile) and line description (Segment Profile), • Driver/ATO, able to operate the train.
3) System: The aim of this prototype is to demonstrate a platform able to interface TMS – ATO-TS in order to provide an automated environment for smooth train operations using ATO/C-DAS. The purpose of this demonstration is to prove a function of given framework between TMS subsystem and ATO-TS developed in Subtask 15.4.4. supporting autonomous train operations. In detail, the TMS subsystems will generate timetable and train path data able to provide Journey Profile (JP) and Segment Profile (SP) data useful to the ATO-TS subsystem for JP-SP packet generation to be sent to the ATO/C-DAS OB. This ATO/C-DAS OB will use JP-SP data to drive the train to achieve the planned timetable, including energy usage optimalisation, if the timetable circumstances allow.
4) Goals: Demonstrate a function of an Integration Platform to interface TMS and ATO/C-DAS.
5) Forecast window: 3-4 hours.
6) Objectives: Seamless data exchange between TMS and ATO/C-DAS for different subsystems involved in automatic train operation, including energy saving driving strategy.
7) Inputs: Data exchanged between actors according to CDM data structures.
7) Outputs: Data exchanged between actors according to CDM data structures.

8) Demo scenarios to be covered:
Traffic under minor timetable disturbances (delays and unfulfilled headways), based on different criteria and taking into account the global situations of the line through TMS – ATO interaction.

(UC-FP1-WP10-39)

9) Methodology (how):
Scenario preparation for an integrated system (integration platform) between ATO-TMS in order to improve traffic condition based on interaction with ATO-TMS. Evaluate integration platform performance.

10) Interactions with other WPs:
FP1/(WP12, Task 12.2.3), FP1/(WP15, Task 15.4.4), FP1/(WP30, Tasks 30.4, 30.5).

11) Interactions with other FPx or SP:
FP2- R2DATO, FP6-FUTURE.

13) Physical: Yes.

14) How to evaluate the demo

- Monitor and log the interlocking status and its changes according to dispatcher's (or automated TMS subsystem's) input,
- Monitor the involved train operation (movement) based on current train path and schedule and its changes,
- Using network capture software,
- Collect data (packets) exchanged between TMS and Integration Platform, Integration Platform and ATO-TS, ATO-TS and ATO-OB,
- Present the data contents in a visually readable format.

15) Diagram with the interaction:

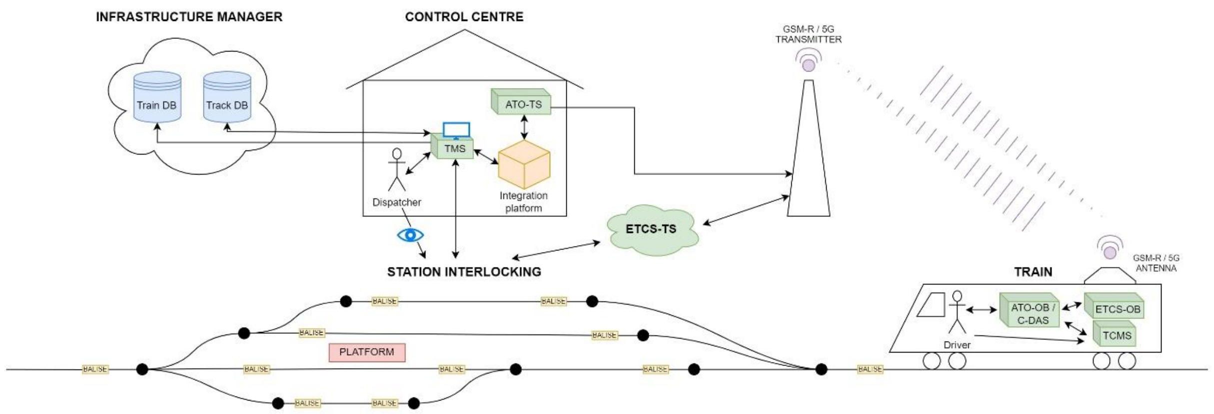


Table 49: Demo 15.1 (AZD, PR, STS) description

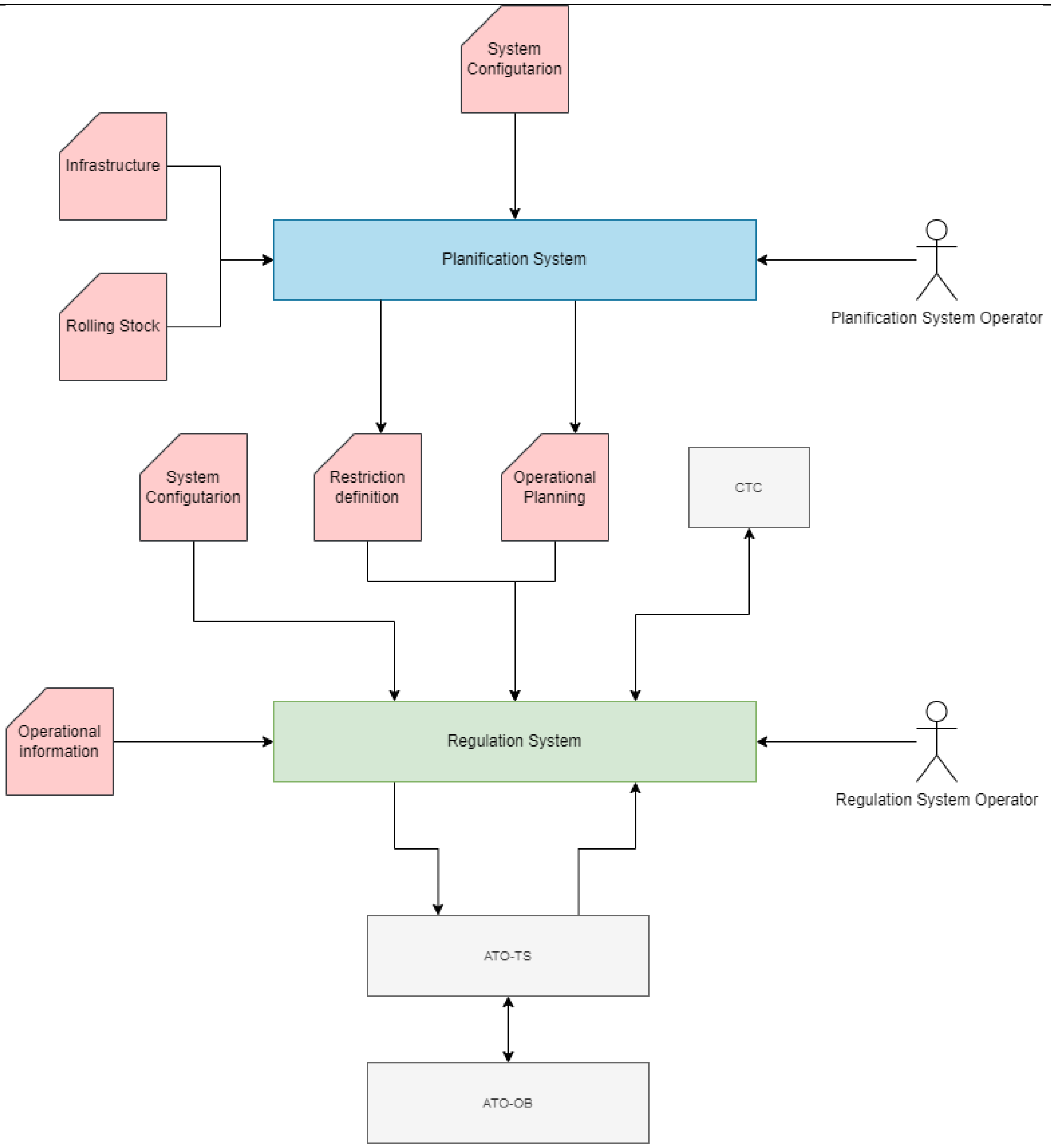
Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
15.2	**CAF, ADIF (reviewer)**	16	16.5	Testing and demonstrating the modelling for future operation of traffic regulation strategies (Operational Concept) for improved global behaviour of the traffic under minor timetable disturbances (delays and unfulfilled headways), based on different criteria and taking into account the global situations of the line through TMS – ATO interaction.	M40-M44	4/5	15

Table 50: Demo 15.2 (CAF, ADIF (reviewer)) summary

Task 16.5 - Testing and demonstrating the modelling for future operation of traffic regulation strategies (Operational Concept) for improved global behaviour of the traffic under minor timetable disturbances (delays and unfulfilled headways), based on different criteria and taking into account the global situations of the line through TMS – ATO interaction. (CAF, ADIF (reviewer)) - Demo 15.2
1) Given is: • Rail traffic regulation in presence of slight disturbances between 1% and 5% of the planning. • Data used in field "Inputs".
2) Actors: • TMS Regulation System, • TMS Operator, • ATO-OB, • RBC, • Track elements, • ATO-TS
3) System: As benefit, it is expected an automatic regulation without the need for operator intervention, optimizing multiple operational situations such as: arrival times, departure times, time spent on the route, stopping times, return times… If the variables mentioned above are not being met, they will be modified by the regulation system to adapt to the planning. In addition to the above-mentioned inputs, concepts such as flow of people, historical estimates,

destinations, which are used by the algorithmic processes for the calculation of optimal times, are also considered. If the times obtained from algorithmic and/or real-time data are not within an acceptable range, the control system will generate a warning for replanning.
4) Goals: • With a given planning, the regulation system has to be able to enforce it to the railway traffic by solving the possible evidence that may arise. • The regulation system is responsible for giving a solution in front of situations that can affect the optimal functioning of a line in front of the planned route, as can be time-travel and stop and other eventualities. • To this end, it regulates and ensures that delays are minimized, energy consumption is optimized, etc.
5) Forecast window: It will vary depending on the regulatory strategy to be applied.
6) Objectives: This regulator will have a special feature, which is the ability to regulate by timetable and headway in a mixed way. It will be necessary to consider either the time of day that it is or the space through which the truck runs. If we look at what time of the day it is, it will be assessed whether it is a rush hour or an off-peak hour. If it is a rush hour, it will be regulated by headway, while if it is an off-peak hour, it will be regulated by timetable. If we assess the space through which the track runs, we will have to consider whether it is an area of branches or an urban core. In this case, in the first situation, the regulation would be done by timetable, while in the second situation it would be done by headway. All these small disturbances that arise while the trains are running will be solved thanks to an algorithm that will be able to analyse the disturbances that are occurring and carry out the traffic regulation to recover the planning. To carry out this demonstration, an integration of our TMS solution with our emulated ATO will be performed in a laboratory environment. Through our algorithm we will be able to generate and send from TMS new Operational Plans to the ATO-TS and then from here new JPs (if they are necessary) will be send to our ATO-OB when a situation has changed. In the opposite direction, our ATO-OB will send the SR (inside it we will include the train position and the timing points estimation) to the ATO-TS and the TMS will be informed and will check if the disturbance between the nominal time and the reported one are fulfilled. If it is not fulfilled, a new regulation is done, and the new JPs will be sent.
7) Inputs: • Current status (e.g., position of the trains), • Run trains (travel time) that the planning shows us,

• Planning, • Regulation data (system configuration specified by the customer for those variables that can define their value), • Field element data.
8) Outputs: KPIs of status of activities and adjustment to plan and if not recoverable should be replanned.
9) Demo scenarios to be covered: • Regulation by time and space, • Regulation at the border between urban areas and branch lines. (UC-FP1-WP10-36, UC-FP1-WP10-37, UC-FP1-WP10-38)
10) Methodology (how): Testing of multiple use cases and test cases in the lab.
11) Interactions with other WPs: FP1-(WP8).
12) Interactions with other FPx or SP: FP6-FUTURE/(WP8).
13) Physical: No in this 1st call, only laboratory demonstration.
14) How to evaluate the demo Check that the use cases are satisfactorily fulfilled.
15) Diagram with the interaction:



In the following diagram, it is shown with more detail, which are the topics covered by this demonstration in WP15.

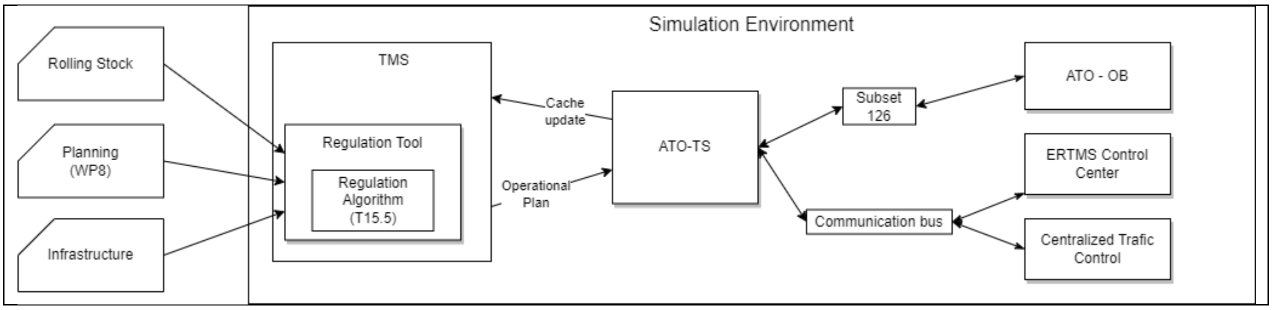


Table 51: Demo 15.2 (CAF, ADIF (reviewer)) description

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
15.3	**MERMEC**	16	16.5	Improvement of traffic forecast and operational plan update through TMS and ATO-TS integration	M40-M44	4/5	12

Table 52: Demo 15.3 (MERMEC) summary

Task 16.5 - Improvement of traffic forecast and operational plan update through TMS and ATO-TS integration (MERMEC) - Demo 15.3
1) Given is: • Baseline data: capacity plan, track topology. • ATO-TS functionality. • TMS Forecast and Conflict Detection and Resolution functionalities.
2) Actors: • TMS Operator, • CCS/ATO-TS simulator • TMS   o Components: TMS Event Logger, Deviation Detection module, TMS Forecast Calculation module, TMS Conflict Detection module, TMS Conflicts Resolution module, TMS Operational Plan, TMS User Interface.
3) System: This demonstrator provides an improved and realistic forecasting to the TMS Operator and updated Operational plan (RTTP) thorough the integration with the ATO-TS. The system is composed by a simulation environment with a CCS/ATO-TS and a TMS User Interface (e.g. Train Graph).
4) Goals: Improving forecasting calculation by using ATO-TS feedback (Status Report) and updating RTTP to be exchanged with ATO-TS.
5) Forecast window: 3-4 hours.

6) Objectives: • Improving Forecasting, • Updating RTTP, • Improving Conflict Detection.
7) Inputs: • Baseline data: ○ Capacity plan, track topology.
8) Outputs: Updated TMS RTTP and Operational Plan.
9) Demo scenarios to be covered: Operational Plan update through TMS and ATO-TS interaction. (UC-FP1-WP10-62)
10) Methodology (how): Comparing of forecast before and after ATO-TS integration.
11) Interactions with other WPs: FP1-(WP17/18).
12) Interactions with other FPx or SP: SP requirements.
13) Physical: No.
14) How to evaluate the demo By evaluating differences in train graphs views when the train is controlled by ATO or not.
15) Diagram with the interaction:

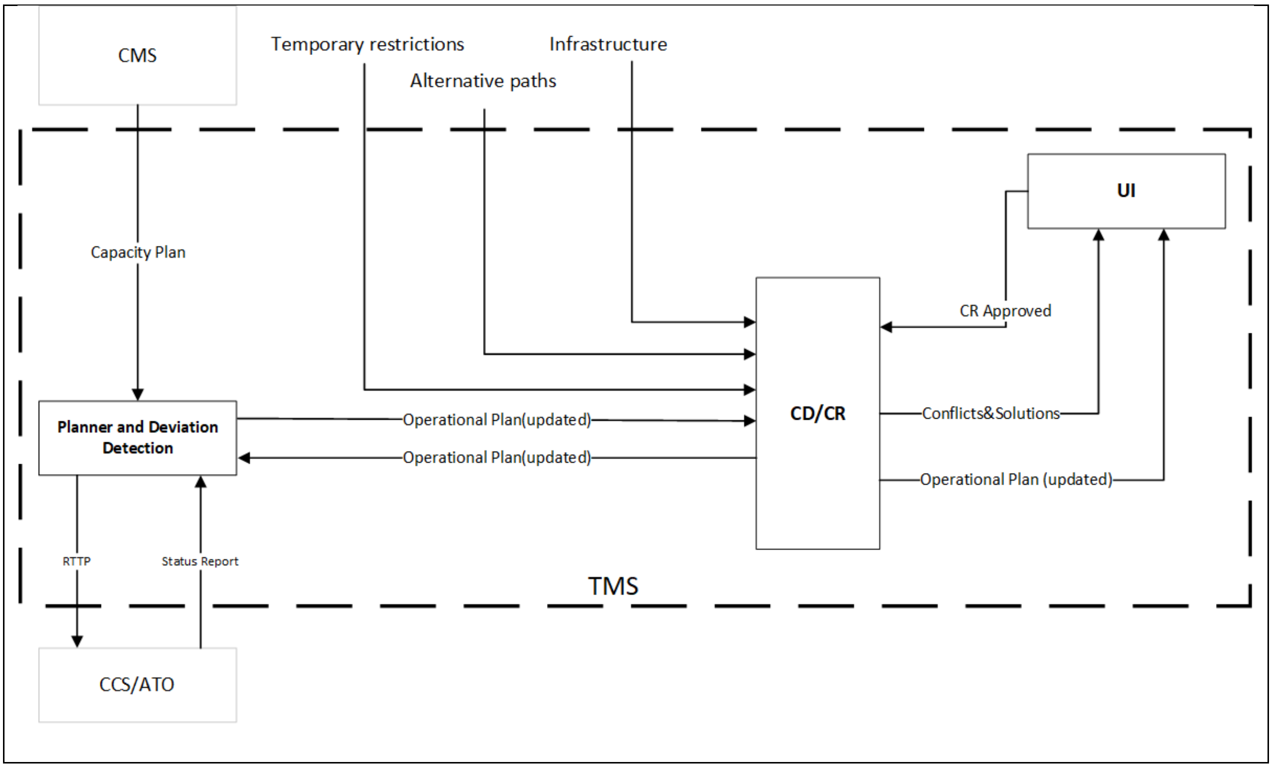


Table 53: Demo 15.3 (MERMEC) description

8.4. Descriptions of the demonstrations associated with WP17/18

The overall objectives of WP17 (development) and WP18 (demonstration) are linked to TEs 16 and 17. With the WP17/18 group it is pursued to specify the requirements and implement the algorithms providing decision support and whenever possible automatic decisions for traffic management optimisation as well as to verify their suitability for different applications.

It also provides the criteria for benchmarking of different implementations. The benchmarking will be performed individually by different implementations. A Platform will also be provided for benchmarking which can be used by different implementation on voluntarily basis.

A) Demo 16 (Task 18.2.1)- Demonstrator for Real-Time Conflict Identification & Resolution (ENYSE, ÖBB-INFRA, PR, NRD)

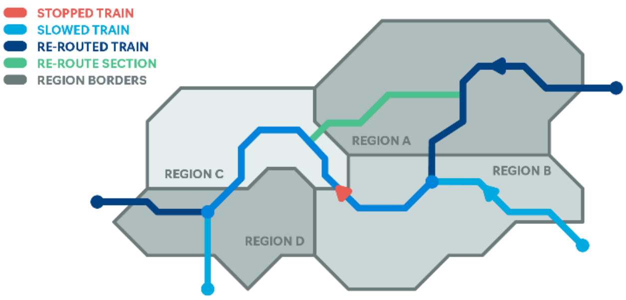
Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
16	ENYSE, ÖBB-INFRA, PR, NRD	18	18.2.1	Demonstrator for Real-Time Conflict Identification & Resolution.	M40-M46	5	17

Table 54: Demo 16 (ENYSE, OBB-INFRA, PR, NRD) summary

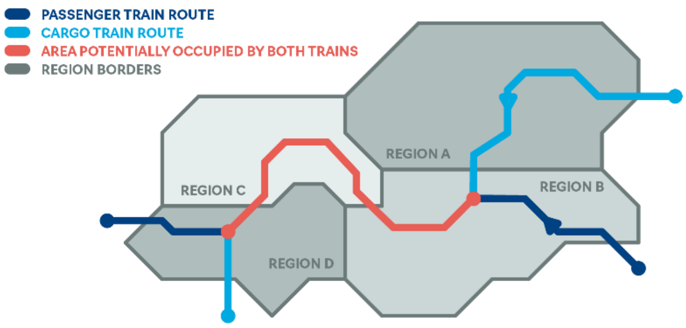
Task 18.2.1- Demonstrator for Real-time Conflict Identification & Resolution. (ENYSE, ÖBB-INFRA, PR, NRD)

1) Given is:

Scenario 1 (reactive): A train is on its way according to schedule. Due to an unforeseeable technical malfunction, it must stop and blocks the track. The conflict detection system detects the issue and notifies dispatchers. The conflict resolution system calculates the possible solutions, including slowing down trains in the near vicinity as well as large scale re-routing of other trains. The conflict resolution module ranks possible solutions by KPIs and presents them to the dispatchers, who select their preferred solution and start the appropriate countermeasures.



Scenario 2 (predictive): A passenger train and a freight train are on their way. Based on real-time data, the conflict detection system predicts that both trains would theoretically occupy the same track in 15 minutes and notifies dispatchers. The conflict resolution system calculates the possible solutions, including slowing down the cargo train and platform changes of other trains. The conflict resolution module ranks possible solutions by KPIs and presents them to the dispatchers, who select their preferred solution and start the appropriate countermeasures.



2) Actors:

- Train,
- Regional Dispatchers A and B, traffic re-routing, instructions to affected trains,
- Regional Dispatcher C, conflict prevention, traffic re-routing, instructions to affected trains,
- Regional Dispatcher D, traffic re-routing, instructions to affected trains,
- Train Dispatcher (Regions A, B, C, D), coordination of traffic re-routing,

- Traffic Control Center: Conflict Detection System (CDS), which detects conflicts and notifies responsible dispatchers depending on the current circumstances,
- Event Logger, logs everything, input into and output from the CDS.

3) System:
The system detects conflicts from the current traffic situation (Conflict Identification Module) in the network and determines actions to resolve these (Conflict Resolution Module). This is possible through either real-time Simulation of the whole network or through Reinforcement Learning. The system should aid in preventing conflicts that can be mitigated by having enough knowledge about the current situation. This leads to conflicts being prevented before they happen or at least lower potential impacts after an unforeseen incident. The demonstration is limited in its effectiveness as the amount of data included in calculations (like the number of trains and their properties) is limited. Interfaces exist to following stakeholders: Dispatcher, Train, Event Logger, Customer Information Systems, RU Transport Controllers, Railyard Managers, Staffing and Rolling Stock Management.

4) Goals:
The overall goal is to have a system that detects conflicts from the current traffic situation in the network and determines actions to resolve these.

Important to differentiate between predictive system measures, such as weather-related measures, maintenance, constructions etc., and reactive system measures in case of unexpected conflicts, e.g., malfunction of a signal, accidents, track-damage etc.

The system presents each resolution-option in a clear and concise manner to ease the decision-making process of the dispatcher.

Depending on severity of a conflict (safety- and time-critical) the system provides a set of ranked solutions which may address different areas with focus on predefined Key Performance Indicators (e.g., speed of train, track-layout, train-schedules...).

5) Forecast window:
The default value of the forecast duration should be the scheduled time required to travel the longest train line in the restricted railway network but no longer than 6 hours in advance (maximum forecast). The prerequisite is to have a conflict-free network for the next 30 min calculated. In particular, conflicts should be detected 60 minutes in advance.

6) Objectives:
The aim of the system is to proactively prevent conflicts that can be anticipated with a sufficient understanding of the current situation. In this way, it is averted conflicts before they occur or, at least, minimize potential consequences following unforeseen incidents.

The system assesses conflict severity and, for critical or time-sensitive cases, offers carefully selected prioritized solutions.

Additionally, the system is designed to present each available resolution option in a transparent and concise manner, with the primary aim of simplifying and expediting the decision-making process for dispatchers responsible for network operations. This ensures that critical decisions can be made promptly and with a high degree of confidence. Furthermore, the solution should always aim to meet predefined key performance indicators, considering the specific nature of the conflict. Besides those already mentioned under item 4, this could be cost efficiency, operational resilience, emergency response time.
7) Inputs: As many data sources as possible – real-time as well as historical data. This could be real-time train positions and mechanical conditions of trains, Operational Plans, infrastructure constraints, weather data and weather forecast, etc.
8) Outputs: Depending on severity of a conflict (safety- and time-critical) the system provides a set of at least 3 ranked solutions which may address different areas with focus on predefined KPIs (e.g., speed of train, track-layout, train-schedules). They are presented within a predetermined time window. This period is subject to the conflict's nature (differentiate between predictive and reactive system measures). The data should be presented in a clear, structured, and concise format. Human-Centered Design principles will be applied, considering the needs and preferences of dispatchers when decision support is needed. Especially in an ad hoc conflict, it must be ensured that the dispatcher's cognitive load is at a minimum. Moreover, all relevant notifications in regard to a conflict are presented to dispatchers and TCC (outputs via API) as well as to all other stakeholders mentioned in 3) in real-time.
9) Demo scenarios to be covered: The scenarios explained in 1) should be covered (**Scenario 1 (reactive) and Scenario 2 (predictive)** (UC-FP1-WP10-41 to 44)
10) Methodology (how): For creating algorithms for structured conflict detection and resolution a sequence of procedural stages must be carried out: 1. Use cases & Scoping, 2. User Story, 3. Requirement Specification, 4. Human Machine Interface (HMI), 5. Technical Specification, 6. Algorithm Development, 7. Safety Assessment, 8. Infrastructure Requirements, 9. Creation of Deliverable.
11) Interactions with other WPs: None.

12) Interactions with other FPx or SP:
SP interaction, TE17 must conform to any specifications handed down by the SP. The results of WP17 feed back into the SP.

13) Physical:
No.

14) How to evaluate the demo
Testing the demonstration involves a systematic approach to assess its performance by using clearly defined evaluation metrics (KPIs), in this demo it will be: Detection time, Calculation time and Quality of Solution.

Additionally, it is necessary to establish benchmark criteria or thresholds for each of the a.m. metrics. Collect data on the actual detection time, calculation time, and the quality of solutions for the tested scenario. This data may include timestamps for detection and calculation and objective measures of solution quality.

Analyze Detection Time: Evaluate the conflict detection module´s performance in terms of detection time by comparing the recorded detection times against the predefined benchmark criteria. Identify scenarios where detection times exceed acceptable limits.

Analyze Calculation Time: Assess the calculation time for conflict resolution in an analogous manner, comparing actual calculation times against the established criteria. Analyze scenarios that exceed acceptable calculation times.

Quality of Solution Assessment: Evaluate the quality of solutions generated by the conflict resolution module. This assessment may involve comparing solutions against predefined standards, such as the ability to prioritize safety-critical conflicts or optimize train schedules.

Performance Optimization: Identify areas where the demonstration falls short in terms of detection time, calculation time, or solution quality. Consider optimizing algorithms, hardware, or software components to address these shortcomings.

User Feedback: Gather feedback from potential users, such as rail operators and dispatchers, who have interacted with the demonstration. Their input can provide valuable insights into the usability and effectiveness of the system.

Iterative Testing: Continuously test and refine the demonstration based on the results of initial testing and user feedback. Repeat the process iteratively to improve performance.

Reporting: Creation of comprehensive reports summarizing the results of the evaluation, including any areas that need improvement and the steps taken to address them.

Validation and Validation Testing: Once the demonstration meets or exceeds benchmark criteria for detection time, calculation time, and solution quality, perform validation testing in a controlled environment to confirm its effectiveness.

15) Diagram with the interaction:

Following diagram demonstrates the communication paths (without considering specific timelines).

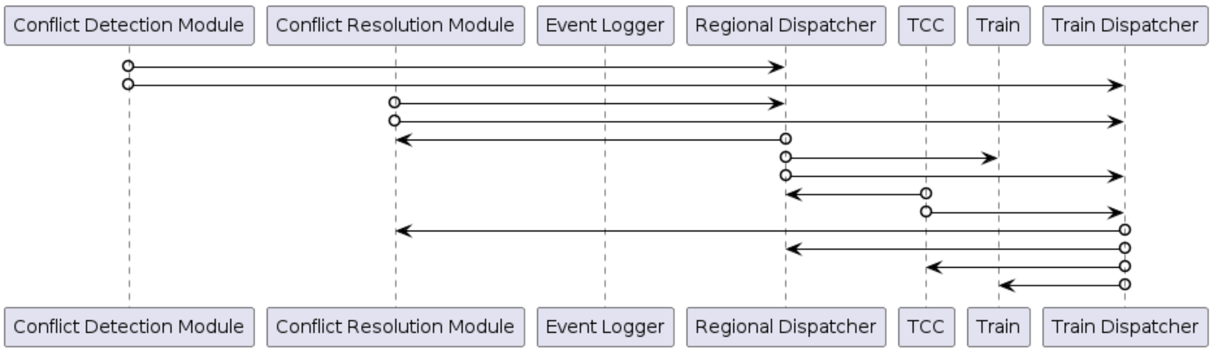


Table 55: Demo 16 (ENYSE, OBB-INFRA, PR, NRD) description

B) Demo 17 (Task 18.2.2)- Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection and Resolution using AI (ENYSE)

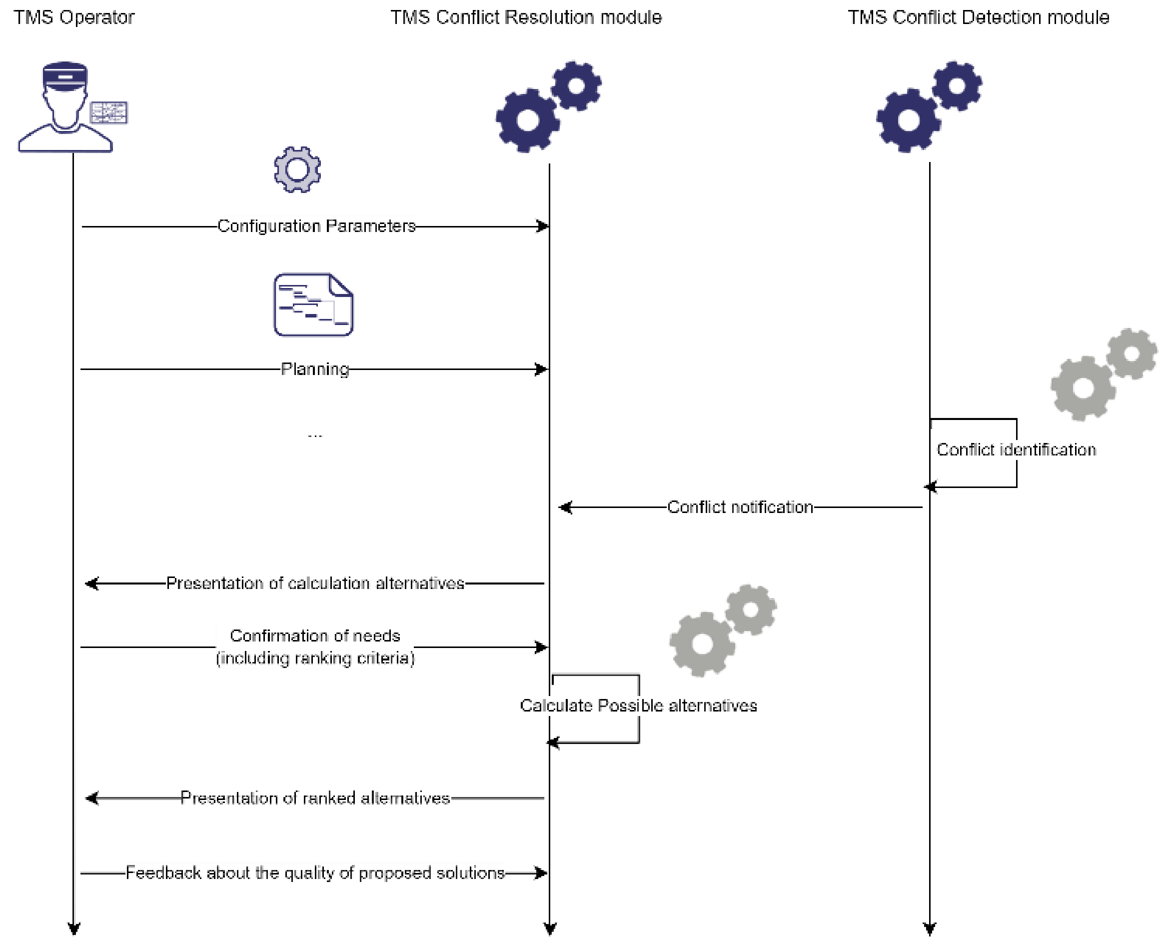
Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
17	ENYSE	18	18.2.2	Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection and Resolution using AI.	M40-M46	5	17, 10

Table 56: Demo 17 (ENYSE) summary

Task 18.2.2- Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection and Resolution using AI (ENYSE)
1) Given is: • Geographical data: fully detailed examples of depots and terminal stations, • Operational data: Operational Plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR).

• A train is about to enter/leave a depot or a terminal station area. Under those circumstances, conflict(s) is (are) detected and train cannot proceed further.
2) Actors: • TMS/TMS Operator,   ○ Components: TMS Conflict Identification module, TMS Conflict Resolution module.
3) System: The demonstration provides the technical basis for demonstrating conflict identification and resolution in a decision support system context based on AI for specific application in depots and terminal stations.
4) Goals: To test and demonstrate use cases in relation to TE17 regarding: • Conflict identification and resolution using AI, • Suitability of the solution applied to depots and terminal stations environment, • Possible application to regional lines (as per request for FP6).
5) Forecast window: Half a day (6-12 hours).
6) Objectives: • Improve decision making process in case of conflict when operating trains in depots and terminal stations, • Train and optimize AI algorithm for conflict resolution in depots and terminal Station environments.
7) Inputs: • Geographical data: fully detailed examples of depots and terminal stations, • Operational data: Operational Plan and microscopic infrastructure model including planned or operational maintenance restrictions (TCR).
8) Outputs: • AI algorithm for conflict detection, • User interface for providing data regarding the detected conflict, • User Interface for selecting different alternatives to resolve the conflict, • AI algorithm for conflict resolution, • User interface for providing feedback to train of the AI algorithm, • User interface to select the criteria for ranking different to the default configured one.
9) Demo scenarios to be covered: The following scenarios:

• Conflict detecting for a train entering Depot, • Conflict detecting for a train leaving Depot, • Conflict detecting for a train entering Terminal Station, • Conflict detecting for a train leaving Terminal Station, • Combined conflict types, • Complex conflict scenarios. (UC-FP1-WP10-45)
10) Methodology (how): • Scenario preparation for different conflict scenarios involving different types of conflicts, • Comparing optimization results with results based on manually conflict resolution or no resolution at all.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: FP6 – FUTURE (Application to Regional Lines).
13) Physical: No.
14) How to evaluate the demo • Conflict detection, • Successfully provide ranked alternatives, • Solutions found within the defined time frame.
15) Diagram with the interaction:



A conflict is detected when a train is about to enter/leave a depot or a terminal station, then

TMS Conflict Identification module detects conflict when a train is about to be introduced at the depot and triggers notification to TMS Operator ==> impact on the depot
TMS Conflict Identification module detects conflict when a train is about to leave the depot and triggers notification to TMS Operator ==> impact on main line
TMS Conflict Identification module detects conflict when a train is about arriving a terminal station and triggers notification to TMS Operator ==> impact on the terminal station
TMS Conflict Identification module detects conflict when a train is about leaving a terminal station and triggers notification to TMS Operator ==> impact on main line
2. The TMS Conflict Resolution module presents info about the conflict to the TMS Operator and propose different calculation alternatives based on user needs (including ranking criteria), then

3. The TMS Conflict Resolution module calculates possible solutions and presents them ranked (according to the defined criteria) to the TMS Operator, and then

4. The TMS Operator provides feedback about the quality of the proposed solutions (if any)

Table 57: Demo 17 (ENYSE) description

C) Demo 18 (Task 18.2.3)- Demonstrator for Improved Decision Support (HACON)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
18	HACON	18	18.2.3	Demonstrator for Improved Decision Support	M40-M46	5	17

Table 58: Demo 18 (HACON) summary

Task 18.2.3- Demonstrator for Improved Decision Support (HACON)
1) Given is: • An operational plan for a smaller national or regional scope with mixed freight and passenger trains and capacity restrictions, • A set of active Control Rules reflecting earlier control decisions, • A number of conflicts identified from the train running forecast calculation in a minor or major disruption situation.
2) Actors: • TMS, • TMS Operator (TC: Train/Traffic Controller using the TMS).
3) System: The demonstration provides the technical basis for demonstrating optimized conflict resolution in a decision support system context. The graphical user interface will feature Train Graphs, network views as well as train schedule details views.
4) Goals: To test and demonstrate use cases in relation to TE17 regarding: • Optimized conflict resolution, • Decision support using sand-boxes and What-if? scenario approach and, • Implementation of selected solution scenarios.
5) Forecast window: 3-4 hours.
6) Objectives: Optimize cost/benefit ratio of effective train operations resulting from implementation of optimized solution scenarios.
7) Inputs: Baseline data: operational plan and microscopic infrastructure model including planned or

operational maintenance restrictions (TCR).
8) Outputs: • Adjusted timetable suggested to planner in DSS subsystem (sand-box) for implementation, • Updated operational plan after implementation of optimized solution scenario, • Adjusted or new active Control Rules reflecting train control decisions incorporated in the solution scenario, • Optimized solution traffic management decisions (Control Rules) implemented, • Calculated forecast considering implemented decisions.
9) Demo scenarios to be covered: The following scenarios are covered: • Single train-train conflicts, • Single train-restriction conflicts, • Combined conflict types, • Complex conflict scenarios, • Establishment of decision-making results by means of Control Rules. (UC-FP1-WP10-46)
10) Methodology (how): • Scenario preparation for triggering different impact quality (conflict scenarios) involving different types of conflicts, • Comparing optimization results with results based on manually conflict resolution or no resolution at all, • Making use of fast and reliable heuristics or mathematical optimization, sand-boxes and what-if? scenarios.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None.
13) Physical: No. Cloud based demonstration.
14) How to evaluate the demo Successful test of the use cases and requirements related to the demo scope.
15) Diagram with the interaction:

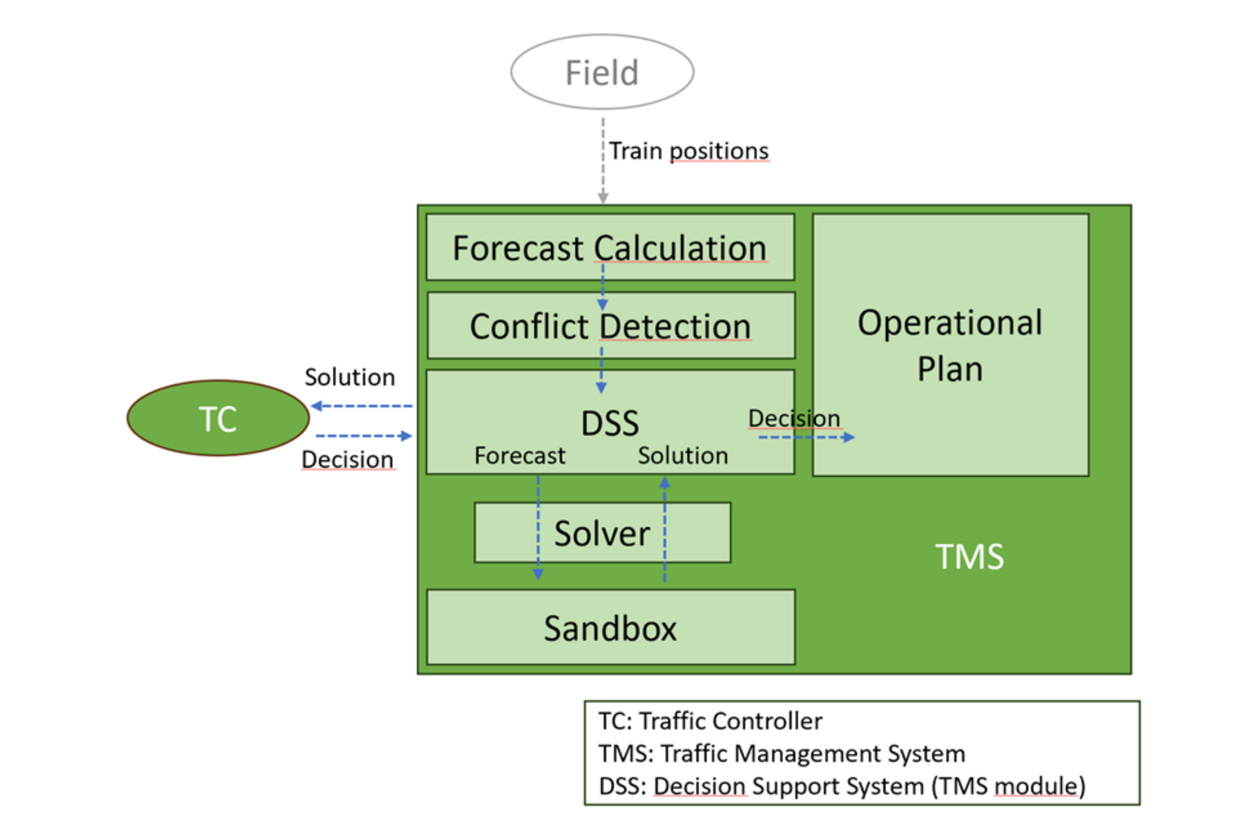


Table 59: Demo 18 (HACON) description

D) Demo 19 (Task 18.2.4)- Demonstrator for Advanced Automation of Real-time Operation (GTSD)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
19	GTSD	18	18.2.4	Demonstrator for Advanced Automation of Real-time Operation	M40-M46	5	16

Table 60: Demo 19 (GTSD) summary

Task 18.2.4- Demonstrator for Advanced Automation of Real-time Operation (GTSD)
1) Given is: • Optimized and conflict-free short-time operational plan from TMS. • Common data model (CDM) with TMS. • Detailed train capability and status from ETCS system. • Detailed field asset status from ETCS system.
2) Actors:

TMS Operator, user of the TMS providing the Operational Plan. Detection and resolution of conflict.
3) System: The system has to minimize impact of very short-term disturbances or deviations from Operational Plan. The algorithm is designed to avoid trains running into situations, where they are blocking other trains or driving in deadlock situation itself. This gives TMS Operator the possibility to implement measures for conflict resolution on a much less complex and time-consuming complexity of disturbed situation. Outcome is to minimize deviation from active Operational Plan. Main benefit is to reduce time for timetable recovery after short-term disturbances. Boundary of the system is TMS algorithm that delivers a conflict-free and optimized production plan and the interface SCI-CMD top vital APS.
4) Goals: Minimise impact caused by very short-term deviation/disturbances following Operational Plan.
5) Forecast window: 0 – few minutes where TMS Operator cannot make manual decisions.
6) Objectives: Develop an algorithm which is able to do automated decision, minimizing impact of deviations and disturbances during real-time operation. Demonstration shall show interoperability between TMS and APS enabling best possible execution of given operational plan.
7) Inputs: • Optimized and conflict-free short-time Operational Plan from TMS via SCI-OP interface. • Detailed train and asset status information via SCI-CMD interface.
8) Outputs: • MA request to APS with timing and extension via SCI-CMD. • Feedback Loop to TMS with information about granted/rejected MA as well as train and asset status via SCI-OP.
9) Demo scenarios to be covered: Demo covers use cases UC-FP1-WP10-47 to 50. Demo scenarios are: • Change the Operational Plan on short notice causing short-term deviations at the execution level. • Create various disturbances due to point and train failures. • Create various disturbances caused by delays. • Create disturbances by rejected MA request during real-time operation. • Show interaction with APS while implementing automated very short-term mitigation actions.

- Show TMS Operator interaction and possibility to reject automated decision proposed by algorithm.
- Show feedback loop to TMS algorithm.

10) Methodology (how):

Trainable AI real-time algorithm, based on a fixed relation of aspects to be considered for decision making.

11) Interactions with other WPs:

None.

12) Interactions with other FPx or SP:

FP2-R2DATO/(WP44/45), providing requests to Movement Authority approval, shortening and cancelation via SCI-CMD to APS demonstration FP2.

13) Physical:

No, designed for lab simulation within FP1.

FP2-R2DATO/WP45 demonstration is intended to use FP1/(WP17, task 17.2.5) prototype to perform physical field testing on DB test line in Erzgebirge Germany.

14) How to evaluate the demo

Demo will include a simulation environment to simulate real-time operation. User interface will allow to visualize Operational Plan conflicts and impact on a time distance graph. UI and various rest API's allow to implement disturbances. Operator notification will be visualized as well.

Evaluation will be done based on test cases executing automated interaction between TMS and APS

15) Diagram with the interaction:

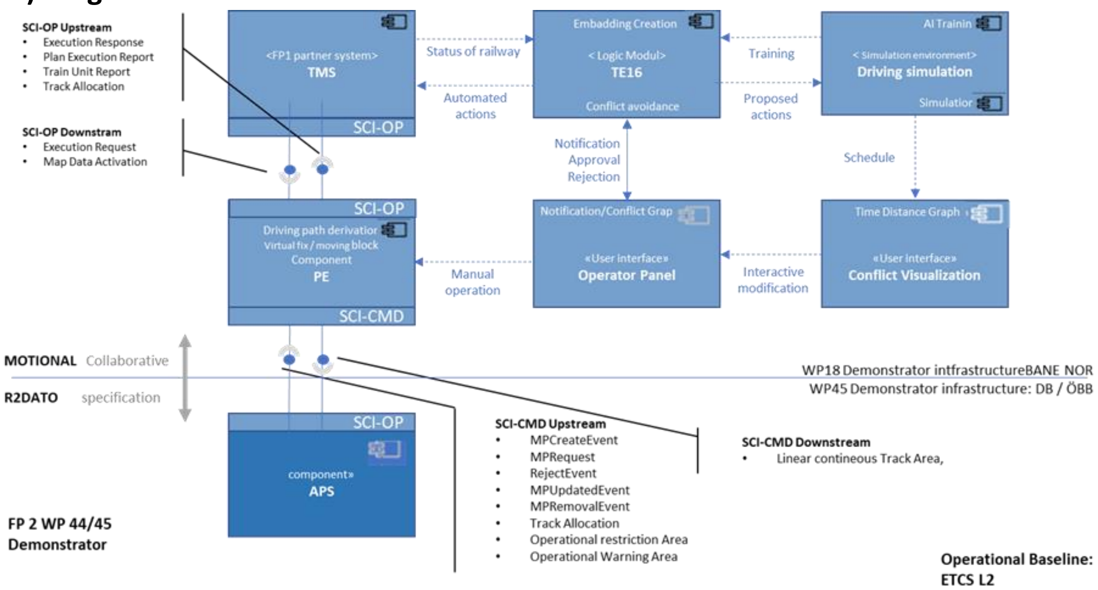


Table 61: Demo 19 (GTSD) description

E) Demo 20 (Task 18.2.5)- Demonstrator for Advanced Decision Support for Real-time Operation (STS)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
20	STS, FS	18	18.2.5	Demonstrator for Advanced Decision Support for Real-time Operation	M40-M46	5	17

Table 62: Demo 20 (STS, FS) summary

Task 18.2.5- Demonstrator for Advanced Decision Support for Real-time Operation (STS, FS)
1) Given is: • Operational production plan with a single- or multi-regional national scope with mixed freight and passenger trains. It includes capacity restrictions, train information, train deviations, and a set of constraints reflecting operator decisions, • Preliminary production plan modelling a resolution scenario with the same scope of the operational production plan, • Common Data Model (CDM) with TMS.
2) Actors: • TMS Operator, user of the TMS providing the Operational Plan.
3) System: The purpose of this demonstration is to provide decision support to TMS Operators, enabling them to effectively manage deviations from the planned timetables. The demonstration will achieve this by analysing the Operational Plan obtained from the TMS and performing conflict detection and resolution. Multiple optimized versions of the Operational Plan will be generated, each derived from the application of a pre-configured set of criteria. Through analysis and comparison of the different identified solutions, TMS Operators will be able to leverage the benefits of the What-if and Impact Analysis approaches.
4) Goals: • Conflict detection and resolution, • Conflict types covered: o Resource concurrency (between trains), o Capacity restrictions (between trains and resources).
5) Forecast window: 3-4 hours.
6) Objectives: Develop an algorithm for optimizing conflict detection and resolution. Provide multiple solution

scenarios modelling the mitigations for the deviations identified. Identification of the best solution scenario and its automatic activation will be explored.
7) Inputs: Operational production plan from TMS.
8) Outputs: (Optimized) Preliminary production plan(s).
9) Demo scenarios to be covered: Occurrence of a conflict which is detected and a new Operational is delivered. (UC-FP1-WP10-51), (UC-FP1-WP10-52), (UC-FP1-WP10-53)
10) Methodology (how): Heuristics or AI -based algorithms to be considered for both detection and resolution.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None.
13) Physical: No.
14) How to evaluate the demo: By KPIs. The evaluation will be based on the KPIs selected amongst those listed in both X2RAIL Deliverable D8.2 "Standardized and automated conflict handling solution", Section 10 and PRIME Platform of Railway Infrastructure Managers in Europe - "Key Performance Indicators for performance benchmarking", Version 3.1, 24th May 2019. The selection of the most adequate KPIs will be based on the joint work in ST17.2.6.
15) Diagram with the interaction:

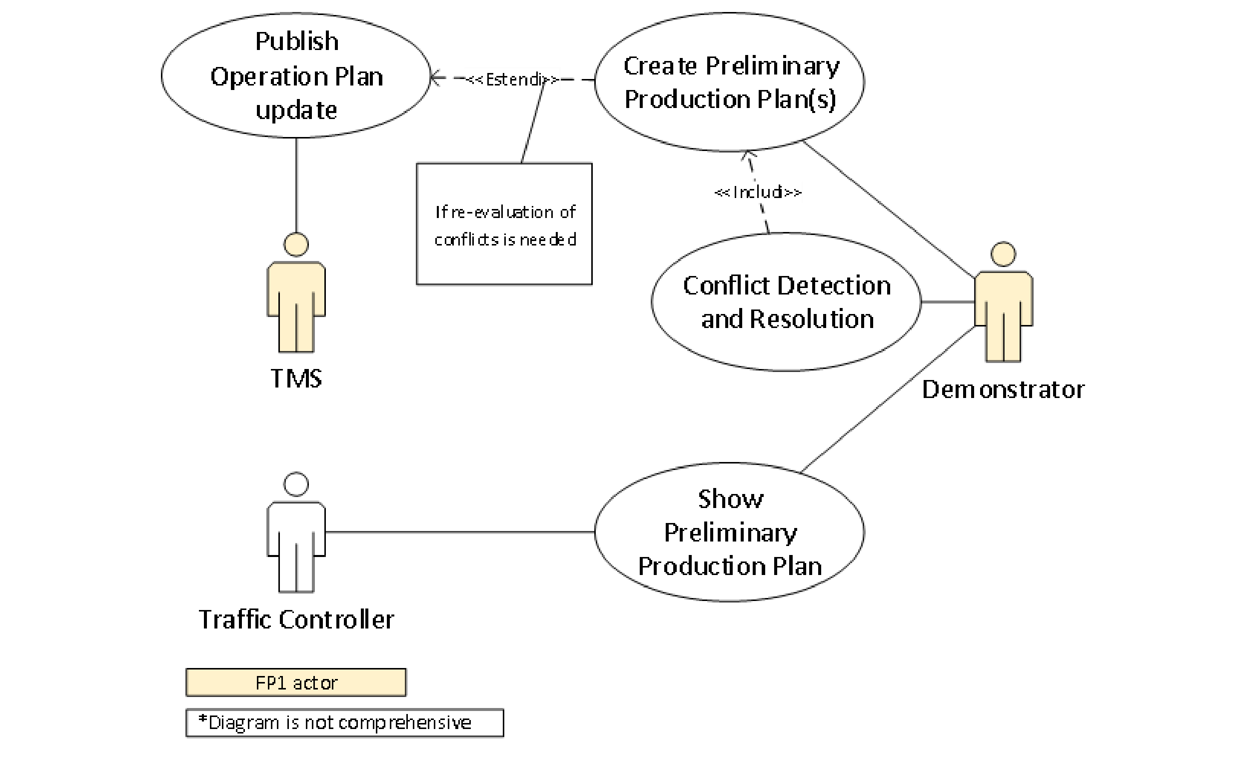


Table 63: Demo 20 (STS, FS) description

F) Demo 21 (Task 18.2.6)- Demonstrator for Advanced Conflict Decision Support and Route Setting (AZD)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
21	AZD	18	18.2.6	Demonstrator for Advanced Conflict Decision Support and Route Setting	M40-M46	5	16, 17

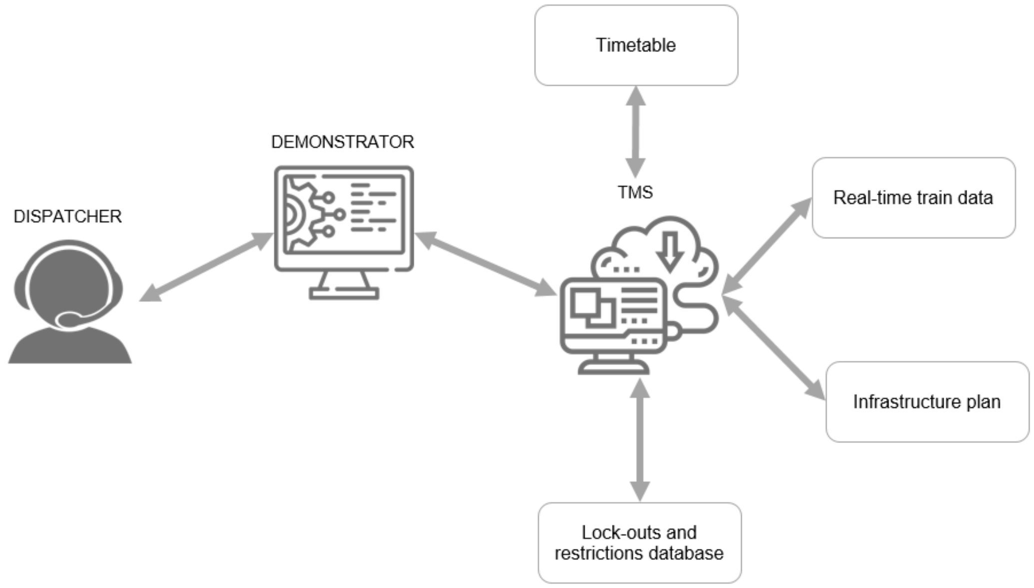
Table 64: Demo 21 (AZD) summary

Task 18.2.6 - Demonstrator for Advanced Conflict Decision Support and Route Setting (AZD)
1) Given is: • Chosen railway route or small regional control area controlled by the TMS, • Actual timetable for passenger trains and freight trains, • Timetable forecast at least 1 hour.
2) Actors: • Train dispatcher: Train dispatcher means from AZD point of view dispatcher managing line of track and operate several railway stations. Typically, dispatcher in CTC (Control Traffic Center). It is responsible for smooth trains operation in defined operation area. • Regional dispatcher: Regional dispatcher operates one separate railway station.

3) System: The main purpose of the system is to support automatic route setting decisions by detecting conflicts in a defined forecast time-window and proposing conflict-free solution(s) to resolve them. The system works in real-time operation and interacts with the TMS and with the systems of the IMs and RUs.
4) Goals: To optimize railway operation by providing decision support to TMS actors.
5) Forecast window: 0,5-2 hours.
6) Objectives: Demonstration, working in real-time with actual operation data, will include the graphical representation of the detect conflict/deadlock situation in the traffic management client application, including warning notice with situational context.
7) Inputs: • Train timetable, • Operational data from TMS, • Train information (passenger, freight, length, number of cars, etc), • Infrastructure information.
8) Outputs: • Automatic conflict resolution or warning notice if conflict is too complex, • Automatic route setting if ARS is available.
9) Demo scenarios to be covered: • Detect conflict automatically, • Apply algorithm for select optimal solution(s), • Inform dispatcher and provide list of scenarios, • Apply chosen scenarios (some types of conflict will be solved automatically in later version of demo). (UC-FP1-WP10-54 and UC-FP1-WP10-55).
10) Methodology (how): Suitable algorithms working in real-time and making a real-time operation.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None.
13) Physical: No – demonstration will be part of the TMS system.
14) How to evaluate the demo: By KPIs: • Detection time,

- Calculation time,
- Quality of solutions (evaluated by dispatchers),
- Conflict-freeness of solutions.

15) Diagram with the interactions:



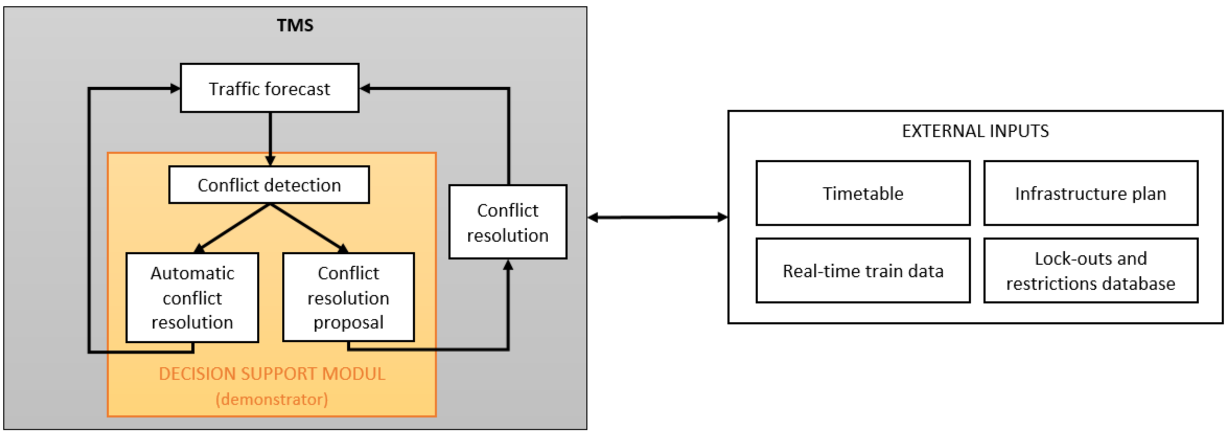


Table 65: Demo 21 (AZD) description

G) Demo 22 (Task 18.2.7)- Decision Support for improved traffic management operation (INDRA)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
22	INDRA	18	18.2.7	Decision Support for improved traffic management operation	M40-M46	5	17

Table 66: Demo 22 (INDRA) summary

Task 18.2.7- Decision support for improved traffic management operation (INDRA)
1) Given is: • An operational production plan including scheduled-target-forecasted timetables of involved trains. • Infrastructure topology elements. • Train characteristics (weight, max. speed, length...). • Scenarios for normal and disturbed conditions.
2) Actors: • TMS, Train Management System that includes the ACR (Automatic Conflict Resolution) and DSS (Decision Support System). • TMS Operator, Train/Traffic Controller using the TMS in charge of operating the system.
3) System: Two processes should be distinguished, automatic conflict detection and resolution, where the system automates the conflict resolution procedure within a specific and limited scope, without requesting confirmation from the user. • **Conflict detection** is the process in which the system is capable of identifying predicted conflicts in a geographically restricted railway network within a limited period of time. • **Conflict resolution** is the process by which the TMS Operator modifies the corresponding train circulations to prevent the conflict detected. The process builds a new feasible timetable compatible with the current status of the network, defining routes, and times for all circulating trains. Exploration of all techniques in the conflict resolution, which involves three phases, viability, assessment and application.
4) Goals: This task aims to detect conflicts and improve the Decision Support System by providing a What-if tool based on real-time operation disruptions.
5) Forecast window: 2-4 hours (configurable parameter).
6) Objectives: • For a conflict or number of conflicts or incidents, develop a system to automatically solve them, taken into account pre-defined parameters for the solution. • Release the TMS Operator from conflict resolution. • Solve conflicts faster.
7) Inputs: • Timetable of involved trains data.

• Production plan modelling a resolution scenario with the same scope of the operational production plan. • Topology elements and temporary entities of the infrastructure. • Incidents in the infrastructure (possessions, isolations, station closure).
8) Outputs: • Scheduled-target-forecasted timetables of involved trains without conflicts, • Replanning of circulations involved in those conflicts.
9) Demo scenarios to be covered: • Computational load management, • What - if scenarios through a sandbox. (UC-FP1-WP10-56, UC-FP1-WP10-57)
10) Methodology (how): By operating within a specific time period (temporal range), the system generates a disturbance (TMS, possession). It proceeds with the detection of all existing conflicts in the specified window and actively explores potential solutions for imminent conflicts. Through an evaluation process, it carefully assesses these possible solutions, considering various parameters and leveraging knowledge of the network to choose the most optimal option. The system then executes an automatic conflict resolution, providing a new timetable. As an alternative approach, there is the option to apply the conflict resolution within a controlled environment, the sandbox. The next step involves checking the effect of the resolution on all train paths, considering factors such as the number of newly generated conflicts and any resulting delays. To bring about a comprehensive solution, the system employs a replanning strategy, with the establishment of a refined and adjusted timetable.
11) Interactions with other WPs: FP1/ (WP6, WP7), compare results (applicability of the methods) solving conflicts strategies and algorithms in planificat6ion (WP6/WP7) and regulation (WP17/W18).
12) Interactions with other FPx or SP: No
13) Physical: No. It is tested in a simulation environment.
14) How to evaluate the demo: • Detection of all possible existing conflicts, • Compare the initial schedule (with conflicts) with the final schedule (without conflicts).

15) Diagram with the interaction:

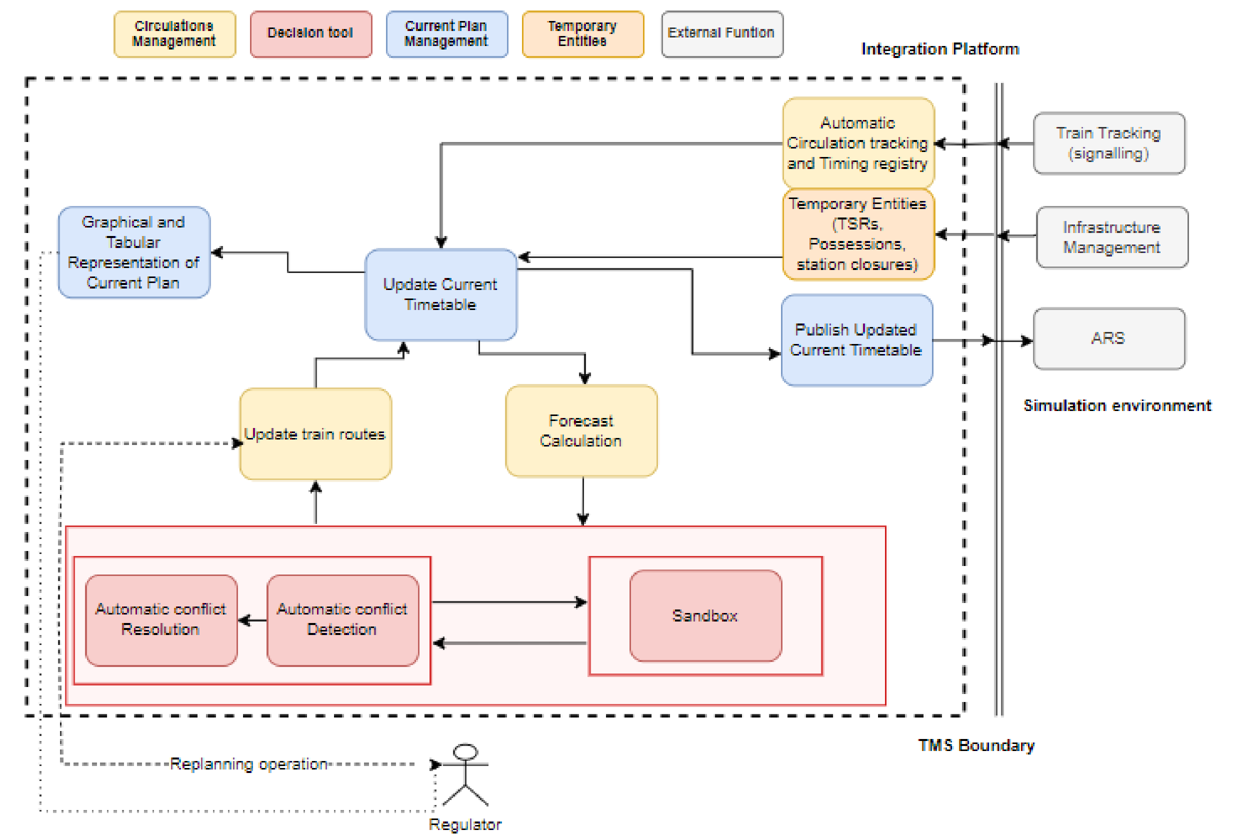


Table 67: Demo 22 (INDRA) description

H) Demo 23 (Task 18.2.8)- Demonstrator for Automation of Real-time Operation (MERMEC)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
23	MERMEC, FS	18	18.2.8	Demonstrator for Automation of Real-time Operation	M40-M46	5	16, 17

Table 68: Demo 23 (MERMEC. FS) summary

Task 18.2.8- Demonstrator for Automation of Real-time Operation (MERMEC and FS)
1) Given is: • Baseline data: capacity plan, track topology. • The TMS identifies as conflicts: ○ Allocation of a resource to more than one train run for the same period, ○ Allocation of a not appropriate resource to a train run,

◦ Allocation of an unavailable resource. • The TMS detects and should resolve the conflict. • In automatic mode, the TMS will evaluate multiple solutions and resolve the conflict without human intervention, • In semi-automatic mode, the TMS will propose multiple solutions and the TMS Operator will select one from these.
2) Actors: • TMS operator, user who is in charge of operating with the TMS system. • TMS: ◦ Components: TMS Event Logger (that logs the TMS activities), Deviation Detection module (that detects all the deviations), TMS Forecast Calculation module (that evaluates the forecast by using all the relevant inputs), TMS Conflict Detection module (that detects all the conflicts), TMS Conflicts Resolution module (that provides conflict solutions), TMS Operational Plan (that provides new operational plan evaluating the relevant inputs), TMS HMI (an user interface to show data).
3) System: The demonstration provides an advanced algorithm for real-time automatic conflict detection and resolution by using different data sources such as TMS Operational Plans and real-time status of railway. The TMS HMI is composed by tables and train graph.
4) Goals: Providing conflict detection after a train deviation and applying or suggesting conflict solution.
5) Forecast window: 3-4 hours.
6) Objectives: • Detect conflicts, • Provide more solutions to resolve a conflict based on algorithm chosen, • Provide an automatic solution.
7) Inputs: Baseline data: capacity plan, track topology.
8) Outputs: Updated or suggested TMS Operational Plan.
9) Demo scenarios to be covered: • Resource unavailable (disruption, …), • Resource concurrency. (UC-FP1-WP10-58 and UC-FP1-WP10-59)

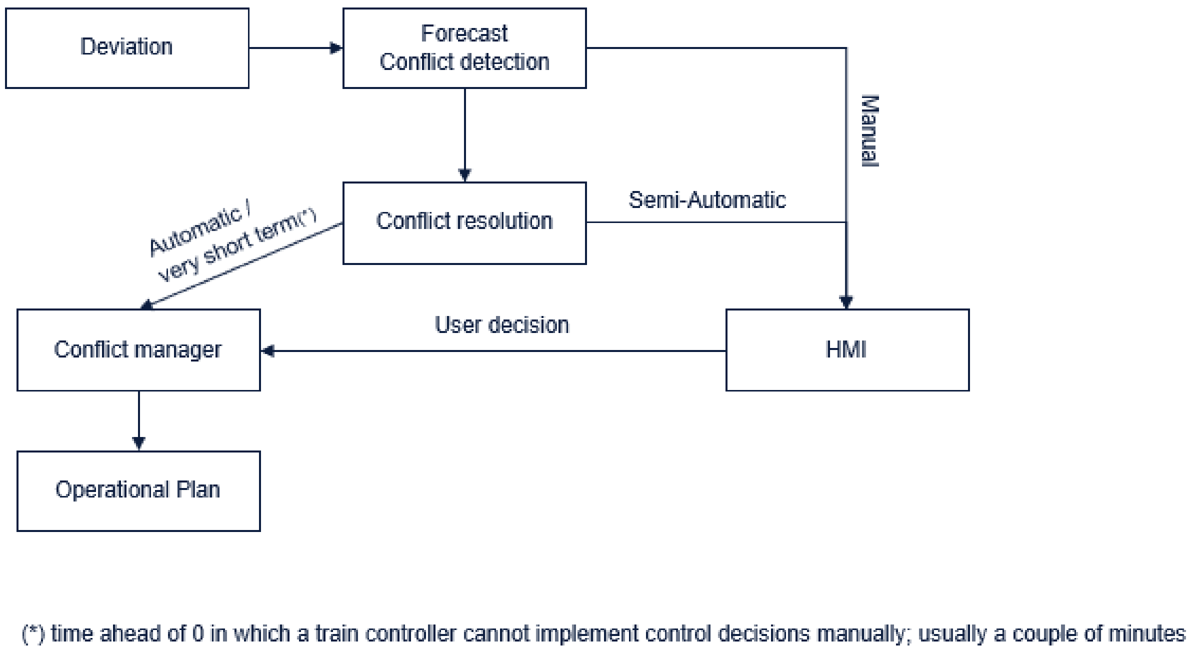
10) Methodology (how):
10) Methodology (how): New fast and reliable algorithm.
11) Interactions with other WPs: FP1/(WP11, WP12), the demo interacts with WP11/12 to exchange data such as the Operational Plan with the ATO, or the forecast with the neighbouring TMS for instance.
12) Interactions with other FPx or SP: SP requirements.
13) Physical: No.
14) How to evaluate the demo By testing of the use cases and checking the requirements related to the demo.
15) Diagram with the interaction: 

Table 69: Demo 23 (MERMEC. FS) description

I) Demo 24 (Task 18.3.1)- Simulation of real-time conflict identification and resolution (ÖBB-INFRA, PR, NSR, ENYSE, NRD)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
24	ÖBB-INFRA,	18	18.3.1	Simulation of real-time conflict	M40-M46	5	17

	PR, NSR, ENYSE, NRD			identification and resolution			

Table 70: Demo 24 (OBB-INFRA, PR, NSR, ENYSE, NRD) summary

Demo 24 is merged with Demo 16. Demo 16 is only a simulation tool, which for example injects conflicts to the algorithms. It is wanted to also use it as a preparation for the higher TRL demo in the next call. It is not a stand-alone Demo and actually part of Demo 16.

J) Demo 25 (Task 18.3.2)- Performance evaluation of optimisation algorithms for local level traffic management in a single region (SNCF)

Demonstrations for WS1.2							
No	**Beneficiaries**	**WP(s)**	**Task(s)**	**Description of Demonstration**	**Indicative Timeframe**	**TRL**	**TE**
25	SNCF	18	18.3.2	Performance evaluation of optimisation algorithms for local level traffic management in a single region	M40-M46	5	17

Table 71: Demo 25 (SNCF) summary

Task 18.3.2- Performance evaluation of optimisation algorithms for local level traffic management in a single region (SNCF)
1) Given is: • The optimization algorithm, • A microscopic simulator acting as the real-world environment, • Perturbation scenarios to be tested, • Infrastructure, rolling stock and timetable data.
2) Actors: • TMS,includes the ACR (Automatic Conflict Resolution) and DSS (Decision Support System). • IM, responsible for traffic management. • TMS Operator, Train/Traffic Controller using the TMS in charge of operating the system. • Disruption management, generic contingency plans for specific situations.
3) System: This demonstration is an assessment suite for real-time traffic management algorithms. It will consist of the use of a microscopic traffic simulator in connection with the optimization algorithms designed in Subtask 17.2.3 for a single control area. The simulator replaces reality to mimic in a laboratory environment the specifications of a real practical deployment. In particular, a closed-loop deployment is considered, in which optimization operates in the background, periodically optimizing traffic based on the prediction

of the state of operations in the near future in a whole control area. For example, every five minutes, the optimization algorithm receives a prediction of the operations state in the next hour, detects potential conflicts and resolves them as well as possible, taking three minutes to find the best solution. This solution is then implemented in the simulator as if it was reality, while the next optimization runs to resolve possibly unpredicted new conflicts. The problem dealt with is complex, including up to some dozens of trains in possibly large control areas, generating several of potential conflicts when perturbations occur. In the demonstration, no human interaction will be considered. However, a validation step can be included in the closed-loop deployment before the optimized decisions are implemented.
4) Goals: Develop algorithms for local TMS and evaluate them in order to underline strength and weaknesses.
5) Forecast window: 2 hours.
6) Objectives: • Develop optimization algorithms for real-time local TMS, • Test the algorithms on a microscopic simulator, • Evaluate and possibly improve the algorithms, • Have a final evaluation of qualities and limitations of TMS algorithms.
7) Inputs: Infrastructure, rolling Stock and timetable data, a perturbation scenario.
8) Outputs: TMS decisions and circulation replanning, algorithm evaluation.
9) Demo scenarios to be covered: Perturbation scenarios at local level on a single region. (UC-FP1-WP10-60 and UC-FP1-WP10-61)
10) Methodology (how): The optimization algorithm will run at periodic interval to optimize the current situation based on the information on theorical timetable and on predictions of the future situation. The operational decisions will be input to the microscopic simulator in order to implement them and evaluate the quality of the decisions.
11) Interactions with other WPs: None.
12) Interactions with other FPx or SP: None.

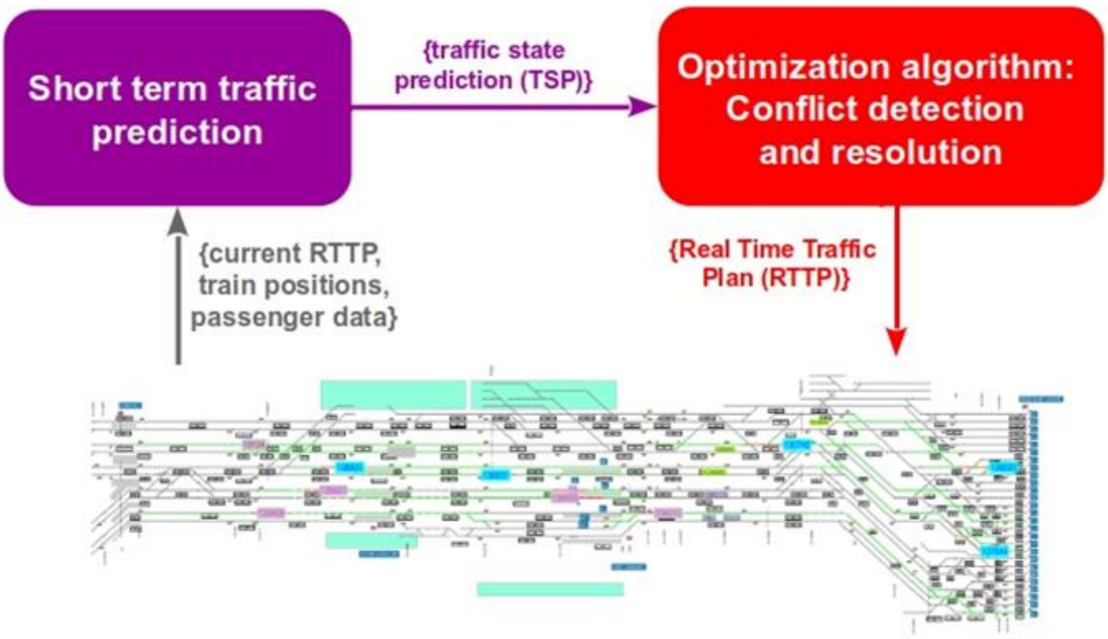
13) Physical: No.
14) How to evaluate the demo An evaluation module will be developed, giving information on the quality of the proposed solution for several standard perturbation scenarios.
15) Diagram with the interaction: 

Table 72: Demo 25 (SNCF) description

9. Mapping table demos – uses cases – TEs –HL requirements

As part of WP10, in particular in Task 10.1 and Task 10.2, the 3 main activities that were developed are the description of the technical enablers with the definition of the high-level requirements associated with them, the identification and definition of the use cases and finally the high-level specification of the demonstrations for WS1.2.

In the Table 73, Table 74, Table 75 and Table 76, the mapping of the demos and use cases is summarized with the TEs and their high-level requirements associated. There is a table per each WP group WP11/12, WP13/14, WP15/16 and WP17/18.

Demos WS1.2		Mapping demos-TE-HLR		Mapping use cases- TEs - HL req		
No	**Partner**	**TE**	**HL req**	**Use case ID**	**TE**	**HL req**
1	ATSA	8,10	8.1, 8.2, 10.2, 10.3	UC-FP1-WP10-01	8	8.1
				UC-FP1-WP10-02	8	8.1
				UC-FP1-WP10-03	8, 10	8.2, 10.2, 10.3
2	PKP	9	9.4	UC-FP1-WP10-04	9	9.4
3	STS	8	8.1	UC-FP1-WP10-05	8	8.1
4	INDRA	8	8.1	UC-FP1-WP10-06	8	8.1
5	MERMEC	8,9	8.5, 9.2, 9.4	UC-FP1-WP10-07	8,9	8.5, 9.2, 9.4
				UC-FP1-WP10-08	8,9	8.5, 9.2, 9.4
6	HACON	8,9	8.2, 8.3, 8.4, 8.5, 9.1, 9.2, 9.3, 9.4	UC-FP1-WP10-09 (ADIF)	8,9	8.5, 9.2, 9.4
				UC-FP1-WP10-10	8	8.2, 8.3, 8.4,
				UC-FP1-WP10-11	8,9	8.4, 8.5, 9.1, 9.2, 9.3, 9.4
7	HACON	10	10.1, 10.2, 10.3, 10.4	UC-FP1-WP10-12	10	10.1, 10.2, 10.3, 10.4
				UC-FP1-WP10-13 (ADIF)	10	10.1
				UC-FP1-WP10-14 (ADIF)	10	10.1
8	TRV	10	10.1	UC-FP1-WP10-15	10	10.1
				UC-FP1-WP10-16	10	10.1
9	CEIT	10	10.2	UC-FP1-WP10-17	10	10.2

Table 73: Mapping of demonstrations and use cases for WP11/12 with the TEs and HLRs

Demos WS1.2		Mapping demos-TE-HLR		Mapping use cases- TEs - HL req		
No	**Partner**	**TE**	**HL req**	**Use case ID**	**TE**	**HL req**
10.1 + 11	STS	11, 13, 14	11.2, 11.3, 13.1-13.11, 14.1-14.13	UC-FP1-WP10-19	11, 13, 14	11.2, 11.3, 13.1-13.11, 14.1-14.13
				UC-FP1-WP10-20	11, 14	11.2, 11.3, 14.1-14.13
				UC-FP1-WP10-21	11, 14	11.2, 11.3, 14.1- 14.13
				UC-FP1-WP10-22 (ADIF)	13,14	13.9, 14.1-14.7, 14.10
				UC-FP1-WP10-23 (ADIF)	13,14	13.9, 14.1-14.7, 14.10
10.1	TRV	11	11.1, 11.2, 11.3	UC-FP1-WP10-26	11	11.1-3
				UC-FP1-WP10-28	11	11.1-3
10.2	NSR	13, 14	13.4, 13.5, 13.6, 13.8-13.11, 14.1-14.4, 14.6-14.10	UC-FP1-WP10-24	13, 14	13.4-13.6, 13.8- 13.11, 14.1-14.4, 14.6-14.10
				UC-FP1-WP10-25	14	14.6-14.10
10.3	HACON	13, 14	13.1-13.2, 13.8, 13.11, 14.2-14.3, 14.7, 14.11, 14.13	UC-FP1-WP10-18	13,14	13.1-13.2, 13.8, 13.11, 14.2, 14.3, 14.7, 14.11, 14.13
11	TRV	11	11.1, 11.2, 11.3,	UC-FP1-WP10-26	11	11.1-3
				UC-FP1-WP10-28	11	11.1-3

Table 74: Mapping of demonstrations and use cases for WP13/14 with the TEs and HLRs

Demos SG2		Mapping demos-TE-HLR		Mapping Use cases- TEs - HL req		
No	**Partner**	**TE**	**HL req**	**Use case ID**	**TE**	**HL req**
12	PR, TRV, NSR, KB, ADIF, CAF	12, 15	12.1-12.2, 15.2-15.6	UC-FP1-WP10-30	15	15.2,15.4, 15.6
				UC-FP1-WP10-31	12, 15	12.1-12.2, 15.2,15.3, 15.4, 15.5
				UC-FP1-WP10-32	12, 15	12.2, 15.2,15.3, 15.4, 15.5,15.6
13.1	TRV, PR, NSR, STS	12, 15	12.1-12.2, 15.3	UC-FP1-WP10-35	12, 15	12.1-12.2, 15.3

13.2	INDRA	12, 15	12.1-12.2, 15.3, 15.7	UC-FP1-WP10-33	12, 15	12.1-12.2, 15.3, 15.7
13.3	CEIT	15	15.7	UC-FP1-WP10-34	15	15.7
13.4	STS	12, 15	12.2, 15.1, 15.6	UC-FP1-WP10-40	12, 15	12.2, 15.1, 15.6
14	PR, TRV, NSR, KB	12, 15	12.1-12.2, 15.2-15.6,	UC-FP1-WP10-30	15	15.2,15.4, 15.6
				UC-FP1-WP10-31	12, 15	12.1-12.2, 15.2,15.3, 15.4, 15.5
				UC-FP1-WP10-32	12, 15	12.2, 15.2,15.3, 15.4, 15.5,15.6
15.1	AZD, PR, STS	15	15.1	UC-FP1-WP10-39 (AZD)	15	15.1
15.2	CAF, ADIF	15	15.2,15.3, 15.4	UC-FP1-WP10-36 (CAF)	15	15.2, 15.3, 15.4
				UC-FP1-WP10-37 (CAF)	15	15.2, 15.3, 15.4
				UC-FP1-WP10-38 (CAF)	15	15.2, 15.3, 15.4
15.3	MERMEC	12	12.2	UC-FP1-WP10-62 (MERMEC)	12	12.2

Table 75: Mapping of demonstrations and use cases for WP15/16 with the TEs and HLRs

Demos WS1.2		Mapping demos-TE-HLR		Mapping use cases- TEs - HL req		
No	**Partner**	**TE**	**HL req**	**Use case ID**	**TE**	**HL req**
16-24	ENYSE, ÖBB-INFRA, PR, NRD, NSR	TE17	17.1, 17.2, 17.6	UC-FP1-WP10-41	17	17.1
				UC-FP1-WP10-42	17	17.6
				UC-FP1-WP10-43	17	17.2, 17.6
				UC-FP1-WP10-44	17	17.2, 17.6
17	ENYSE	17	17.1-17.7, 10.1	UC-FP1-WP10-45	17	17.1-17.7, 10.1
18	HACON	17	17.1, 17.2	UC-FP1-WP10-46	17	17.1, 17.2
19	GTSD	16	16.1, 16.2, 16 .3, 16.4, 16.5, 16.6	UC-FP1-WP10-47	16	16.1, 16.2, 16.4, 16.5, 16.6
				UC-FP1-WP10-48	16	16.1, 16.2, 16.4, 16.5, 16.6
				UC-FP1-WP10-49	16	16.2, 16 .3, 16.6
				UC-FP1-WP10-50	16	16.1, 16.2, 16.4, 16.5, 16.6
20	STS/FS	17	17.1, 17.2,	UC-FP1-WP10-51 (STS)	17	17.1, 17.2, 17.4

			17.4	UC-FP1-WP10-52 (FS)	17	17.1, 17.2, 17.4
				UC-FP1-WP10-53 (FS)	17	17.1, 17.2, 17.4
21	AZD	16, 17	16.1, 16.2, 17.1, 17.2, 17.3, 17.4	UC-FP1-WP10-54	16, 17	17.1, 17.2, 17.3, 17.4, 16.1, 16.2
				UC-FP1-WP10-55	16, 17	16.1, 17.1, 17.3, 17.4
22	INDRA	17	17.1, 17.2, 17.3, 17.4, 17.7	UC-FP1-WP10-56	17	17.1, 17.3, 17.4
				UC-FP1-WP10-57	17	17.1, 17.2, 17.3, 17.4, 17.7
23	MERMEC / FS	16,17	16.1, 16.2, 17.1, 17.4, 17.7	UC-FP1-WP10-58 (MERMEC)	16, 17	16.2, 17.1, 17.
				UC-FP1-WP10-59 (MERMEC)	16, 17	16.1, 16.2, 17.1, 17.7
				UC-FP1-WP10-53 (FS)	17	17.1, 17.2, 17.4
25	SNCF	17	17.1, 17.2, 17.3, 17.4, 17.5, 17.7	UC-FP1-WP10-60	17	17.1, 17.2, 17.3, 17.4, 17.5, 17.7
				UC-FP1-WP10-61	17	17.1, 17.2, 17.3, 17.4, 17.5, 17.7

Table 76: Mapping of demonstrations and use cases for WP17/18 with the TEs and HLRs

10. Interactions with other work packages of FP1, other FPx or SP/RNE

In this chapter, Table 77 shows the interactions with other WPs of FP1, other FPx and SP/RNE are summarised. They have been identified through the use cases definition and demo description activities (see Chapter 7) and Chapter 8).

WP	Demo/UC of WS1.2	Other FP1 WPs	Other FPx	SP/RNE
WP 11/12	**Demo 1 (ATSA)**	-	-	SP interaction
	UC-FP1-WP10-01	-	-	SP interaction
	UC-FP1-WP10-02	-	-	SP interaction
	UC-FP1-WP10-03	-	-	SP interaction
	Demo 2 (PKP)	FP1/(WP21)	-	-
	UC-FP1-WP10-04	-	FP3-IAM4RAIL/(WP14, WP15)	-
	Demo 3 (STS)	FP1/(WP15, Task 15.4.4)	FP2-R2DATO	-
	UC-FP1-WP10-05	FP1/(WP15, Task 15.4.4)	-	-
	Demo 4 (INDRA)	FP1/(WP8/9, WP15/16)	-	SP interaction
	UC-FP1-WP10-06	FP1/WP16 (Task 16.3)	-	-
	Demo 5 (MERMEC)	FP1/(WP17/18)	-	SP and RNE cross-border topics
	UC-FP1-WP10-07	-	-	SP/RNE: cross-border topic
	UC-FP1-WP10-08	FP1/(WP17/18, Tasks 17.2.8, 18.2.8)	-	SP/RNE: cross-border topic
	Demo 6 (HACON)	FP1/(WP4/5)	FP5-TRANS4M-R	SP/RNE: cross-border topic
	UC-FP1-WP10-09 (ADIF)	-	-	SP/RNE: cross-border topic
	UC-FP1-WP10-10	-	-	SP/RNE: cross-border topic
	UC-FP1-WP10-11	-	-	SP/RNE: cross-border topic
	Demo 7 (HACON)	-	FP3-IAM4RAIL/(WP8/9) FP5-TRANS4M-R/ (WP25/26) FP6-FUTURE/(WP6)	SP interaction
	UC-FP1-WP10-12	-	FP3-IAM4RAIL FP5-TRANS4M-R	-
	UC-FP1-WP10-13 (ADIF)	-	-	-
	UC-FP1-WP10-14 (ADIF)	-	-	-
	Demo 8 (TRV)	FP1/WP4/5	FP5-TRANS4M-R/(WP32)	-
	UC-FP1-WP10-15	-	FP5-TRANS4M-R	-

	UC-FP1-WP10-16	-	FP5-TRANS4M-R	-
	Demo 9 (CEIT)	-	FP3-IAM4RAIL	-
	UC-FP1-WP10-17	-	FP3-IAM4RAIL	-
WP 13/14	**Demo 10.1 (STS)**	-	FP3-IAM4RAIL/(WP3, WP4)	-
	UC-FP1-WP10-19	-	-	-
	UC-FP1-WP10-20	-	FP3-IAM4RAIL/(WP3, WP4)	-
	UC-FP1-WP10-21	-	FP3-IAM4RAIL/(WP3, WP4)	-
	UC-FP1-WP10-22 (ADIF)	-	-	-
	UC-FP1-WP10-23 (ADIF)	-	-	-
	Demo 10.2 (NSR)	-	-	-
	UC-FP1-WP10-24	-	-	-
	UC-FP1-WP10-25	-	-	-
	Demo 10.3 (HACON)	FP1/(WP4/5)	FP3-IAM4RAIL((WP8/9, Task 8.4)	SP interaction.
	UC-FP1-WP10-18	-	FP3-IAM4RAIL	
	Demo 11 (TRV + STS +INDRA)	FP1/(WP15/16)	-	-
	UC-FP1-WP10-26 (TRV)	-	-	-
	UC-FP1-WP10-28 (TRV)	-	-	-
	UC-FP1-WP10-19 (STS)	-	-	-
	UC-FP1-WP10-20 (STS)	-	FP3-IAM4RAIL/(WP3-4)	-
	UC-FP1-WP10-21 (STS)	-	FP3-IAM4RAIL/(WP3-4)	-
WP15/ 16	**Demo 12**	-	FP2-R2DATO/ (WP17, WP39) FP6-FUTURE (under discussion)	
	UC-FP1-WP10-30 (PR)	-	FP2-R2DATO/(WP39)	-
	UC-FP1-WP10-31 (PR)	-	FP2-R2DATO/(WP39)	-
	UC-FP1-WP10-32 (PR)	-	FP2-R2DATO/(WP32), FP2-R2DATO/(WP39)	-
	Demo 13.1 (TRV, PR, NSR, STS)	-	-	SP interaction
	UC-FP1-WP10-35 (TRV)	-	-	SP interaction
	Demo 13.2 (INDRA)	-	-	-
	UC-FP1-WP10-33 (INDRA)	-	FP2-R2DATO	
	Demo 13.3 (CEIT)	-	-	-
	UC-FP1-WP10-34 (CEIT)	-	FP2 -R2DATO	
	Demo 13.4 (STS)	FP1/(WP12, Task 12.2.3), FP1/(WP10, Task 10.3) and FP1/(WP30, Tasks 30.4, 30.5)	-	-
	UC-FP1-WP10-40 (STS)	FP1/WP12(task12.2.	-	-

		3)		
	Demo 14	-	FP2/(WP32, Task 32.2)	-
	UC-FP1-WP10-30 (PR)	-	FP2-R2DATO/(WP39)	-
	UC-FP1-WP10-31 (PR)	-	FP2-R2DATO/(WP39)	-
	UC-FP1-WP10-32 (PR)	-	FP2-R2DATO/(WP32), FP2-R2DATO/(WP39)	
	Demo 15.1 (AZD, STS PR)	FP1/WP12 (Task 12.2.3), WP15 (Task 15.4.4), WP30 (Tasks 30.4 and 30.5)	FP2-R2DATO FP6-FUTURE	
	UC-FP1-WP10-39 (AZD)	-	FP2-R2DATO FP6-FUTURE	
	Demo 15.2 (CAF, ADIF)	FP1/(WP8)	FP6-FUTURE/ (WP8)	-
	UC-FP1-WP10-36 (CAF)	-	FP6-FUTURE	-
	UC-FP1-WP10-37 (CAF)	-	FP6-FUTURE	-
	UC-FP1-WP10-38 (CAF)	-	FP6-FUTURE	-
	Demo 15.3 (MERMEC)	FP1/(WP17/18)	-	SP requirements
	UC-FP1-WP10-62 (MERMEC)	FP1/(WP17/18)	-	SP requirements
WP17/ 18	**Demo 16 (ENYSE, ÖBB-INFRA, PR, NRD)**	-	-	SP interaction
	UC-FP1-WP10-41	-	-	SP interaction
	UC-FP1-WP10-42	-	-	SP interaction
	UC-FP1-WP10-43	-	-	SP interaction
	UC-FP1-WP10-44	-	-	SP interaction
	Demo 17 (ENYSE)	-	FP6-FUTURE (application to Regional Lines)	-
	UC-FP1-WP10-45	-	FP6-FUTURE (application to Regional Lines)	-
	Demo 18 (HACON)	-	-	-
	UC-FP1-WP10-46	-	-	-
	Demo 19 (GTSD)	-	FP2-R2DATO (WP44/45)	**-**
	UC-FP1-WP10-47	-	FP2-R2DATO/(WP44/45)	-
	UC-FP1-WP10-48	-	FP2-R2DATO/(WP44/45)	-
	UC-FP1-WP10-49	-	FP2-R2DATO/(WP44/45)	-
	UC-FP1-WP10-50	-	FP2-R2DATO/(WP44/45)	-
	Demo 20 (STS/FS)	-	-	-
	UC-FP1-WP10-51 (STS)	-	-	-
	UC-FP1-WP10-52 (FS)	-	-	-
	UC-FP1-WP10-53 (FS)	-	-	-
	Demo 21 (AZD)	-	-	-
	UC-FP1-WP10-54	-	-	-
	UC-FP1-WP10-55	-	-	-
	Demo 22 (INDRA)	FP1/(WP6, WP7)	-	-

	UC-FP1-WP10-56	FP1/(WP6, WP7)	-	-
	UC-FP1-WP10-57	FP1/(WP6, WP7)	-	-
	Demo 23 (MERMEC/FS)	FP1/(WP11, WP12)	-	SP requirements
	UC-FP1-WP10-58 (MERMEC)	FP1/WP11/12 (Task 11.3.5 and 12.2.5)	-	SP requirements
	UC-FP1-WP10-59 (MERMEC)	-	-	SP requirements
	UC-FP1-WP10-53 (FS)	-	-	-
	Demo 25 (SNCF)	-	-	-
	UC-FP1-WP10-60	-	-	-
	UC-FP1-WP10-61	-	-	-

Table 77: Interactions with other WPs of FP1, other FPx or SP/RNE

11. Conclusions

Deliverable D10.1 falls within the scope of WS1.2 "Operations" of the FP1-MOTIONAL project. Specifically, this includes the outcomes of the specification phase of WS1.2 coming from Task 10.1 and Task 10.2.

In this deliverable, the high-level specifications of requirements, high-level design and high-level use cases based on a state-of-the-art analysis undertaken in conjunction with WS1.2 technical enablers 8 to 17, are aligned, prepared and delivered. The work is linked to the further development of the technical enablers 8 to 17:

- TE8: Real-time connection of rail networks as managed by TMSs and involved actors.
- TE9: Modelling and decision support for cross-border traffic management.
- TE10: 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.
- TE11: HMI for TMS based on User Experience (UX) Design and user input.
- TE12: Real-time convergence between planning & feedback loop from operations.
- TE13: Cooperative planning multi-actors within rail.
- TE14: Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management.
- TE15: TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables.
- TE16: Automation of very short-term train control decisions.
- TE17: Real-time conflict detection & resolution for main line and optimisation.

The document is understood as a conceptual deliverable where the scope within FP1 WS1.2 is described and developed to improve the understanding and facilitate the following steps. This is considered as the basis for the future work in the development and demonstration phases of WS1.2 "Operations" to be done in WP11/12 (Integration of TMSs and processes including cross-border traffic management), WP13/14 (Improved resilience and efficiency of disruption management), WP15/16 (Linking TMS to ATO/C-DAS for optimised operations) and WP17/18 (Automated decisions and decision support for traffic management optimisation). All descriptions are high-level, and more details will be presented in following steps in the deliverables of the development and demonstration WPs.

The content of this report is also used a basis for the continued work in WP10, Task 10.3, relative to the specification of demonstration environment/framework and identification of data structures. The outcomes of Task 10.3 will be presented in deliverable D10.2. The high-level use cases here collected are also transferred to WP2 for the preparation of deliverable D2.3.

Each of the 25 defined demonstrations for WS1.2 are presented along with the related high-level use cases. The traceability between the demos, use cases, technical enablers and high-level requirements associated is established. The interactions with other FP1 WPs, FPx and SP/RNE is also identified.

Starting from the high-level definition defined here, the specifications and requirements for the following topics per WPs will be continued setting up: innovations in the integration of TMS with other systems (including yard and station) and with neighbouring TMS systems (WP11/12), innovations in collaborative DSS for efficient and effective disruption management and HMI for TMS based on User Experience (UX) Design and user input, innovations in TMS – ATO/C-DAS (WP15/16) and automated decisions and decision support for traffic management optimisation (WP17/18).

Due to the ongoing alignment sessions with RNE and the SP and their work, the need to make changes to the use case and demo details to improve the alignment of the final development results cannot be excluded in next phase.

The purpose of the prototypes is to verify the planned goals, using already existing architecture. For most of the demonstrations, the architecture is based on the Shift2Rail TD2.9 demonstrators which are not necessarily compliant with the SP architecture provided only after start of SG2 (TMS) activities in the FP1-MOTIONAL project.

All involved beneficiaries from WS1.2 have collaborated in the writing of this deliverable.

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FP1-WP02-D-HAC-010-02 D2.3 Use Cases for planned technical developments of the project.

Milestone 3 - Requirements received from other FPs.docx (Internal working document from FP1-MOTIONAL project).

13. Appendices

13.1. Appendix A Defined High-level use cases of WS1.2.

Relative to WP11/12 (Integration)

UC-FP1-WP10-01: Information exchange for Automatic Route Setting (ARS)

Name	*Information exchange for Automatic Route Setting (ARS)*
ID	*UC-FP1-WP10-01*
Partner	*ATSA*
Demo associated	*Demo 1 (task 12.2.1)*
Description	*Communication between TMS providing the trip info via Integration Layer (IL) and the CTC System to set the route in the automatic way (ARS).* *The TMS constantly updates the operational Timetable (TT) on the Integration Layer 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 IL.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.1, 12.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors".*
Interactions SP/FP	*SP Interaction*
Actor(s)	*Initiator: TMS / TMS Operator.* *Other systems involved: CTC System, Integration Layer.*
Sequence	1. *The operational timetable including trips of many trains is being published by the TMS on Integration Layer.* 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 IL. 4. *CTC System continues operation according to new / modified timetable.*
Notes	*None*

Table 78: UC-FP1-WP10-01

UC-FP1-WP10-02: Information exchange for Monitor & Control Train

Name	*Information exchange for Monitor & Control Train*
ID	*UC-FP1-WP10-02*
Partner	*ATSA*
Demo associated	*Demo 1 (task 12.2.1)*
Description	*Communication between CTC System providing interlocking and RBC info about train to the TMS system via the Integration Layer.* *CTC System publishes constantly train status information / blocks occupancies received from RBC / interlocking on Integration Layer. TMS accesses Integration Layer and uses this information to optimize operational timetable.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.1, 12.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors".*
Interactions SP/FP	*SP interaction*
Actor(s)	*Initiator: CTC System that receives information from Interlocking/RBC.* *Other systems involved: TMS, Integration Layer.*
Sequence	1. *CTC System periodically while the train moves publishes train status information on Integration Layer.* 2. *Information is stored on IL.* 3. *Registered subscribers are notified about updated train status by IL.* 4. *The information is processed and operational timetable is*

	updated if applicable by the TMS.
Notes	*None*

Table 79: UC-FP1-WP10-02

UC-FP1-WP10-03: Monitor & Control the field elements

Name	*Monitor & Control the field elements*
ID	*UC-FP1-WP10-03*
Partner	*ATSA*
Demo associated	*Demo 1 (task 12.2.1)*
Description	*Information about restrictions, limitations, maintenance activities available on Integration Layer are provided to CTC and TMS systems.* *External systems publish information to Integration Layer about restrictions / limitations like speed restriction, adhesion restriction, power restriction or maintenance activities. CTC System and TMS can use it to include it in the route setting or updating operational timetable.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.1, 12.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors".* *TE10 - "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: Systems publishing infrastructure restrictions to IL.* *Other systems involved: CTC System, TMS, Integration Layer.*
Sequence	*1. External system publishes on Integration Layer information about restriction / limitation like: speed restriction, adhesion restriction, power restriction, maintenance activity.* *2. All registered subscribers are notified about new*

	restriction defined and take proper action: a. *CTC System can use the information in its Automatic Route Setting mechanisms.* b. *TMS can modify operational timetable.*
Notes	*None*

Table 80: UC-FP1-WP10-03

UC-FP1-WP10-04: Support for trans-border travel related decisions for station operator

Name	*Support for trans-border travel related decisions for station operator*
ID	*UC-FP1-WP10-04*
Partner	*PKP*
Demo	*Demo 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 visualized form.* *Proposed use case is based on dashboards and relevant data processing and logic for helping to make an informed decision.* *For example, we can visualize areas (selected main cities) using geographical maps available from the stations within one or more legs of a trans-border journey.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.2, 12.2.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE9 - "Modelling and decision support for cross-border traffic management"*
Interactions SP/FP	*FP3-IAM4RAIL/(WP14, WP15) where the asset management decision support systems for stations are being developed*
Actor(s)	*Station Operator, Data Lake service, DSS*
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.*
Notes	*- System must analyse the trans-border travel availability for selected destination stations.* *- System shall visualise the information in readable way.* *- System must communicate with Data Lake to access necessary info on trans-border travel.*

Table 81: UC-FP1-WP10-04

UC-FP1-WP10-05: Detail train timetable for energy saving ATO

Name	*Detail train timetable for energy saving, ATO-TS*
ID	*UC-FP1-WP10-05*
Partner	*STS*
Demo associated	*Demo 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 optimize the train energy consumption.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.3, 12.2.3*
Impact on other task(s)	*FP1/WP15 (Task 15.4.4)*
Technical Enabler(s)	*TE8* **-** *"Real-time connection of rail networks as managed by TMSs and involved actors"*
Interactions SP/FP	*None*
Actor(s)	*ATO-TS, TMS*
Sequence	1. *Acquisition of the operational plan.* 2. *Evaluation of the detailed train timetables.* 3. *Publishing of the detailed train timetables.*
Notes	*None*

Table 82: UC-FP1-WP10-05

UC-FP1-WP10-06: Information exchange between TMS and C-DAS TS

Name	*Information exchange between TMS and C-DAS TS*
ID	*UC-FP1-WP10-06*
Partner	*INDRA*
Demo associated	*Demo 4 (task 12.2.4)*
Description	*Communication between TMS providing the trip information and C-DAS TS system.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.4, 12.2.4*
Impact on other task(s)	*FP1/WP16 (Task 16.3)*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"*
Interactions SP/FP	*None*
Actor(s)	*TMS, C-DAS TS*
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.*
Notes	*None*

Table 83: UC-FP1-WP10-06

UC-FP1-WP10-07: Cooperative conflict resolution (Two TMSs)

Name	*Cooperative conflict resolution (Two TMSs)*
ID	*UC-FP1-WP10-07*

Partner	*MERMEC*
Demo associated	*Demo 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 WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.5, 12.2.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"* *TE9 - "Modelling and decision support for cross-border traffic management"*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*TMS/TMS Operators*
Sequence	*1. TMS1 Operator chooses a conflict solution.* *2. Conflict solution is sent to TMS 2.* *3. TMS2 Operator accepts or rejects the proposal solution (and eventually adds a note).* *4. When accepted, the conflict is solved in both TMSs.*
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.
Notes	*Prerequisites: Two TMSs, current plans loaded and a conflict in the border common track present.*

Table 84: UC-FP1-WP10-07

UC-FP1-WP10-08: Exchanging real-time train data regarding the border stations

Name	*Exchanging real-time train data regarding the border stations.*
ID	*UC-FP1-WP10-08*
Partner	*MERMEC*
Demo associated	*Demo 5 (task 12.2.5)*
Description	*The TMS shall be able to exchange train characteristic, issues,*

	and forecast information with neighbour TMSs.
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.5, 12.2.5*
Impact on other task(s)	*FP1/WP17-18 (Tasks 17.2.8, 18.2.8)*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"* *TE9 - "Modelling and decision support for cross-border traffic management"*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*TMS*
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.*
Involved components (System)	TMS Event Logger, TMS Deviation Detection module, TMS Forecast Calculation module, TMS Operational Plan, Cooperative Interface.
Notes	*Prerequisites: Two TMSs, current plans loaded and at least a cross border/area train with delay.*

Table 85: UC-FP1-WP10-08

UC-FP1-WP10-09: Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts

Name	*Short-term maintenance needs or accidental situation which requires a pre-alignment of the train journey parts*
ID	*UC-FP1-WP10-09*
Partner	*ADIF FM*
Demo associated	*Demo 6 (task 12.2.6) (Assumed by Hacon)*
Description	*Short-term maintenance needs or accidental situation detected. Exchange of information between TMSs. Pre-alignment between the parts of a journey including a border.*

	Decision/alignment done before crossing the border.
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.6, 12.2.6*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"* *TE9 - "Modelling and decision support for cross-border traffic management"*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*TMS/TMS Operator*
Sequence	1. *Starting point: train operating from TMS A to TMS B without incidences.* 2. *Short-term maintenance needs or accidental situation detected arising in the TMS A.* 3. *The TMS A informs about the change in the operation to the TMS B.* 4. *Pre-alignment between the parts of a journey including a border.* 5. *Alignment done before crossing the border.*
Notes	*This scenario can be also given with an incident in the area B controlled by the TMS B.*

Table 86: UC-FP1-WP10-09

UC-FP1-WP10-10: Sending and Receiving train running forecast information

Name	*Sending and Receiving train running forecast information*
ID	*UC-FP1-WP10-10*
Partner	*HACON*
Demo associated	*Demo 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 WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.6, 12.2.6*

Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*TMS/TMS Operator*
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.*
Notes	*Preconditions:* *- a planned inbound cross-border freight path available in local TMS.*

Table 87: UC-FP1-WP10-10

UC-FP1-WP10-11: Pre-aligned decisions cross-border

Name	*Pre-aligned decisions cross-border*
ID	*UC-FP1-WP10-11*
Partner	*HACON*
Demo associated	*Demo 6 (task 12.2.6)*
Description	*Aligning decisions by knowing capacity restrictions behind the border (until next node behind the border)*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.6, 12.2.6*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE8 - "Real-time connection of rail networks as managed by TMSs and involved actors"* *TE9 - "Modelling and decision support for cross-border traffic management"*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*TMS/TMS Operator*

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.*
Notes	*Preconditions:* *- 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.*

Table 88: UC-FP1-WP10-11

UC-FP1-WP10-12: Consider constraints or needs of integrated processes and related systems integrated

Name	*Consider constraints or needs of integrated processes and related systems integrated*
ID	*UC-FP1-WP10-12*
Partner	*HACON*
Demo associated	*Demo 7 (task 12.2.7)*
Description	*Provide forecast / updated operational plan considering yard/station planning, digital maintenance planning, ETS simulation, crew/rolling stock assignment*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.7, 12.2.7*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE10 - "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.* *FP5-TRANS4M-R: integration of yard capacity production.*

Actor(s)	*TMS/TMS Operator, Operators of integrated systems*
Sequence	*1. Train related to path started in local network.* *2. A TCR is imported/updated from track maintenance planning system DMPS (IAMS, FP3).* *3. Forecast calculation from current position shows up with conflict(s) with the imported TCR.* *4. TMS Operator adapts Operational Plan to solve the conflict(s).* ***a. Yard management system and processes*** *5. Updated Operational Plan is sent to Yard Management System causing a conflict in a yard track for handling the train.* *6. Conflict is solved by Yard Operator by adapting conflicting track reservations.* ***b. Station management system and processes*** *7. Updated Operational Plan is sent to Station Management System causing a conflict in a depot /station track for handling or holding the train.* *8. Conflict is solved by Station Operator by adapting conflicting track reservations.* ***c. Energy management (Electric Traction System)*** *9. Updated Operational Plan is sent to Electric Traction System (ETS) Simulator causing a power restriction conflict when train will depart from one of the next stops at a station.* *10. Conflict is solved by ETS Simulator handing back the solution to TMS.* *11. TMS is adapting operational plan followed by recalculation of the forecast.* ***d. Real-time crew dispatching*** *12. Updated Operational Plan because of the delay, a conflict with a crew link for driver exchange, reflected by a Control Rule in the Operational Plan is detected and automatically solved by TMS by delaying the linked outbound train accordingly.* *13. TMS automatically updates the Operational Plan followed by re-calculation of the forecast and sending updated Operational Plan to Crew Dispatching System.*

	e. Real-time rolling stock dispatching *14. Updated Operational Plan because of the delay, a conflict with a rolling stock link for material exchange, reflected by a Control Rule in the Operational Plan is detected and automatically solved by TMS by delaying the linked outbound train accordingly.* *15. TMS automatically updates the Operational Plan followed by re-calculation of the forecast and sending updated Operational Plan to Rolling Stock Dispatching System.*
Notes	*None*

Table 89: UC-FP1-WP10-12

UC-FP1-WP10-13: Train running forecast of the TMS improved by integration of TMS with systems and processes related to yards, stations and so on.

Name	*Train running forecast of the TMS improved by integration of TMS with systems and processes related to yard or station management, asset/maintenance planning and management, real-time crew / rolling stock dispatching and electric traction systems.*
ID	*UC-FP1-WP10-13*
Partner	*ADIF FM (assumed by HACON)*
Demo associated	*Demo 7 (task 12.2.7)*
Description	*Input received from yard/station planning, digital maintenance planning, ETS simulation, crew/rolling stock assignment systems by the TMS. Calculation of the train running forecast by the TMS considering this information. Result, train running forecast improved.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.7, 12.2.7*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE10 - "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*
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.*
Notes	*None*

Table 90: UC-FP1-WP10-13

UC-FP1-WP10-14: Planning and/or management of systems and processes using information received from the TMS

Name	*Planning and/or management of systems and processes related to yard or station management, asset/maintenance planning and management, real-time crew / rolling stock dispatching and electric traction systems taking into account the information received from the TMS*
ID	*UC-FP1-WP10-14*
Partner	*ADIF FM (assumed by HACON)*
Demo associated	*Demo 7 (task 12.2.7)*
Description	*The TMS sends to the other planning/management local systems (yard, stations, etc) info of updated train running forecast and/or updated operational plan. The local systems use this information.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.7, 12.2.7*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE10 - "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*
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 takes into account the updated information received from the TMS to implement its actions.*
Notes	*None*

Table 91: UC-FP1-WP10-14

UC-FP1-WP10-15: Sending and Receiving track allocation information between TMS and YCS

Name	*Sending and Receiving track allocation information between TMS and YCS*
ID	*UC-FP1-WP10-15*
Partner	*TRV*
Demo associated	*Demo 8 (task 12.2.8)*
Description	*Trigger: Change(s) in track allocation for YCS.* *Results: 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.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.8, 12.2.8*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE10 - "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*
Sequence	*None*

Notes	*None*

Table 92: UC-FP1-WP10-15

UC-FP1-WP10-16: Notifying TMS and YCS operators about disruptions and requests

Name	*Notifying TMS and YCS operators about disruptions and requests*
ID	*UC-FP1-WP10-16*
Partner	*TRV*
Demo associated	*Demo 8 (task 12.2.8)*
Description	*Trigger: Spontaneous or operator-initiated deviation from plan.* *Results: Interactions between TMS and YCS Operators through their systems about disruptions and requests on changes in plan for track allocation.*
Related to WP(s)	*WP11/12*
Related to task/subtask(s)	*Tasks 11.3.8, 12.2.8*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE10 - "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*
Sequence	*None*
Notes	*None*

Table 93: UC-FP1-WP10-16

UC-FP1-WP10-17: IAMS interface

Name	*IAMS interface*
ID	*UC-FP1-WP10-17*
Partner	*CEIT*
Demo associated	*Demo 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). To receive information about asset status and planned interventions and deliver allocated paths to execute inspections and interventions.*
Related to WP(s)	*WP11/12*
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)	*TE10 - "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*
Sequence	*1. IAMS requests the interventions of the Inspection Vehicle on specific track paths (to TMS or to Inspection Vehicle directly).* • *IAMS provides critical status alerts of the assets of the infrastructure to TMS.* • *Inspection Vehicle routes are set by TMS using the information received from IAMS and Inspection Vehicle location.* • *Inspection Vehicle receives the route for the intervention on the specific track.* *2. Use of TMS is optional, a direct link between IAMS and Inspection Vehicle can be considered in case of lack of TMS.*
Notes	*None*

Table 94: UC-FP1-WP10-17

Relative to WP13/14 (Incident management)

UC-FP1-WP10-18: Involving multi-actors in decision making

Name	*Involving multi-actors in decision making*

ID	*UC-FP1-WP10-18*
Partner	*HACON*
Demo associated	Demo 10 (task 14.1.2)
Description	*Options for changes of the Operational Plan for addressing incidents and related conflict scenarios are shared and commented on by multiple actors including responsible RU and maintenance staff (MMS Operator)*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2.3, 14.1.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE13* **-** *"Cooperative planning multi-actors within rail".* *TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management"*
Interactions SP/FP	*FP3-IAM4RAIL: IAMS/DMPS integration for track maintenance information*
Actor(s)	*TMS/TMS Operator, involved RU, MMS Operator, CMS/CMS User, IAMS*
Sequence	*1. A major incident causes an immediate blockage of a track section in TMS.* *2. TMS Operator enters track blockage restriction in TMS leading to conflicts with running and planned trains.* *3. TMS generates solution options for regulating today's trains conflicting with the track blockage.* *4. TMS Operator accepts a solution and TMS implements Operational Plan change for today's trains accordingly.* *5. CMS receives blockage restriction from TMS.* *6. CMS users are starting to analyse the impact on planned trains for the next days.* *7. CMS user registers accidental possession request for track repair and sent to IAMS (DMPS).* *8. Accidental possession (including different track blockages and temporary speed restrictions for 4 days) is set-up for track repair in IAMS (DMPS) and sent to CMS/TMS.*

	9. *CMS users and involved RUs are replanning the impacted trains in CMS leading to introduction of a new resource link between two trains.* 10. *Replanning results in CMS (capacity plan updates) are sent back to TMS.* 11. *TMS is updating its Operational Plan accordingly.* 12. *The RU sends the new resource link to TMS/CMS for considering the knock-on effects of further plan changes or delays.*
Notes	*None*

Table 95: UC-FP1-WP10-18

UC-FP1-WP10-19: Critical alarm management

Name	*Critical alarm management*
ID	*UC-FP1-WP10-19*
Partner	*STS*
Demo associated	Demo 10 (task 14.1.2) and *Demo 11 (Task 14.2)*
Description	*The CTC System Operator is supported to reduce the effort and stress required to manage critical events, by providing through the HMI different type of help (suggestion, useful info...) and supporting the critical event resolution.*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2 (13.2.1, 13.2.5), 13.5 (13.5.1, 13.5.2, 13.5.4)*
Impact on other task(s)	*Task 13.6 (13.6.1, 13.6.3), 14.1*
Technical Enabler(s)	*TE11 - “HMI for TMS based on User Experience (UX) Design and user input”.* *TE13 - “Cooperative planning multi-actors within rail”.* *TE14 - “Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management”*
Interactions SP/FP	*None*
Actor(s)	*CTC System Operator, IAMS, TMS, Integration Layer, the MMS Operator, the IM and all other subsystems/actors potentially involved into the provision of alarm and/or implementation of the remediation, depending on the type of possible failure.*

Sequence	1. *The Integration Layer conveys an alarm to the system, which classifies it as critical or not by using the DSS.* 2. *If the event is critical, the DSS selects a series of countermeasures to be visualised to the operator.* 3. *The operator makes a decision and contacts the other actors for its implementation;* 4. *The effectiveness of the decision is assessed and sent back to the system in order to learn the quality of the DSS.* 5. *If the event is new or no remediation is included in the system, the operator is required to make a decision and the system learns from such a decision.*
Notes	*All the interactions of the involved actors with the system are computer-based.*

Table 96: UC-FP1-WP10-19

UC-FP1-WP10-20: Short-term management of a possible asset failure

Name	*Short-term management of a possible asset failure*
ID	*UC-FP1-WP10-20*
Partner	*STS*
Demo associated	*Demo 10 (task 14.1.2)* and *Demo 11 (Task 14.2)*
Description	*The system receives monitoring information, determines if it is a symptom of an upcoming failure of an asset and evaluates which is the preferable time window in which to plan intervention and the kind of intervention*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2 (13.2.2), 13.5 (13.5.1, 13.5.2)*
Impact on other task(s)	*Task 13.6 (13.6.1, 13.6.3), 14.1*
Technical Enabler(s)	*TE11 - "HMI for TMS based on User Experience (UX) Design and user input".* *TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management"*
Interactions SP/FP	*FP3-IAM4RAIL/(WP3-4)*
Actor(s)	*CTC System Operator, IAMS, TMS, Integration Layer, the MMS Operator the IM and all other subsystems/actors potentially*

	involved into the provision of alarm and/or the implementation of the remediation, depending on the type of possible failure.
Sequence	1. *The Integration Layer conveys sensing data on assets to the system and TMS-related data and determines the probability of having a failure from IAMS.* 2. *If the failure probability is high, the DSS selects a series of countermeasures to be visualised to the operator and how to reschedule traffic.* 3. *The operator makes a decision and contacts the other actors for its implementation and TMS for traffic rescheduling.* 4. *The effectiveness of the decision is assessed and send back to the system in order to learn the quality of the DSS.* 5. *If the failing asset is new or no remediation is included in the system, the operator is required to make a decision and the system learns from such a decision.*
Notes	*All the interactions of the involved actors with the system are computer-based*

Table 97: UC-FP1-WP10-20

UC-FP1-WP10-21: Preventive functional assessment (PFA)

Name	*Preventive functional assessment (PFA)*
ID	*UC-FP1-WP10-21*
Partner	*STS*
Demo associated	*Demo 10 (task 14.1.2)* and *Demo 11 (Task 14.2)*
Description	*To cope with a lack of monitoring data for assets that are not used for a long period, preventive functional assessment needs to be conducted. The system continuously monitors the assets and support the CTC System Operator in identifying such assets and suggesting when the PFA needs to be done rearranging the railway traffic accordingly.*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2 (13.2.2), 13.5 (13.5.2)*
Impact on other task(s)	*Task 13.6 (13.6.1, 13.6.3), 14.1*
Technical Enabler(s)	*TE11 - "HMI for TMS based on User Experience (UX) Design and user input".*

	TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management"
Interactions SP/FP	*FP3-IAM4RAIL(WP3-4)*
Actor(s)	*CTC System operator, IAMS, TMS, DSS, Integration Layer, the MMS Operator, the IM and all other subsystems/actors potentially involved into the provision of alarm and/or the implementation of the PFA, depending on the type of asset to be assessed.*
Sequence	*1. The Integration Layer conveys sensing data on assets to the system and TMS-related data and determines which asset has been not monitored for a long period and a PFA is needed.* *2. If an asset needs to be subject to PFA, the DSS selects a series of actions to be visualised to the operator and how to reschedule traffic.* *3. The operator makes a decision and contacts the other actors for its implementation and TMS for traffic rescheduling.* *4. The effectiveness of the decision is assessed and send back to the system in order to learn the quality of the DSS.* *5. If the asset for PFA is new or no actions has been found in the system, the operator is required to make a decision and the system learns from such a decision.*
Notes	*All the interactions of the involved actors with the system are computer-based*

Table 98: UC-FP1-WP10-21

UC-FP1-WP10-22: Disruption management and activation of emergency services.

Name	*Disruption management and activation of emergency services.*
ID	*UC-FP1-WP10-22*
Partner	*ADIF FM*
Demo associated	*Demo 10 (task 14.1.2) (assumed by STS)*
Description	*When a failure in the train or the trackside is detected, the*

	system shows on the IM Operator's HMI information about the failure occurred, which is leading to the traffic disruption. Such information is acquired from TMS and/or sensors deployed at the assets. It is also indicated that an intervention is required, in particular, the need to activate emergency services/organisation.
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.5 (13.5.1), 13.2 (13.2.1, 13.2.2, 13.2.3)*
Impact on other task(s)	*Tasks 13.6 (13.6.1, 13.6.3), 14.1*
Technical Enabler(s)	*TE13 - "Cooperative planning multi-actors within rail"; and* *TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption management".*
Interactions SP/FP	*None*
Actor(s)	*IM Operator, TMS, TMS Manager, TMS Operator, Emergency Coordinator*
Sequence	*1. TMS monitors and controls the traffic and the signalling systems.* *2. From the monitoring of the state of trackside assets, the system receives information about a disruption due to an asset failure (train or infra failure). As a consequence of this, the traffic is interrupted in the line. The information is received/collected from different subsystems.* *3. Alarm indication received by the operator.* *4. System shows through the HMI to the IM Operator info about failure type.* *5. System shows through the HMI info about the disruption if known (duration, train affected, section of the network affected).* *6. To help in the making decision of the operator, System displays through the HMI suggestions/proposal of steps to follow to mitigate/resolve the situation as soon as possible.* *7. The decision of activation of emergency services is made by the responsible managing the incident (alternative*

	transport to transport passengers, shuttle service, trailer train to help the train).
Notes	*Pre-Conditions:* - *TMS monitoring and controlling the traffic and the signalling systems.* - *Asset failure detected leading to a traffic disruption.* - *TMS capable of detecting (receiving the info from the monitoring of the sub-systems, even throughout an Alarm Dispatcher Module integrated in the TMS) and informing real-time incidents in the sub-systems to the IM Operators. Management of alarm indications.* - *Multi-actor workflow including decision negotiation and management.* - *HMI available to receive the reporting of information/suggestions.*

Table 99: UC-FP1-WP10-22

UC-FP1-WP10-23: Disruption management and activation of a maintenance intervention

Name	*Disruption management and activation of a maintenance intervention*
ID	*UC-FP1-WP10-23*
Partner	*ADIF FM*
Demo associated	*Demo 10 (task 14.1.2) (assumed by STS)*
Description	*When a failure in the train or the trackside is detected, the IM system shows on the HMI information about the failure occurred which is leading to the traffic disruption. It is also indicated that an intervention is required, specifically a maintenance intervention (needed resources (people), expected duration, impact on traffic…).*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.5 (13.5.1, 13.5.3), 13.2 (13.2.1, 13.2.2, 13.2.3*
Impact on other task(s)	*Tasks 13.6 (13.6.1, 13.6.3), 14.1*
Technical Enabler(s)	*TE13 - "Cooperative planning multi-actors within rail"; and* *TE14 - "Integration of incident management and customer*

	information, with IM and RU interaction and Decision Support for Disruption management".
Interactions SP/FP	*None*
Actor(s)	*IM Operator, TMS, TMS Operator, DSS, MMS Manager and MMS Operator*
Sequence	*1. The IM system receives information about a disruption because of asset failure (train or infra failure). The traffic is interrupted in the affected section. This is detected by the monitoring of the different subsystems.* *2. HMI shows to the CTC System Operator info about failure and the proposal of steps which are needed to mitigate the problem.* *3. DSS provides info of necessary maintenance tasks to mitigate the failure, including required resources (people, assets, ...), expected duration, impact on traffic.*
Notes	*See UC-FP1-WP10-22: Disruption management and activation of emergency services.*

Table 100: UC-FP1-WP10-23

UC-FP1-WP10-24: Solving of Rolling stock dispatching conflicts using reserves and swaps

Name	*Solving of Rolling stock dispatching conflicts using reserves and swaps*
ID	*UC-FP1-WP10-24*
Partner	*NSR*
Demo associated	*Demo 10 (Task 14.1)*
Description	*Conflicts in the rolling stock circulation of a railway operator are usually solved manually. We aim to develop an algorithm that can automatically solve such rolling stock circulation conflicts that result from disruptions. The input is the actual rolling stock schedule, a disruption and the corresponding modified timetable. The output is the adjusted rolling stock schedule.*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2 (13.2.4), 14.1*

Impact on other task(s)	*None*
Technical Enabler(s)	*TE13 - "Cooperative planning multi-actors within rail"; and* *TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption Management".*
Interactions SP/FP	*None*
Actor(s)	*RU-rolling stock dispatcher*
Sequence	*1. Monitor conflicts in the rolling stock schedule.* *2. Prioritize the conflicts based on impact.* *3. Select conflict with highest impact and find solutions for this conflict by running the algorithm.* *4. Evaluate the proposed solutions.*
Notes	*None*

Table 101: UC-FP1-WP10-24

UC-FP1-WP10-25: Proactive solving of macro tasks for crew dispatching

Name	*Proactive solving of macro tasks for crew dispatching*
ID	*UC-FP1-WP10-25*
Partner	*NSR*
Demo associated	*Demo 10 (Task 14.1)*
Description	*When conflicts in a driver/guard duty occurs, algorithms exist to help dispatchers solve these conflicts. Currently, these algorithms need manual triggering. We aim to move towards autonomous conflict solving by the system, under certain predefined conditions.*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2 (13.2.4), 14.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE14 - "Integration of incident management and customer information, with IM and RU interaction and Decision Support for Disruption Management".*
Interactions SP/FP	*None*
Actor(s)	*RU - crew dispatcher*

Sequence	1. *Monitor conflicts.* 2. *Let the algorithm solve the conflicts.* 3. *Evaluate pro-active solution proposals from the algorithm.* 4. *Accept/decline solution proposals.*
Notes	*None*

Table 102: UC-FP1-WP10-25

UC-FP1-WP10-26: Trespassing

Name	*Trespassing*
ID	*UC-FP1-WP10-26*
Partner	*TRV/VTI*
Demo associated	*Demo 11 (Task 14.2)*
Description	*Detection of one or more unauthorized persons entering the track area, leading to a stop in traffic until the TMS Operator is able to confirm that the track is clear (of obstacles).*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2, 13.3, 14.1, 14.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE11 - "HMI for TMS based on User Experience (UX) Design and user input".*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS operator, Emergency/rescue services, Train driver.*
Sequence	1. *Trespassing is detected (by a detection system or by a person).* 2. *The TMS Operator is informed that a trespassing occurs.* 3. *The affected area is protected from train traffic (automatically or by the TMS Operator).* 4. *The emergency/rescue services are contacted (if not already informed) and send to the area of interest.* 5. *The emergency/rescue services search the area and contact the TMS Operator when the track area is clear.*

	6. *The track area is confirmed clear, and the traffic re-planned continues accordingly.*
Notes	*Trespassing causes a lot of delays and are today the main cause to injuries and deaths in the railway system. In this situation, the TMS Operator needs support to determine if the track area is clear.* *The use case includes human-machine interaction based on users' experience.*

Table 103: UC-FP1-WP10-26

UC-FP1-WP10-28: Infrastructure problems detected by railway staff

Name	*Infrastructure problems detected by railway staff*
ID	*UC-FP1-WP10-28*
Partner	*TRV/VTI*
Demo associated	*Demo 11 (Task 14.2)*
Description	*The Train driver (or other railway staff) notices something unusual and contacts the TMS Operator by voice communication system. Depending on the information given by the Train driver the TMS Operator has to decide if the traffic can go on and under which conditions. In this situation, the TMS Operator needs support to determine how serious the problem is and which subsequent actions that are appropriate.*
Related to WP(s)	*WP13/14*
Related to task/subtask(s)	*Tasks 13.2, 13.3, 14.1, 14.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE11 - "HMI for TMS based on User Experience (UX) Design and user input".*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator, Train driver, IM- Trackside staff.*
Sequence	1. *A potential infrastructure failure is detected by a Train driver who contacts the TMS Operator.* 2. *The TMS Operator understands that actions are needed.* 3. *Traffic is protected within affected area.* 4. *The TMS Operator contacts maintenance personnel and initiates a new temporary Operational Plan.*

	5. *The TMS Operator is informed that the problem is solved and the TMS Operator re-plans accordingly.*
Notes	*In contrast to detected by any technical system. In this situation, the TMS Operator needs support from personnel at the suspected point of failure to determine how serious the problem is and which subsequent actions that are appropriate.* *The use case includes human-machine interaction based on users' experience.*

Table 104: UC-FP1-WP10-28

Relative to WP15/16 (TMS-ATO/C-DAS)

UC-FP1-WP10-30: Train Path Envelope calculation

Name	*Train Path Envelope calculation*
ID	*UC-FP1-WP10-30*
Partner	*PR*
Demo associated	*Demo 12 (task 16.2), Demo 14 (task 16.4)*
Description	*Based on an RTTP received from the TMS, the ATO-TS computes TPEs for all connected trains with possibly additional Timing Points to guarantee conflict-free traffic, which are sent to the ATO-OBs of the connected trains.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.3, 15.4, 16.2, 16.4.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP2-R2DATO/(WP39)*
Actor(s)	TMS/TMS Operator, ATO-TS
Sequence	*1) TMS sends RTTP to ATO-TS* *2) ATO-TS generates TPEs for all trains* *2a) If there are conflicting TPEs then ATO-TS tries to resolve them* *2b) If conflicts cannot be resolved for current RTTP, the TMS is warned* *3) ATO-TS sends conflict-free TPEs within SPs and JP to all*

	connected ATO-OB
Notes	*None*

Table 105: UC-FP1-WP10-30

UC-FP1-WP10-31: TMS-ATO feedback loop

Name	*TMS-ATO feedback loop*
ID	*UC-FP1-WP10-31*
Partner	*PR*
Demo associated	*Demo 12 (task 16.2), Demo 14 (task 16.4)*
Description	*The ATO-TS updates the TPEs based on Status Reports from the ATO-OBs or asks the TMS to provide a new RTTP based on infeasible TPEs instances.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.3, 15.4, 16.2, 16.4.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE12 - "Real-time convergence between planning & feedback loop from operations [TRL 4/5]."* *TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP2-R2DATO/(WP39)*
Actor(s)	*TMS/TMS Operator, ATO-TS, ATO-OB, Train Driver*
Sequence	*1. ATO-TS receives status reports from TMS or from ATO-OB* *2a. For ATO-OB updates: ATO-TS updates TPEs.* *2b. If no feasible TPE can be generated, TMS is warned to update RTTP.* *2c. For infeasible TPEs: TMS generates and sends updated RTTP to ATO-TS.* *3. For RTTP update: ATO-TS updates TPEs (see UC-FP1-WP10-30)* *4. ATO-TS sends updated conflict-free TPEs within SPs and JP to all ATO-OBs.*
Notes	*None*

Table 106: UC-FP1-WP10-31

UC-FP1-WP10-32: TMS-ATO operation interactions between human actors in different conditions

Name	*TMS-ATO operation interactions between human actors in different conditions*
ID	*UC-FP1-WP10-32*
Partner	*PR*
Demo associated	*Demo 12 (task 16.2), Demo 14 (task 16.4)*
Description	*Actions by and HF impact of human operators (i.e. Train drivers, CTC System Operators, TMS Operator) when using ATO-TMS*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.3, 15.4, 16.2, 16.4*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE12 - "Real-time convergence between planning & feedback loop from operations [TRL 4/5]."* *TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP2-R2DATO/(WP32), FP2-R2DATO/(WP39)*
Actor(s)	*TMS/TMS Operator ATO-TS, ATO-OB, CTC System Operator, Train Driver*
Sequence	*1. Interactions in normal conditions.* *2. Interactions in disturbed conditions (small delays).* *3. Interactions in disrupted conditions (changed services).*
Notes	*None*

Table 107: UC-FP1-WP10-32

UC-FP1-WP10-33: TMS enhancements to support C-DAS operations

Name	*TMS enhancements to support C-DAS operations*
ID	*UC-FP1-WP10-33*
Partner	*INDRA*
Demo associated	*Demo 13 (Task 16.3)*
Description	*Analysis of improvements in the TMS operation based on the data provided by C-DAS*

Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Task 16.3*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE12 - "Real-time convergence between planning & feedback loop from operations [TRL 4/5]."* *TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP2-R2DATO*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. TMS receives Status Report (SR).* *2. TMS optimises operation module triggers forecast calculation using position, speed, expected arrival times at timing points, …* *3. TMS operator replans in short term (a new RTTP is generated) using the graphical view and conflict detection/resolution.*
Notes	*None*

Table 108: UC-FP1-WP10-33

UC-FP1-WP10-34: C-DAS simulator

Name	*C-DAS simulator*
ID	*UC-FP1-WP10-34*
Partner	*CEIT*
Demo associated	*Demo 13 (Task 16.3)*
Description	*Improved simulation environment to improve efficiency of C-DAS operations considering the interaction with the TMS (received RTTP) and the effect of the OB2TS communications, on-board location estimation and energy optimisation on the JP/TPE calculation.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.3, and 16.3*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and*

	target times for ATO and dynamic timetables"
Interactions SP/FP	*FP2-R2DATO*
Actor(s)	*TMS, C-DAS TS, C-DAS OB*
Sequence	*In a simulation environment:* 1. *C-DAS TS receives RTTP* 2. *From the RTTP, C-DAS TS generates JP/TPEs for the trains* 3. *C-DAS OB calculates improved train trajectories with the JP received from C-DAS TS taking into account positioning accuracy and communications performance.* 4. *Status reports are sent back to C-DAS TS and JP/TPEs are updated*
Notes	*The actors C-DAS TS and C-DAS OB are both simulated*

Table 109: UC-FP1-WP10-34

UC-FP1-WP10-35: RTTP-updates to increase C-DAS efficiency

Name	*RTTP-updates to increase C-DAS efficiency*
ID	*UC-FP1-WP10-35*
Partner	*TRV*
Demo associated	*Demo 13 (Task 16.3)*
Description	*Provides support for updating the RTTP, manually and/or to some extent automatically, to improve the quality of the RTTP for C-DAS-equipped trains and optimize the overall efficiency of traffic management, in particular when there is a mix of trains with and without C-DAS.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.3, 16.3*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE12 - "Real-time convergence between planning & feedback loop from operations [TRL 4/5]."* *TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*SP interaction*
Actor(s)	*TMS/TMS Operator, RTTP Updater*

Sequence	1. *The TMS Operator turns on functionality for "improve C-DAS planning".* 2. *RTTP Updater calculates if there are inefficiencies in the current RTTP for the C-DAS trains. In particular, inefficiencies may be caused by non-C-DAS-trains deviating from its RTTP. When inefficiencies are detected, continue with next step.* 3. *RTTP Updater calculates an updated proposed RTTP (p-RTTP).* 4. *TMS illustrates relevant parts of p-RTTP, together with other relevant information* 5. *TMS Operator inspects p-RTTP and determine if and how RTTP should be adjusted.* 6. *The TMS Operator updates the RTTP. Minor modifications of RTTP might be made automatically without any explicit acceptance from TMS operator.* 7. *TMS sends the updated RTTP to C-DAS TS for normal handling for C-DAS equipped trains.* 8.
Notes	

Table 110: UC-FP1-WP10-35

UC-FP1-WP10-36: Traffic regulation based on the time of the day

Name	*Traffic regulation based on the time of the day*
ID	*UC-FP1-WP10-36*
Partner	*CAF*
Demo associated	*Demo 15 (task 16.5)*
Description	*In this use case, the regulation of transport in the face of possible disturbances will be defined by the time, whether it is a rush or an off-peak hour.* *If it is a rush hour, it will be regulated by headway.* *If it is an off-peak hour, it will be regulated by timetable*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.5, 16.5*
Impact on other task(s)	*None*

Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP6-FUTURE*
Actor(s)	*TMS/TMS Operator, ATO-OB*
Sequence	*It is needed at least two trains to test the interval regulation.* *1. Train A suffers a delay at the station exit of 5% of the planned time.* *2. It is evaluated if the established schedule is being met.* *3. Two situations:* *a. If it is fulfilled, end of the use case* *b. If it is not fulfilled, it is assessed whether it is in a peak or off-peak hour, to generate the regulation strategy.* *i. Time-base Regulation. Rush hour. In the checks it must be verified that it is regulating by interval.* *ii. Time-Base Regulation. Off-peak hour. In the checks, it must be verified that it is being regulated by time.* *4. The necessary Journey profile is generated with the new regulation conditions in order to recover the planning that was being worked on.* *5. The JPs are transmitted to the trains.* *6. Trains execute the received JPs.* *7. The regulation algorithm checks at the target point set by the regulation strategy whether schedule compliance has been recovered.* *8. Two situations:* *a. If compliance is achieved, end of the use case.* *b. If not fulfilled, return to section 3b.*
Notes	*Minimum two trains*

Table 111: UC-FP1-WP10-36

UC-FP1-WP10-37: Traffic regulation based in track areas

Name	*Traffic regulation based in track areas*
ID	*UC-FP1-WP10-37*
Partner	*CAF*
Demo associated	*Demo 15 (task 16.5)*

Description	*The regulation in this case will be defined by space, i.e. it will be influenced by whether the train is in an urban area or on the contrary in a branch line area.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.5, 16.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP6-FUTURE*
Actor(s)	*TMS/TMS Operator, ATO-OB*
Sequence	*It is needed at least two trains to test the interval regulation.* *1. Train A suffers a delay at the station exit of 5% of the planned time.* *2. It is evaluated if the established schedule is being met.* *3. Two situations:* *a. If it is fulfilled, end of the use case.* *b. If it is not fulfilled, it is assessed whether it is in a rush or an off-peak hour, to generate the regulation strategy.* *i. Space-based Regulation. Urban core. Checks should verify that it is being regulated by interval.* *ii. Space-based Regulation. Branches. In the checks it must be verified that it is being regulated by time schedule.* *4. The necessary Journey profile is generated with the new regulation conditions in order to recover the planning that was being worked on.* *5. The JPs are transmitted to the trains.* *6. Trains execute the received JPs.* *7. The regulation algorithm checks at the target point set by the regulation strategy whether schedule compliance has been recovered.* *8. Two situations:* *a. If compliance is achieved, end of the use case.* b. *If not fulfilled, return to section 3b.*
Notes	*Minimum two trains*

Table 112: UC-FP1-WP10-37

UC-FP1-WP10-38: Traffic regulation considering adhesion factors

Name	*Traffic regulation considering adhesion factors*
ID	*UC-FP1-WP10-38*
Partner	*CAF*
Demo associated	*Demo 15 (task 16.5)*
Description	*The regulation in this case will be defined by space or by time, i.e., focusing on space, it will be influenced by whether the train is in an urban area or on the contrary in a branch line area, otherwise, if we focus on time there will be these two options:* • *If it is a rush hour, it will be regulated by headway.* • *If it is an off-peak hour, it will be regulated by timetable.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.5, 16.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP6-FUTURE*
Actor(s)	*TMS/TMS Operator, ATO-OB*
Sequence	*It is needed at least two trains to test the interval regulation.* *1. Train A receives a JP coming from the regulation system warning that there is a change of adhesion.* *2. The ETCS curve is reduced and therefore the ATO curve is reduced. This implies that the speed of the train is reduced.* *3. There is a delay of 5 to 10% over the planning in which the train is operating.* *4. An assessment is made as to whether the established schedule is being adhered to.* *5. Two situations:* *a. If it is fulfilled, end of the use case* *b. If it is not fulfilled, it is evaluated whether it is regulated by time of day or by the space through which the train is running.* *6. Two situations:* *a. If the train is running taking into account, the time of*

	day. i. It is assessed whether it is in a peak or off-peak hour, in order to generate the regulation strategy. ii. The necessary Journey profile is generated with the new regulation conditions in order to recover the planning that was being worked on. Iii. The JPs are transmitted to the trains in real-time, without the need for the trains to arrive at the stations. Iv. Trains execute the received JPs. v. The regulation algorithm checks at the target point set by the regulation strategy whether schedule compliance has been recovered. Vi. Two situations: 1. If complied with, end of the use case. 2. If not complied with, return to section 6.a.i. b. If the train runs taking into account, the space through which it is running. i. It is assessed whether it is located in the urban core or in a branch area, in order to generate the regulation strategy. ii. The necessary Journey profile is generated with the new regulation conditions in order to recover the planning that was being worked on. iii. The JPs are transmitted to the trains in real-time, without the need for the trains to arrive at the stations. iv. Trains execute the received JPs. v. The regulation algorithm checks at the target point set by the regulation strategy whether schedule compliance has been recovered. vi. Two situations: 1. If compliance is met, end of the use case 2. 2. If not complied with, return to section 6.b.i.
Notes	*Minimum two trains*

Table 113: UC-FP1-WP10-38

UC-FP1-WP10-39: ATO-TMS integration

Name	*ATO-TMS integration*
ID	*UC-FP1-WP10-39*

Partner	*AZD*
Demo associated	*Demo 15 (task 16.5)*
Description	*Demonstration of ATO-TS-TMS integration platform (Integration Layer) developed in subtask 15.4.4 to prove a function of given framework between TMS subsystem and ATO-TS supporting autonomous train operations to manage data transfer between the technologies/subsystems involved in WP15*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 15.4.4, 16.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*FP2-R2DATO, FP6-FUTURE*
Actor(s)	• *Integration Layer* • *TMS/ TMS Operator* • *ATO-TS* (or GoA3-4 equivalent system) • Train Driver/ATO-OB able to operate the train
Sequence	1. *The TMS – ATO-TS integration platform (Integration Layer) continuously reacts to the events that occur on both TMS and ATO-TS sides.* 2. *The TMS operator or autonomous TMS subsystem sets train paths for involved train(s).* 3. *The TMS provides the planned timetable and is able to adjust this timetable regarding the current traffic situation.* 4. *The ATO-TS communicates with ATO-OB/C_DAS OB of involved train(s):* a. *Presents the adjusted timetable and train path following the input from TMS to the trains.* b. *Gets positions and estimated arrival times from the trains, and passes this information to the TMS and its subsystems in order to be able to optimise the traffic.*
Notes	STS will provide the integration platform developed in subtask 15.4.4

Table 114: UC-FP1-WP10-39

UC-FP1-WP10-40: Performances comparison between C-DAS-C and C-DAS-O architectures

Name	*Performances comparison between C-DAS-C and C-DAS-O architectures*
ID	*UC-FP1-WP10-40*
Partner	*STS*
Demo associated	*Demo 13 (task 16.3)*
Description	*Demonstration of two C-DAS architectures, C-DAS-C (according to D15.1) and C-DAS-O (according to D15.1), and the comparison between their performances in terms of energy saving using algorithms from WP12.* *The innovation of the approach lies in comparing two architectures:* • *the C-DAS-C that calculates trackside train positions and therefore the energy saving profiles thus avoiding the integration with onboard odometry to collect train positions, thus limiting onboard installations to drastically reduce recurrent engineering costs;* • *the C-DAS-O that makes onboard all energy saving calculations thus requiring the onboard installation of a GPS sensor.*
Related to WP(s)	*WP15/16*
Related to task/subtask(s)	*Tasks 16.3*
Impact on other task(s)	*FP1/WP12 (Task 12.2.3)*
Technical Enabler(s)	*TE12 - "Real-time convergence between planning & feedback loop from operations [TRL 4/5]."* *TE15 - "TMS speed regulation of trains, precise routes and target times for ATO and dynamic timetables"*
Interactions SP/FP	*None*
Actor(s)	Integration Layer, TMS, ATO-TS, C-DAS TS, C-DAS OB

Sequence	1. *Demonstration of a C-DAS-C architecture (with the C-DAS module at trackside level) and collection of the results.* 2. *Demonstration of a C-DAS-O architecture (with the C-DAS module on board) and collection of the results.* 3. *Comparison between performances of the two architectures in terms of energy saving.*
Notes	*None*

Table 115: UC-FP1-WP10-40

UC-FP1-WP10-62: Operational Plan update through TMS and ATO-TS interaction

Name	*Operational Plan update through TMS and ATO-TS interaction.*
ID	*UC-FP1-WP10-62*
Partner	MERMEC
Demo associated	Demo 15.3
Description	Improving forecasting calculation by using ATO-TS feedback (Status Report) and updating RTTP to be exchanged with ATO-TS.
Related to WP(s)	WP15/16
Related to task/subtask(s)	Tasks 15.3, 16.5
Impact on other task(s)	FP1 WP17/18 (Task 17.2.8, 18.2.8)
Technical Enabler(s)	TE 12 - "Real-time convergence between planning & feedback loop from operations"
Interactions SP/FP	SP requirements.
Actor(s)	TMS, TMS Operator, ATO-TS
Sequence	1. *TMS sends RTTP to CCS/ATO-TS.* 2. *TMS receives a Status Report from CCS/ATO-TS* 3. *Forecast is updated using the information of the above report.* 4. *Any conflicts are detected by TMS.* 5. *Conflicts are solved.* 6. *RTTP and Operational Plan are updated.* 7. *TMS sends updated RTTP to CCS/ATO-TS*

Involved components (System)	*TMS Event Logger, TMS Deviation Detection module, TMS Forecast Calculation module, TMS Conflict Detection module, TMS Conflicts Resolution module, TMS Operational Plan, TMS UI*
Notes	*Prerequisites: current capacity plan loaded.*

Table 116: UC-FP1-WP10-62

Relative to WP17/18 (Detection and resolution of conflict)

UC-FP1-WP10-41: Notification of conflict

Name	*Notification of conflict*
ID	*UC-FP1-WP10-41*
Partner	*ÖBB-INFRA*
Demo associated	*Demo 16 (task 18.2.1)*
Description	*TMS Conflict Detection Module detects conflict and triggers notification to TMS Operator.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Task 17.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP interaction*
Actor(s)	*TMS/ TMS Operator*
Sequence	1. *The system reacts either to already happened unforeseeable conflicts e.g. due to technical or human errors, etc, or it forecasts the upcoming conflicts and calculates countermeasures to prevent them from happening.* 2. *The system simulates the trains and predicts a possible conflict in a given time frame.* 3. *The notification to the TMS Operator is triggered.*
Involved components (System)	TMS Conflict Detection module
Notes	*None*

Table 117: UC-FP1-WP10-41

UC-FP1-WP10-42: Presentation of notification

Name	*Presentation of notification*
ID	*UC-FP1-WP10-42*
Partner	*ÖBB-INFRA*
Demo associated	*Demo 16 (task 18.2.1)*
Description	*Notifications about the conflict are presented to the TMS Operator.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Task 17.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP interaction*
Actor(s)	*TMS/ TMS Operator*
Sequence	*1. Based on the types of conflicts, the notification about the conflict is presented to the TMS Operator.*
Involved components (System)	TMS Conflict Detection module
Notes	*None*

Table 118: UC-FP1-WP10-42

UC-FP1-WP10-43: Presentation of additional information on conflict

Name	*Presentation of additional information on conflict*
ID	*UC-FP1-WP10-43*
Partner	*ÖBB-INFRA*
Demo associated	*Demo 16 (task 18.2.1)*
Description	*Upon the TMS Operator's interaction (e.g. mouse click), additional information about the conflict is presented (e.g. train type, train number, reason for conflict). If calculation of solutions is already finished, solutions are presented as well. All*

	"additional information" is presented in a clear and concise manner.
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Task 17.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP interaction*
Actor(s)	*TMS/ TMS Operator*
Sequence	*1. The TMS Operator interacts with the system to receive additional information on the conflict.* *2. All relevant information to take reactive or predictive measures are presented.* *3. The TMS Operator performs the measures.*
Involved components (System)	*TMS Conflict Detection module, TMS Conflict Resolution module*
Notes	*None*

Table 119: UC-FP1-WP10-43

UC-FP1-WP10-44: Resolution of conflict

Name	*Resolution of conflict*
ID	*UC-FP1-WP10-44*
Partner	*ÖBB-INFRA*
Demo associated	*Demo 16 (task 18.2.1)*
Description	*TMS Conflict Resolution Module assesses the conflict's impact on the rail network and calculates - within a predefined timeframe - three different options (different number or options could be provided) to resolve the conflict (e.g. redirecting other trains etc.). If no resolution is calculated (e.g. after calculation abort), the module triggers a notification to the TMS Operator and operational management. The TMS Operator provides feedback to the system regarding the quality of proposed solutions.*
Related to WP(s)	*WP17/18*

Related to task/subtask(s)	*Task 17.2.1*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP interaction*
Actor(s)	*TMS/ TMS Operator*
Sequence	*1. The TMS Conflict Resolution module gets notified about the conflict.* *2. The TMS Conflict Resolution module calculates possible solutions and triggers the presentation to the TMS Operator.* *3. The TMS Operator provides feedback about the quality of the proposed solutions.*
Involved components (System)	TMS Conflict Resolution module
Notes	*None*

Table 120: UC-FP1-WP10-44

UC-FP1-WP10-45: Automatic Conflict Detection and Resolution using AI applied to Depots and Terminal Stations environment

Name	*Automatic Conflict Detection and Resolution using AI applied to Depots and Terminal Stations environment*
ID	*UC-FP1-WP10-45*
Partner	*ENYSE*
Demo associated	*Demo 17 (task 18.2.2)*
Description	*Provide updated operational plan by applying optimized conflict resolution to the conflicts indicated by the forecast based on the user choosing from the list of all possible solutions identified by AI*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.2, 18.2.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*

Interactions SP/FP	*FP6 - FUTURE (application to Regional Lines)*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. A conflict is detected when a train is about to enter/leave a depot or a terminal station, then* *a. TMS Conflict Identification Module detects conflict when a train is about to be introduced at the depot and triggers notification to TMS Operator ==> impact on the depot* *b. TMS Conflict Identification Module detects conflict when a train is about to leave the depot and triggers notification to TMS Operator ==> impact on main line* *c. TMS Conflict Identification Module detects conflict when a train is about arriving a terminal station and triggers notification to TMS Operator ==> impact on the terminal station* *d. TMS Conflict Identification Module detects conflict when a train is about leaving a terminal station and triggers notification to TMS Operator ==> impact on main line* *2. The TMS Conflict Resolution module presents info about the conflict to the TMS Operator and propose different calculation alternatives based on user needs (including ranking criteria), then* *3. The TMS Conflict Resolution module calculates possible solutions and presents them ranked (according to the defined criteria) to the dispatcher, and then* *4. The TMS Operator provides feedback about the quality of the proposed solutions (if any)*
Notes	*None*

Table 121: UC-FP1-WP10-45

UC-FP1-WP10-46: Optimized conflict resolution based on realistic forecast calculation

Name	*Optimized conflict resolution based on realistic forecast calculation*
ID	*UC-FP1-WP10-46*

Partner	*HACON*
Demo associated	*Demo 18 (task 18.2.3)*
Description	*Provide updated operational plan by applying optimized conflict resolution to the conflicts indicated by the forecast*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.3, 17.2.6, 18.2.3*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS / TMS operator*
Sequence	1. *An incoming train position report or a TCR change causes train delays and related conflicts of impacted trains are detected following the updated train running forecast.* 2. *TMS Operator initiates optimized Conflict Resolution.* 3. *TMS displays solutions to trains' conflicts in a sandbox for studying.* 4. *TMS Operator confirms implementation of the solution.* 5. *Operational Plan is updated accordingly.*
Notes	*None*

Table 122: UC-FP1-WP10-46

UC-FP1-WP10-47: Automated very short-term decision making for real-time operation for departing train

Name	*Automated very short-term decision making for real-time operation for departing train*
ID	*UC-FP1-WP10-47*
Partner	*GTSD*
Demo associated	*Demo 19 (Subtask 18.2.4)*
Description	*Within a time slot between 0 and few minutes system detects a blocking for a train, ready to depart from platform. System will stop the train at platform to avoid higher impact.*
Related to WP(s)	*WP17/18*

Related to task/subtask(s)	*Subtask 17.2.5, 18.2.4*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE16 - "Automation of very short-term train control decisions"*
Interactions SP/FP	*FP2-R2DATO/(WP44/45)*
Actor(s)	*TMS/TMS Operator*
Sequence	*None*
Notes	*Assumption: Development can be started in 2023 using existing X2R4 CDM environment to exchange Data with TMS.*

Table 123: UC-FP1-WP10-47

UC-FP1-WP10-48: Automated very short-term decision making for real-time operation to keep sequence

Name	*Automated very short-term decision making for real-time operation to keep sequence*
ID	*UC-FP1-WP10-48*
Partner	*GTSD*
Demo associated	*Demo 19 (Subtask 18.2.4)*
Description	*Within a time, slot between 0 and few minutes system detects a sequence conflict with other train. System will delay lower priority train if impact on operational plan can be minimized.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Subtask 17.2.5, 18.2.4*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE16 - "Automation of very short-term train control decisions"*
Interactions SP/FP	*FP2-R2DATO/(WP44/45)*
Actor(s)	*TMS/TMS Operator*
Sequence	*None*
Notes	*Assumption: Development can be started in 2023 using existing X2R4 CDM environment to exchange Data with TMS.*

Table 124: UC-FP1-WP10-48

UC-FP1-WP10-49: Operator notification in case of automated very short-term decision making

Name	*Operator notification in case of automated very short-term decision making*
ID	*UC-FP1-WP10-49*
Partner	*GTSD*
Demo associated	*Demo 19 (Subtask 18.2.4)*
Description	*Operator must be informed about automated decision making by system. He must know impact and remaining time to reject automated action.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Subtask 17.2.5, 18.2.4*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE16 - "Automation of very short-term train control decisions"*
Interactions SP/FP	*FP2-R2DATO/(WP44/45)*
Actor(s)	*TMS/TMS Operator*
Sequence	*None*
Notes	*None*

Table 125: UC-FP1-WP10-49

UC-FP1-WP10-50: For real-time operation system must request movement authorities

Name	*For real-time operation system must request movement authorities*
ID	*UC-FP1-WP10-50*
Partner	*GTSD*
Demo associated	*Demo 19 (Subtask 18.2.4)*
Description	*System must simulate timing and extend of Movement Authorities to execute TMS plan best possible.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Subtask 17.2.5, 18.2.4*

Impact on other task(s)	*None*
Technical Enabler(s)	*TE16 – "Automation of very short-term train control decisions"*
Interactions SP/FP	*FP2-R2DATO/(WP44/45)*
Actor(s)	*TMS/APS*
Sequence	*None*
Notes	*Assumption 1: FP2-APS is executing ETCS L3 Moving Block or ETCS L3 Hybrid, Moving Block which track occupations.* *Assumption 2: SCI-CMD interface specification is available in a mature state, ready for standardization.* *If these assumptions cannot be applied, this part has to be postponed to next wave projects.*

Table 126: UC-FP1-WP10-50

UC-FP1-WP10-51: Optimized conflict detection and resolution

Name	*Optimized conflict detection and resolution*
ID	*UC-FP1-WP10-51*
Partner	*STS*
Demo associated	*Demo 20 (Subtask 18.2.5)*
Description	*Provide forecasted operational plan by applying optimized conflict detection and resolution; multiple plans shall come from the optimal solution according to different specified criteria.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.6, 18.2.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	1. *Acquisition of the Operational Plan.* 2. *Analysis of the Operational Plan.* 3. *Generation of multiple Preliminary Production Plans, each guided by a given set of criteria.* 4. *Publishing of the Preliminary Production Plans.*

Notes	*None*

Table 127: UC-FP1-WP10-51

UC-FP1-WP10-52: Train that cannot continue its route

Name	*Train that cannot continue its route*
ID	*UC-FP1-WP10-52*
Partner	*FS*
Demo associated	*Demo 20 (Subtask 18.2.5)*
Description	*The TMS Operator may suspend the automatic route setting for a train in the event the train cannot continue.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Subtask 17.2.6, 18.2.5*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. The TMS Operator recognizes a train that could cause a traffic disruption.* *2. The TMS Operator suspends the automatic route setting for this train.* *3. The optimizer considers the train unavailable to move for a configurable time interval.* *4. When the service is reallocated, the forecast calculation and automatic conflict resolution are updated.*
Involved components (System)	*TMS Conflict Detection module, TMS Conflict Resolution module, TMS HMI*
Notes	*None*

Table 128: UC-FP1-WP10-52

UC-FP1-WP10-53: Dispatcher constraints entry

Name	*Dispatcher constraints entry*

ID	*UC-FP1-WP10-53*
Partner	*FS*
Demo associated	*Demo 20, 23 (Subtasks 18.2.5 and 18.2.8)*
Description	*The TMS Operator sets one or more constraints which are binding for the optimizer.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Subtasks 17.2.6, 17.2.8, 18.2.5, 18.2.8*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. The TMS Operator sets a constraint into the system.* *2. The optimizer cannot remove the constraint defined by the TMS Operator.* *3. The optimizer must take into account the constraint in the elaborations.*
Involved components (System)	*TMS Conflict Detection module, TMS Conflict Resolution module, TMS HMI*
Notes	*None*

Table 129: UC-FP1-WP10-53

UC-FP1-WP10-54: Ability to provide multiple solutions

Name	*Ability to provide multiple solutions*
ID	*UC-FP1-WP10-54*
Partner	*AZD*
Demo associated	*Demo 21 (task 18.2.6)*
Description	*The system shall provide multiple conflict-free resolutions if possible.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.6, 18.2.6*

Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"* *TE16 - (partially)*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. Detection of the conflict.* *2. Request to resolve the conflict.* *3. Multiple conflict-free solutions should be provided.*
Notes	*None*

Table 130: UC-FP1-WP10-54

UC-FP1-WP10-55: Real-time operation of algorithm

Name	*Real-time operation of algorithm*
ID	*UC-FP1-WP10-55*
Partner	*AZD*
Demo associated	*Demo 21 (task 18.2.6)*
Description	*Automatic conflict detection as soon as they appear in time, conflict resolution on request.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.6, 18.2.6*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"* *TE16 - (partially)*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. Conflict occurrence in the traffic forecast.* *2. Immediate detection of the conflict by TMS.* *3. Identification of the type of conflict by TMS.* *4. The visual representation of the conflict depending on its type.*

Notes	*None*

Table 131: UC-FP1-WP10-55

UC-FP1-WP10-56: Automatic Conflict detection and resolution

Name	*Automatic Conflict detection and resolution*
ID	*UC-FP1-WP10-56*
Partner	*INDRA*
Demo associated	*Demo 22 (Subtask 18.2.7)*
Description	*For a conflict or number of conflicts, develop a system to automatically solve them, taken into account pre-defined parameters for the solution*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.7*
Impact on other task(s)	*FP1/ (WP6, WP7)*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. Define types of conflict involved in the automatic conflict detection and resolution.* *2. Define detection conditions for each type of conflict.* *3. 3.Define available resolution methods for each type of conflict.* *4. Define assessment of each resolution method.* *5. Order resolution methods by propriety (assessment) for each type of conflict.* *6. Apply the resolution method according to assessment.*
Notes	*None*

Table 132: UC-FP1-WP10-56

UC-FP1-WP10-57: Decision support system for different conflicts

Name	*Decision support system for different conflicts*

ID	*UC-FP1-WP10-57*
Partner	*INDRA*
Demo associated	*Demo 22 (Subtask 18.2.7)*
Description	*Develop a system that allows to simulate different situations e.g. the conflict solution obtained in WP17, and other solutions applied by TMS Operator.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 18.2.7*
Impact on other task(s)	*FP1/(WP6, WP7)*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator*
Sequence	*1. The system operates in real-time detecting all existing conflicts based on forecast calculation.* *1. It presents them in an open sandbox for visualization.* *2. Utilizing the sandbox environment, a resolution method is applied to address the identified conflicts.* *3. The behaviour of elements involved in the scenario is monitored within the sandbox.* *4. Conflict resolution is applied, so that changes can be made in the timetable, providing a new free-conflict one.*
Notes	*None*

Table 133: UC-FP1-WP10-57

UC-FP1-WP10-58: Conflict detection and resolution

Name	*Conflict detection and resolution*
ID	*UC-FP1-WP10-58*
Partner	*MERMEC*
Demo associated	*Demo 23 (task 18.2.8)*
Description	*Providing conflict detection after a train deviation and applying or suggesting conflict solution.*
Related to WP(s)	*WP17/18*

Related to task/subtask(s)	*Tasks 17.2.8,18.2.8*
Impact on other task(s)	*FP1/(WP11-12) (Tasks 11.3.5, 12.2.5)*
Technical Enabler(s)	*TE16 – "Automation of very short-term train control decisions"* *TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP requirements.*
Actor(s)	*TMS/ TMS Operator*
Sequence	*1. A deviation for a train is detected by the related module.* *2. Forecast is updated for the above train.* *3. Conflicts are detected and shown to the TMS Operator (semi-automatic mode).* *4. Conflicts are solved and solution is applied in automatic mode or proposed to the TMS Operator in semi-automatic mode.* *5. TMS Operator can choose a solution in semi-automatic mode.*
Involved components (System)	*TMS Event Logger, TMS Deviation Detection module, TMS Forecast Calculation module, TMS Conflict Detection module, TMS Conflicts Resolution module, TMS Operational Plan, TMS HMI*
Notes	*Prerequisites: current plan loaded.*

Table 134: UC-FP1-WP10-58

UC-FP1-WP10-59: Very short-term decision

Name	*Very short-term decision*
ID	*UC-FP1-WP10-59*
Partner	*MERMEC*
Demo associated	*Demo 23 (task 18.2.8)*
Description	*In automatic and semi-automatic mode in the case in which the operational plan has to be performed within a couple of minutes the system shall actuate it.*
Related to WP(s)	*WP17/18*
Related to task/subtask(s)	*Tasks 17.2.8,18.2.8*
Impact on other task(s)	*None*

Technical Enabler(s)	*TE16 – "Automation of very short-term train control decisions"* *TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*SP requirements.*
Actor(s)	*TMS*
Sequence	*1. A conflict with a conflict solution proposal is present on TMS HMI.* *2. The conflict should be solved in at last couple of minutes or it remains unsolved, so the TMS Conflict Resolution module forces the solution that is based on the chosen algorithm.* *3. The conflict disappears on TMS HMI.*
Involved components (System)	*TMS Event Logger, TMS Deviation Detection module, TMS Forecast Calculation module, TMS Conflict~~s~~ Detection module, TMS Conflict~~s~~ Resolution module, TMS Operational Plan, TMS HMI.*
Notes	*Prerequisites: current plan loaded, semi-automatic mode and a conflict to be solved is present (e.g., the TMS Operator has not made any choice).*

Table 135: UC-FP1-WP10-59

UC-FP1-WP10-60: Evaluation platform

Name	*Evaluation platform*
ID	*UC-FP1-WP10-60*
Partner	*SNCF*
Demo associated	*Demo 25 (task 18.3.2)*
Description	*Development of a platform, based on a microscopic simulator, to evaluate the performances of the TMS*
Related to task/subtask(s)	*Tasks 17.2.3,18.3.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator, IM*

Sequence	1. *Acquisition of all the input data: simulation model and parameters, optimization algorithms.* 2. *Definition of the features of the prediction and of the parameters of the interfaces between the prediction, the simulator and the optimization algorithms.* 3. *Definition and implementation of the evaluation KPIs.*
Notes	*None*

Table 136: UC-FP1-WP10-60

UC-FP1-WP10-61: Test bed for local TMS evaluation

Name	*Test bed for local TMS evaluation*
ID	*UC-FP1-WP10-61*
Partner	*SNCF*
Demo associated	Demo 25 (task 18.3.2)
Description	*Performance evaluation of optimisation algorithms for local level traffic management in a single region*
Related to task/subtask(s)	*Subtask 17.2.4, 18.3.2*
Impact on other task(s)	*None*
Technical Enabler(s)	*TE17 - "Real-time conflict detection & resolution for main line and optimization"*
Interactions SP/FP	*None*
Actor(s)	*TMS/TMS Operator, IM*
Sequence	1. *Definition of specific deployment parameters (which KPIs for the optimization algorithm and for the evaluation, frequency of the optimization, types of operational decisions).* 2. *Run of the evaluation platform to evaluate the algorithm performances.* 3. *If needed, improvement of the optimization algorithms and return to steps 1 and 2 for further evaluation.*
Notes	*Required inputs: historical data on perturbation scenarios, topology of the network, theoretical timetable, an evaluation platform, optimization algorithms*

Table 137: UC-FP1-WP10-61

13.2. Appendix B_ Innovative part of the developments/demos

The following table briefly identify the innovative part behind each demo making up the WS1.2 "Operations" and explain why it is an improvement of the existing system.

Demonstrations for WS1.2				
No	**Partners**	**Task**	**Description of Demonstration**	**Improvement, innovative input behind the development and demo**
WP11/12				
1	ATSA	12.2.1	Interfaces from the communication Platform to the Timetable Management Applications and to the Traffic Control (RBC, IXL).	TMS - CTC communication via Integration Layer (Communication Platform) using generic API with interoperable data model (CDM compliant). The publish - subscribe information exchange pattern, client systems separation by communication platform additionally promotes interoperability and efficiency in distributed and scalable environment. The demonstrator will show operational timetable exchange, train status, route status delivery and restrictions/ limitations exchange. All information will be available on communication platform via generic API allowing other systems to interact with it - access to read or provide / supplement additional related information enhancing railway operations.
2	PKP	12.2.2	Integration solution for the data exchange and storage system (data lake) allowing the exchange through interfaces, […].	Allows multifaceted integration of disparate data sources, including TMS leading to data centralization. This allows for fluid creation of decision support solutions including integration of trans-border travel into station commercialization planning.
3	STS	12.2.3	Interface from TMS Planning system to ATO-TS control module to maximise the energy efficiency […]	Use of train position at different granularities to identify the optimal number of extra timing points to be added into the Detailed Timetable to reach a compromise between energy savings, driver's workload, and onboard installations adding substantial recurrent engineering costs.
4	INDRA	12.2.4	Interfaces from the communication Platform to wayside C-DAS operation system, focusing on speed profiles functionalities.	Our development enhances real-time communication between TMS and C-DAS TS, improving operational responsiveness. Bi-directional data exchange provides vital status updates, ensuring coordination. Compliant with CDM (S2R) standards, our solution promotes interoperability and efficiency, ultimately enhancing railway operations.

5	MERMEC	12.2.5	Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between […]	Communication between neighbouring TMS to exchange run time train data (forecast, delay, ...) to be used to better evaluate conflicts
6	HACON	12.2.6	interfaces and decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border operations (supporting Destination 5 activities).	TMS-to-TMS communication for exchange of Train Forecast and operational restrictions including their status, including cross-borders.
7	HACON	12.2.7	Interfaces for integration of TMS with other services such as station and yard management systems […]	TMS communication with local (station/yard) CMS for exchanging information impacting capacity production and yard/station management. Consideration of knock-on delay effects caused by crew exchange or re-use of rolling stock and related train links sent by RUs. Provide operational feedback to CMS for improved capacity planning. Improved forecast calculation taking power restrictions into account as provided by Electric Traction Systems.
8	TRV	12.2.8	Interface of TMS to Yard Coordination System 2.0 in Malmö node. Work connects to WP 4.	Coordinated track allocation planning at arrival/departure freight yard. Defined processes for foresighted planning regarding request and approval of resource needs at the yard. Foresight in conflict detection regarding track allocation. Information exchange between different roles of users (instead of making phone calls). Visualization of information need for track allocation. Real-time update of most important information for track allocation (ETA/ETD).
9	CEIT	12.2.9	Interface in view of the future autonomous inspection vehicle for the infrastructure (FP 3) and its integration with the (IAMS). […]	Introduction of the Autonomous Inspection Vehicle (AIV) Novel interfaces towards the integration of TMS, IAMS and AIV. This includes: interfaces to manage the AIV from TMS and IAMS, interfaces to receive info from AIV by TMS and IAMS and interface for IAMS and TMS .
WP13/14				
10.1	STS, TRV	14.1	Collaborative DSS	optimized management of disruption and events, by providing interactive useful information and tools to enhance cooperation among actors (both systems and operator with different responsibilities)

10.2	NSR	14.1	Decision support for rolling stock dispatching	More effective rolling stock dispatching via an optimization algorithm in a decision support system instead of manual dispatching.
10.3	HACON	14.1	Collaborative DSS for efficient and effective disruption management	Multi-actor decision alignment between Traffic Management and infrastructure maintenance& repair planning/management based on TMS integrated with Maintenance Planning System.
11	TRV, STS, INDRA	14.2	HMI for TMS based on User Experience (UX) Design and user input	Analysis and integration of Key Performance Indicators (KPIs) to measure dispatcher workload within the developed HMI, enhancing overall operational efficiency and user experience.
WP15/16				
12	PR, TRV, NSR, KB, ADIF, CAF	16.2	"Live" demonstration for the public (or by video) of future TMS-ATO operations, including human factors	Testing and demonstrating feasibility of operational practice in emulated "real" environment the (S2R) designed ATO Operational Concept.
13.1	TRV, PR, NSR, STS	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management [..]	Improve the quality of the RTTP in the perspective of C-DAS operations by introducing better tools for the traffic controller and functionality to handle traffic with a mixture of trains that are equipped and not equipped with C-DAS. The tools should reduce the workload but still keep the traffic controller in full control of the situation.
13.2	INDRA	16.3	Improvement of forecast calculation through TMS and C-DAS integration	Leveraging interfaces from WP11/WP12, our INDRA TMS integrates C-DAS data, improving dispatcher decision-making and forecast accuracy by refining forecast calculations.
13.3	CEIT	16.3	Improved C-DAS operations	C-DAS performance evaluation considering uncertainties in Train to Ground wireless communication and in Train on-board position estimation.
13.4	STS	16.3	Performances comparison between C-DAS-C and C-DAS-O architectures (STS)	Performances evaluation and comparison in terms of energy saving of two different C-DAS architecture (C-DAS C and C-DAS O).
14	PR, TRV, NSR, KB	16.4	Human factors assessment with human-in-the-loop simulations of the TMS-ATO operational concept regarding all involved actors	Improved human factors management of future ATO technology, including practicability and operational viability

15.1	AZD, PR, STS	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based […]	Testing and demonstration of brand new TMS <-> ATO interoperable platform (developed in SubTask 15.4.4.), in real railway environment (regional line in Czech Republic).
15.2	CAF, ADIF	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based […]	Ability to regulate railway traffic through an algorithm that allows us to do it by headway or by timetable, taking into account the relationship between TMS and ATO.
15.3	MERMEC	16.5	Improvement of traffic forecast and operational plan update through TMS and ATO-TS integration	Improving the forecast evaluation and conflict detection by using the ATO-TS feedback.
WP17/18				
16	ENYSE, ÖBB-INFRA, PR, NRD	18.2.1	Demonstrator for Real Time Conflict Identification & Resolution.	A conflict identification and resolution algorithm. The innovative aspects can be summarized as follows: (i) Two-Part algorithm structure (conflict identification module and conflict resolution module) which enhances the efficiency and effectiveness of the overall system. (ii) Utilization of Flatland for Initial Testing: a simulation framework designed for multi-agent reinforcement learning without the need to create a complex railway model from scratch. This step allowed for rapid prototyping and testing of ideas, (iii) Adoption of Multi-Agent Pathfinding Techniques: The integration of advanced multi-agent pathfinding techniques from the robotics domain, such as Conflict-Based Search (CBS) and Large Neighbourhood Search (LNS), into the railway conflict resolution algorithm is a novel approach. CBS and LNS are powerful strategies that can significantly improve the efficiency and effectiveness of conflict resolution in a multi-agent context like railway systems, (IV) Focus on Real-Time Decision Making: The ultimate goal of designing an algorithm capable of making real-time decisions to mitigate conflicts is ambitious and highly relevant. Real-time decision-making in railway operations can lead to significant improvements in efficiency, safety, and passenger satisfaction.

17	ENYSE	18.2.2	Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection […]	Improve decision making process in case of conflict when operating trains in Depots and Terminal Stations. To do so, the demo will show the results of training and optimizing AI algorithm for conflict resolution in Depots and Terminal Station environments. Demonstrator will also show the differences between a traditional approach and the new one based on AI
18	HACON	18.2.3	Demonstrator for Improved Decision Support	Provision of updated Operational Plan in TMS by applying optimized conflict resolution in a sandbox facilitating a what-if? view. The conflict detection is based on a realistic train running forecast.
19	GTSD	18.2.4	Demonstrator for Advanced Automation of Real time Operation	Performing automated actions from very short-term conflict detection within next few minutes from "now", where no manual operator interaction is possible. In this timespan movement authorities, already granted, are to be deleted or modified by interaction with MBS (moving block system) via PE (plan execution) module. System is designed to operate ETCS L2 moving block operation for trains with and without train integrity supervision. Demonstration will provide a user interface for notification and rejection by operator. Demonstration will send back an updated operational plan to TMS after confirmation by MBS simulator. Goal is to minimise impact on real time operation in case of very short-term disturbances or failures.
20	STS, FS	18.2.5	Demonstrator for Advanced Decision Support for Real time Operation	Support decision-making by facilitating What-If and Impact analysis enabled by multi-criteria conflict detection and resolution.
21	AZD	18.2.6	Demonstrator for Advanced Conflict Decision Support and Route Setting	Facilitation of decision-making processes by applying conflict decision data to Automatic Route Setting.
22	INDRA	18.2.7	Decision Support for improved traffic management operation	Our development introduces an advanced Decision Support System (DSS) for traffic management, automating conflict resolution, providing real-time disruption simulation, and offering a sandbox environment for experimentation. This streamlines operations, reduces regulator workload, and optimizes timetables, significantly enhancing railway efficiency.

23	MERMEC, FS	18.2.8	Demonstrator for Automation of Real time Operation	New conflict detection and resolution algorithm based on realistic forecast calculation evaluating also weather forecasts
24	ÖBB-INFRA, PR, NSR, ENYSE, NRD	18.3.1	Simulation of real time conflict identification and resolution	The simulation of real time conflict identification and resolution provides a predictive approach that foresees the upcoming conflicts and provides solutions for them before happening with the following features: (i) Advanced conflict scenarios: simulating a wide variety of complex and realistic conflict scenarios beyond typical delays and malfunctions. ensures robust testing and adaptability of the algorithm, (ii) Adaptive learning: incorporating adaptive learning algorithms that evolve based on simulation outcomes leads to more resilient and effective conflict resolution strategies, (iii) Integration of real-time data: to test how well the algorithm adapts to real-world, real-time conditions. This approach can enhance the relevance and applicability of the simulation results, (iv) Interactive and immersive visualization tools: to provide a more intuitive understanding of conflict scenarios and resolution strategies, (v) Scenario-based testing and validation: this framework ensures comprehensive coverage and helps identify strengths and weaknesses in the conflict resolution strategies, (vi) Scalability and flexibility: to enable handling of large amount of data of extensive networks, (vii) Incorporating human factors to provide more realistic and practical insights into conflict resolution.

25	SNCF	18.3.2	Performance evaluation of optimisation algorithms for local level traffic management in a single region	The first innovative dimension of this demo consists of the development of a closed-loop framework for assessing the performance of traffic management algorithms. In this framework, a microscopic traffic simulator will play the role of the field, controlling the interlocking and the trains, and monitoring the traffic situation. Periodically (e.g., every five minutes), a conflict detection and resolution algorithm will be executed to make decisions on train routing and passing orders for a future time horizon (e.g., of an hour). It will share these decisions with the simulator, and the latter will control the interlocking for them to be implemented. This type of closed-loop may be implemented in reality if an automated traffic management was to be put in place, or an operator may be in charge of validating the algorithm choice before implementation. With this framework, the performance of algorithms will be assessed. The second innovative dimension of the demo is making this assessment independent on the modelling hypothesis made in the algorithm. This independence brings the assessment much closer to an actual practical evaluation than what is typically done in the state of the art and practice.

Table 138: Innovative part of the demos from WS1.2 "Operations"

13.3. Appendix C Traceability in demo numbering

Once the first version of this deliverable was created and delivered, it was decided to change the demonstration numbering as part of other subsequent deliverables. To achieve alignment, the following table includes the traceability between the numbering used in this deliverable and the new numbering used in subsequent deliverables of FP1-[MOTIONAL].

Partners	Task	Description of Demonstration	Old demo number in D10.1	New demo number in other subsequent deliverables in FP1
ATSA	12.2.1	Interfaces from the communication Platform to the Timetable Management Applications and to the Traffic Control (RBC, IXL).	1	12.1
PKP	12.2.2	Integration solution for the data exchange and storage system (data lake) allowing the exchange through interfaces, […].	2	12.2
STS	12.2.3	Interface from TMS Planning system to ATO-TS control module to maximise the energy efficiency […]	3	12.3
INDRA	12.2.4	Interfaces from the communication Platform to wayside C-DAS operation system, focusing on speed profiles functionalities.	4	12.4
MERMEC	12.2.5	Demonstrator based on the interfaces coming from subtask 11.3.5 (implementing interfaces between […]	5	12.5
HACON	12.2.6	interfaces and decision support module for integration and traffic management of two neighbouring TMSs and IMs including cross-border operations (supporting Destination 5 activities).	6	12.6
HACON	12.2.7	Interfaces for integration of TMS with other services such as station and yard management systems […]	7	12.7
TRV	12.2.8	Interface of TMS to Yard Coordination System 2.0 in Malmö node. Work connects to WP 4.	8	12.8

CEIT	12.2.9	Interface in view of the future autonomous inspection vehicle for the infrastructure (FP 3) and its integration with the (IAMS). [...]	9	12.9
STS, TRV	14.1	Collaborative DSS	10.1	14.1
NSR	14.1	Decision support for rolling stock dispatching	10.2	14.2
HACON	14.1	Collaborative DSS for efficient and effective disruption management	10.3	14.3
TRV, STS, INDRA	14.2	HMI for TMS based on User Experience (UX) Design and user input	11	14.4
PR, TRV, NSR, KB, ADIF, CAF	16.2	"Live" demonstration for the public (or by video) of future TMS-ATO operations, including human factors	12	16.1
TRV, PR, NSR, STS	16.3	Prioritized enhancements developed from WP15 for improved efficiency of C-DAS operations from a traffic management [..]	13.1	16.3
INDRA	16.3	Improvement of forecast calculation through TMS and C-DAS integration	13.2	16.4
CEIT	16.3	Improved C-DAS operations	13.3	16.5
STS	16.3	Performances comparison between C-DAS-C and C-DAS-O architectures (STS)	13.4	16.6
PR, TRV, NSR, KB	16.4	Human factors assessment with human-in-the-loop simulations of the TMS-ATO operational concept regarding all involved actors	14	16.2
AZD, PR, STS	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based [...]	15.1	16.7
CAF, ADIF	16.5	ATO – TMS integration platform developed in subtask 15.3.4, implementing possible new requirements and architecture based [...]	15.2	16.8

MERMEC	16.5	Improvement of traffic forecast and operational plan update through TMS and ATO-TS integration	15.3	16.9
ENYSE, ÖBB-INFRA, PR, NRD	18.2.1	Demonstrator for Real Time Conflict Identification & Resolution.	16	18.1
ENYSE	18.2.2	Demonstrator specific application to Depots and Terminal Stations environments of Algorithms for Automatic Conflict Detection […]	17	18.2
HACON	18.2.3	Demonstrator for Improved Decision Support	18	18.3
GTSD	18.2.4	Demonstrator for Advanced Automation of Real time Operation	19	18.4
STS, FS	18.2.5	Demonstrator for Advanced Decision Support for Real time Operation	20	18.5
AZD	18.2.6	Demonstrator for Advanced Conflict Decision Support and Route Setting	21	18.6
INDRA	18.2.7	Decision Support for improved traffic management operation	22	18.7
MERMEC, FS	18.2.8	Demonstrator for Automation of Real time Operation	23	18.8
ÖBB-INFRA, PR, NSR, ENYSE, NRD	18.3.1	Simulation of real time conflict identification and resolution	24	18.1
SNCF	18.3.2	Performance evaluation of optimisation algorithms for local level traffic management in a single region	25	18.9

Table 139: Traceability between the old and new demo numbering