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FP1 MOTIONAL
European Rail Network and Mobility Management

Deliverable D 3.1
Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high-level design for demonstrators in WPs 4-9

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1. Executive Summary

This document constitutes the Deliverable D3.1 “Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high-level design for demonstrators in WPs 4-9” in the framework of the Flagship Project FP1-MOTIONAL.

The objective of this deliverable is to align, prepare and deliver the high-level specifications of requirements, high-level design, and high-level use cases for the development of the technical enablers 1 to 7. The high-level specification is done in parallel with more detailed specifications from WP4, WP6 and WP8. Participants from all WPs contributed to the texts.

In the project proposal, seven technical enablers were linked to Workstream 1.1 (Planning work packages), i.e., WP4/WP5 (Integration of Planning Systems and Processes), WP6/WP7 (Decision Support and Optimization) and WP8/WP9 (Simulation and Operational feedback). Here, each of the technical enablers are described in detail, including alignment with previous results, current state of practice, assigned development needs and high-level requirements.

An extensive mapping is also a result that is presented in this deliverable. All demonstrators (that further on will be called demonstrations) in Workstream 1.1 are introduced and described, together with related use cases. There are 13 demonstrations and they are all mapped against technical enablers, TRL levels, use cases and the high-level requirements defined for each technical enabler. They are also mapped against simulation environments and frameworks to be used within WP4/WP5, WP6/WP7 and WP8/WP9. Finally, the alignment and interactions between WP4-WP9 demonstrations and other FA1 WPs, other Flagship Projects and SP Task 3 CMS/TMS and RNE are mapped.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
AI	Artificial Intelligence
ATO	Automatic Train Operation
ATP	Automatic Train Protection
C-DAS	Connected Driver Advisory System
CI	Common Interface
CMS	Capacity Management System
ECMT	European Capacity Management Tool
ERA	European Union Agency for Railways
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
FRMCS	Future Rail Mobile Communications System
FTE	Forum Train Europe
GJT	Generalised Journey Time
GoA	Grade of Automation
HL3	Hybrid Level 3
HST	High Speed Train
HTO	Human, Technology, Organisation
IM	Infrastructure Manager
KAJT	Kapacitet i Järnvägstrafiken (engl. Capacity in the Railway Traffic System)
KPI	Key Performance Index
LTP	Long-term Planning
LZB	Linienzugbeeinflussung (Continuous Train Control)
MAWP	Multi Annual Work Program
MILP	Mixed-Integer Linear Programming
NG	Next Generation (Brake System)
PCS	Path Coordination System
PESP	Periodic Event Scheduling Problem
POT	Passenger-Oriented Timetabling
RDG	Rail Delivery Group
RFC	Rail Freight Corridor
RNE	RailNet Europe
RU	Railway Undertaking
S-DAS	Standalone Driver Advisory System
SERA	Single European Railway Area
SFERA	Smart communications For Efficient Railways Activities
SP	System Pillar
SPOT	Strategic Passenger-Oriented Timetabling
STP	Short-Term Planning
TAF	Telematics Applications for Freight services
TAP	Telematics Applications for Passenger services
TCR	Temporary Capacity Restriction

TE	Technical Enabler
TIMO	Timetable Modification Module
TMS	Traffic Management Systems
TOC	Train Operating Company
TPE	Train Path Envelope
TPS	Train Planning System
TRL	Technology Readiness Level
TSI	Technical Specifications for Interoperability
TTR	Timetable Redesign
YCS	Yard Coordination System

3. Background

The present document constitutes the Deliverable D3.1 "Mapping against scope, specification of technical enablers, high-level use cases, high-level requirements, high-level design for demonstrators in WPs 4-9" in the framework of the Flagship Project FP1-MOTIONAL as described in the EU-RAIL Multi Annual Work Program (MAWP).

The document can be seen as a conceptual deliverable where the scope within FA1 Workstream 1.1 is described. The document describes how each WP relates to the technical enablers defined in the EU-RAIL MAWP. Figure 1 shows the different WPs in Workstream 1.1 and the main areas included in each WP.

In this document, the term *demonstration* is used instead of *demonstrator*. This is because most of the results in WP4-9 will consist of principles, algorithms, methods and models. The frameworks that are planned to be developed and used for the 13 demonstrations can be found in Appendix B. Some frameworks are mature and some frameworks are not mature and therefore, *demonstrations* will be the main results from Workstream 1.1.

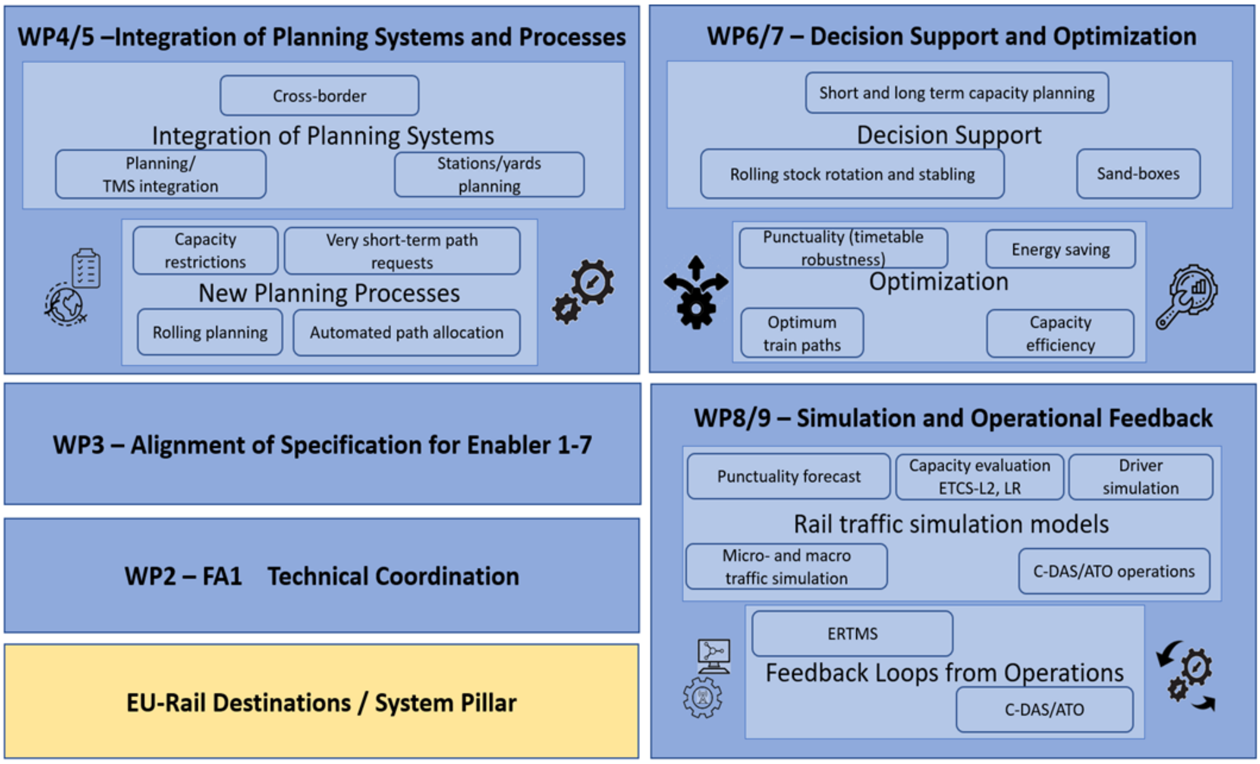

Figure 1. WPs in Workstream 1.1

Workstream 1.1 (Planning) and Workstream 1.2 (Operations) have been planned in parallel while writing the proposal. These workstreams can be divided into three clusters, as explained below.

WP4/WP5, WP11/WP12 – integration cluster

In the integration cluster, developments are focusing on cross-border planning and traffic control. Integration between rail network and nodes, yards and stations are included. Here there are connections with new processes and systems defined together with SP and RNE.

WP6/WP7, WP13/WP14, WP17/WP18 – decision support cluster

In the decision support cluster, algorithms and solutions are developed for short-term and long-term timetable planning. WP13/WP14 includes decision support for co-operative planning and incident and disruption management. WP17/WP18 includes automated train control decisions and real-time optimisation.

WP8/WP9 and WP15/WP16 – simulation and operational feedback cluster

In the simulation and operational feedback cluster, rail traffic simulation models are developed and demonstrated. CDAS/ATO operations and ETCS are important topics. Feedback loops from operations to planning is another area. WP15/WP16 includes 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. This cluster has interactions with Flagship Project R2DATO project about Next Generation Brake Systems with adhesion management functions, DATO Assessment and Potential identification and ETCS HL3 Deployment Strategies.

4. Objective/Aim

The objective of this deliverable is to align, prepare and deliver the high-level specifications of requirements, high-level design and high-level use cases for the development of the technical enablers 1 to 7. The technical enablers are explained in detail in the next section. All use-cases in WS 1.1 are presented in Appendix A. The high-level specification is done in parallel with more detailed specifications from WP4, WP6 and WP8. The state-of-the-art was analysed during the proposal phase, including Shift2Rail results, which are taken into account when development needs are further specified. The work package results provide the foundation for future WS 1.1 developments in WP4, WP6 and WP8 and for the planned demonstrations in WP5, WP7 and WP9. In Appendix B, a mapping of simulation models and frameworks for WS 1.1 demonstrations is presented.

To be able to achieve the expected results, WP3 cooperated closely with other WPs and FPs. This deliverable guided and supported the interactions.

5. Mapping of technical development needs against scope

In the project proposal, seven technical enablers (TEs) were linked to Workstream 1.1 (Planning) work packages WP4/WP5, WP6/WP7 and WP8/WP9. TE1, TE2 and partly TE6 are relevant for RailNet Europe (RNE). The seven TEs are:

- TE1: European cross-border scheduling with international train path planning.
- TE2: Improved capacity allocation using rolling planning and TTR.
- TE3: Decision support for short term planning.
- TE4: Train path and schedule optimisation methods and strategies.
- TE5: Improved rail traffic simulation models for selected Use Cases to forecast punctuality in the network.
- TE6: Integration of TMS with a) yard capacity planning and b) station capacity planning.
- TE7: New planning and operational processes using feedback loops from ERTMS ATO and C-DAS.

In the following sections, all technical enablers will be described in detail, including their alignment with previous results, current state of practice, assigned development needs and high-level requirements. Alignment with previous research means that if there are other research or developments related to the work in Workstream 1.1 (Planning) that will be taken into consideration. Current state of practice is referred to the implementations made by the industry for the respective technical enabler. Assigned development needs are gathered in general, they are the overall needs from the industry and research within each area. All needs might not be covered by tasks in Workstream 1.1. However, the stated high-level requirements for each technical enabler are a subset of the development needs and they are the basis for the tasks in WPs 4-9. All high-level requirements are connected to specific demonstrations.

5.1. Technical enabler 1: European cross-border scheduling with international train path planning

TE1 addresses gaps, issues or weaknesses in today's national train path planning systems to support an integrated cross-border capacity planning and allocation. It identifies new or enhanced capabilities of the national systems to support an improved integration with international path coordination services or processes.

This TE does not cover improvements of capacity allocation or planning processes as such, these are identified by TE2.

5.1.1. TE1: Alignment with previous results

Tools for coordination of cross-border scheduling are developed at RNE. Alignment meetings have been held together with the SP Task 3 (TMS/CMS) and its RNE specialists to identify the needs for future harmonized capacity planning. This input has been used as one source for specification of needs and High-Level Requirements for the specification of TE1 to be addressed by future CMS systems. Within RNE TTR, a Scandinavian Pilot (Denmark, Sweden and Norway) handling the Capacity Model is ongoing. In Sweden, Norway and Denmark, cross-border studies are made using the tools and systems Railsys, Proton and TPS. The FP1-MOTIONAL research activities around TE1 connected to these processes are aligned with the Swedish research program KAJT (KAJT, 2023).

5.1.2. TE1: Current state of practice

In Europe, the legal process for requesting and allocating capacity is the same for passenger and freight trains. However, for pre-alignment (if applicable) and planning of cross-border train paths, the process might differ between freight and passenger paths. Passenger paths are usually aligned and planned at long-term planning (LTP) stage between the infrastructure managers (IMs) during joint alignment sessions with responsible planners of the involved national IMs, although in some networks no pre-alignment takes place for passenger trains. For short-term adaptations, e.g., caused by track work activities, the affected cross-border paths are changed or cancelled, and possibly new train paths are allocated in short-term planning (STP).

In the past years, attempts have been made to offer 'pre-arranged' LTP paths also for freight trains. Since the freight business is more dynamic than passenger transport based on published timetables, the paths effectively allocated by freight during the year usually do not fit well to the original LTP paths. The RUs have to pay for capacity allocated to non-used LTP paths, which in this case resulted in freight-RUs abstaining from LTP path allocation and instead focussing on STP or even ad-hoc path allocation at very short-term timescales. Today, pre-arranged paths are still set-up and maintained at least for international paths on the Rail Freight Corridors (RFCs).

Cross-border paths consist of two or more concatenated national paths. The coordination of national path's allocation for cross-border path requests is supported by the *Path Coordination System (PCS)* tool, hosted by the RNE via the web. Using TAF/TAP TSI based messaging and a joint internet access point, the *Common Interface* (*CI*), cross-border path requests can be entered in the PCS by the RUs and the resulting national path requests are sent to the respective IMs for allocation. However, the alignment of PCS with TAF/TAP TSI is still pending further needs (RNE, 2023a) and not all IMs have sufficiently developed the interface between national systems and PCS, which also has a potential impact on TTR implementation (see TE2), since the required technical coordination for TTR is planned to be performed via the CI. Using a specific coordination workflow and related alignment steps, a consistent cross-border path can be offered back to the Railway Undertaking (RU) and capacity reserved, i.e., allocated at the involved national IMs accordingly. However, the current practice shows that the path coordination is performed via other channels, e.g., phone calls. As a consequence, PCS is mostly used for requesting and offering capacity for the international trains rather than coordination of the international path planning.

This is mostly due to overall processing times for the coordination workflow. RNE is working on a module/new functionality in the PCS (BHT; Border Harmonisation Tool) that allows improving the coordination function of the PCS.

Some of the national capacity planning systems provide already a technical interface allowing integration with PCS. However, the process still lacks harmonisation and efficiency, especially for ad-hoc path requests since there is no capability to anticipate the capacity situation 'behind the border'. An automated allocation is not supported today. The *Timetable Redesign (TTR)* initiative by RNE is expected to provide further improvements in the future, see also TE2 specification description.

The cross-border capacity planning and allocation process is also suffering from non-harmonised planning rules and processes. Up to a certain extent the TTR is addressing this by introducing a joint and central model of capacity objects like *Train Path Envelopes (TPE)* (defined by RNE and not to be confused with TPE defined for ATO) and *Temporary Capacity Restrictions (TCR)* trying to absorb the national differences.

5.1.3. TE1: Assigned development needs

The European cross-border capacity planning systems need to:

- Support IMs with regular information exchange of planned international train paths to ensure optimal alignment of trains between national networks, especially in case of TCR.
- Allow for an improved integration with national planning systems (RNE Tools, bilateral).
- Allow for pre-aligned national paths by 'looking-behind-the-border capability'.
- Today, the PCS coordination process, with its complex workflow, could take some time, which is problematic in many cases, especially for the increased dynamics and digitalisation in freight/logistics management systems. Detailed information about the transport needs, used wagons and load, as well as type and parameters of suggested traction engines are known only late. To shorten the time required for the coordination process, national capacity planners could pre-align their parts before handing their part over to the next national planner in sequence. This can be achieved by being able to identify conflicts with TCRs or other paths behind the border.
- Support Rail Freight Corridors (RFC) with management functions providing a transparent view on RFC capacity allocation.
- Provoke an increased customer satisfaction through improved cross-border quality and timetabling reliability.

5.1.4. TE1: High-level requirements

It shall be possible to support:

- Smooth integrated path coordination (via RNE PCS and the future BHT) by national capacity planning systems of IMs. (TE1a)
- RFC management functions with transparent view on RFC capacity allocation. (TE1b)
- International path planning with national planning systems in line with TTR. (TE1c)
- Capability for harmonised/integrated cross-border planning on macroscopic level and on microscopic level (routing, timing, conflict detection and resolution., TCR regulation). (TE1d)
- Input to harmonised planning rules or paradigms in national planning, including request and response deadlines to achieve adaptation to market demands, but still allowing preparation of tailor-made paths if national or regional realities advise or require them. (TE1e)
- Allowing for increased reactivity and pre-alignment in cross-border path planning and coordination. (TE1f)
- Visibility of TCRs behind the border, typically up to the next railway node (junction of multiple railway lines); timing values (arrivals, departures, passings) for all commercial and operational points along the route up to destination station behind the border, to feed initial pre-aligned internal path request in PCS (speed up coordination times), especially for freight traffic. (TE1g)

5.2. Technical enabler 2: Improved capacity allocation using rolling planning and TTR

This TE aims to define which processes, regulations and support tools need to be in place for an efficient and suitable capacity allocation process all over Europe and how to get a common understanding for them. The developments enable European wide capacity allocation and new processes such as the TTR concept by RNE; and allow consideration of station and yard capacity at the network level.

TE2 includes high-level requirement specifications for integration of new processes in capacity planning and creation of standard reports including cross-border. It foresees the assessment and consideration of existing concepts like e.g., the TTR concept.

The TTR project started in 2014. The initiative originates from RNE and FTE. Both organisations can be classified as industrial organisations on a European level, where RNE mainly has IMs as members and FTE is for RUs. For a more detailed description of TTR and current research, see the following section.

5.2.1. TE2: Alignment with previous results

The main focus of the European regulation and support process research has been on TTR in the recent years. TTR stands for TimeTable Redesign and its main goal is to increase harmonisation between the different European RUs and the respective IMs, to simplify the process of capacity allocation. TTR is still under development and several interesting research proposals will emerge, see the TTR Fact Sheets (RNE, 2022). The largest change compared to the current timetable planning process is that the planning phase starts earlier and is specified in three steps: Capacity Strategy, Capacity Model and Capacity Supply. The three phases are still under development, but the general content is described below.

Capacity Strategy:

The Capacity Strategy shall contain the following parts:

- Geographical area description and/or visualisation of area for which this Capacity Strategy is applicable, and list all involved IMs, terminals, and service facilities.
- Expected capacity of infrastructure in a respective timetable period.
- Overview of available information on the expected usable permanent positive (additional) and also the expected permanent negative capacity impact.
- Temporary Capacity Restrictions:
    - Description of the principles and typology for the planning of TCRs along with available information about the expected crucial major impact TCRs.
- Traffic planning principles and traffic flows:
    - Description of the main principles for each line section, which will be used later in the planning of elements in the capacity models, including the principles for cooperation on capacity management with terminals and service facilities. It should be accompanied with an analysis of rough demand forecast based on current traffic flows and known or possible adjustments in the future along with a common overview of the expected traffic flows at the joint border points of the IM and other IMs involved in the strategy.

Capacity Model:
Based on the principles defined in the Capacity Strategy, the IMs continue in the consolidation of all known and expected capacity volumes; the output of this work is visualised in the Capacity Model. The aim of the Capacity Model is to show, harmonise and discuss more in detail the expected volume of capacity consumed by each market segment (commercial needs) and TCRs. Consequently, the Capacity Model consists of two parts:

- Traffic part - 24-hour overview reflecting market needs.
- TCR part - overview of the capacity consumed by TCRs.

Capacity Supply:
Based on the final Capacity Model, IMs continue in the planning of the capacity taking into account TCRs for every day of the timetable period, partitioned for dedicated purposes (volumes for passenger traffic, volumes for freight traffic and TCRs), but where needed also between various product types (Annual, Rolling Planning ad hoc). The output of this work is visualised in the Capacity Supply. The aim of the Capacity Supply is to show, harmonise between IMs and make the details on the useable capacity for each purpose (passenger, freight and TCRs) available to applicants.

TTR is still under development and several interesting research proposals will emerge. One is how to segment the capacity by using the socio-economic factors (RNE, 2022).

RNE IT modules:
Relevant Central IT Modules are under development:

- TCR Tool: An application that shows common information on a common platform, with common terminology and visualisation of TCRs. The aim is to use the tool for coordination, consultation and publication of TCRs of all IMs. TCRs could be included in the Capacity Model as capacity volumes.
- ECMT Capacity Hub (European Capacity Management Tool): A tool to collect and display the capacity volumes. It is an online application that provides a centralised capacity supply and capacity model overview of lines and routes. The tool combines capacity needs and capacity restrictions on the railway infrastructure based on the information provided by IMs, Allocation Bodies and applicants. It offers the capacity supply and capacity model visualisation.
- PCS CB (Path Coordination System – Capacity Broker): A module for capacity inquiry and request. Capacity Broker module uses harmonised Capacity Product Publication data as an input, and all inquiries and requests from the RUs side will be validated due to it. Capacity Broker summarises all requests from the RUs side and gives the feedback if this requirement fits the available capacity or not, because there could be a problem due to TCR.
- Messaging Module: A module to connect the aforementioned modules with each other, with national (legacy) IT and with central databases.

5.2.2. TE2: Current state of practice

In the SERA directive (European Parliament, 2012), railway planning is divided into long-term planning and ad hoc planning. The long-term planning is concerned with the planning scope of the annual network timetabling process (starting annually on the 2nd Sunday of December) and beyond – involving the assessment of timetable concepts and structures. Train path requests and allocation within an annual timetable period, as well as traffic management are considered ad hoc or short-term planning. Short-term planning and allocation of paths are performed outside the TMS without technical integration of data from operations. risking conflicts and delays at operational times. Before the long-term planning, IMs should present major and high capacity restrictions for a first time at least 24 months, to the extent they are known, and, in an updated form, for a second time at least 12 months before the change of the concerned working timetable.

Today, all timetable processes in Europe have to follow the SERA directive, which makes the timetable process coordinated in time between countries. However, the allocation process and methods can still vary a lot between countries, which is the aim of TTR research and convention to improve. As an example, the Swedish process with milestones can be seen below. The process is in general applicable to the SERA directive, but internal processes and milestones might differ compared to other countries.

1. X-72—X-36 Coordination of measures to achieve an acceptable amount of traffic impact per year per traffic flow/cluster.
2. X-36—X18 Decide on the direction of the execution (major suspension, disruption times, single track, night/day etc.) in order to reduce traffic impact.
3. X-24—X-18 Create prerequisites for the capacity allocation process.
4. December (x-12): Major and High TCR impact (Temporary Capacity Restrictions) is a prerequisite condition for applicants.
5. February: Pre-planning, IM invites railway undertakings, applicants and contracting parties to dialogue on conditions prior to next timetable and future timetables.
6. April: Application for train path and service.
7. April: First date for late path request to annual timetable.
8. April-July: Compilation of proposed train path (Path Elaboration).
9. April-July: Coordination of conflicts of interest (Path Elaboration).
10. July: Draft annual timetable.
11. August: Observations of Draft Timetable from applicants.
12. August-September: Post processing and coordination.
13. August: Final allocation of international traffic applied by PCS.
14. September: Procedure for solving disputes if needed.
15. September: Solving conflicts of interest with application of socio-economic priority criteria (help from charges levied) if needed.
16. September: Declare congested and use of prioritisation criteria, if needed.
17. September: Final annual timetable published.
18. October: Late path request will be processed.
19. October: The Ad-Hoc process begins.
20. November: Updated annual timetable.
21. December (x-0): Annual timetable takes effect.

Regarding TTR, a Scandinavian Pilot (Denmark, Sweden and Norway) handling the Capacity Model is ongoing in order to find out how and when the capacity model should be used.

5.2.3. TE2: Assigned development needs

Since TTR is still under development, there are a lot of things that need consideration. There are areas where TTR research has not come far enough and conceptual thoughts that need adjustments and specifications to fit in with the practical work. These needs can be described by:

- National planning tools where IMs continuously can make train path and TCR information public for all involved planners. These planning tools should also be able to communicate automatically with the jointly coordination tool.
- Changes in both European and national regulatory laws that will affect different EU-countries in different ways.
- Introduction of coherent rules so that the national timetable systems are consistent with the international process. The framework and the process need to go hand in hand.
- Harmonise market rules to give commercial traffic equal prerequisites throughout EU.
- Capability of national planning systems to model capacity demand in conjunction with Capacity Need Announcements and to integrate with the ECMT/Capacity Hub; allow for rolling planning, capacity partitioning and capacity reporting, without losing too much flexibility and national particularities.
- How to segment capacity in a transparent way. One way is to start by mapping how different countries handle their capacity allocation process today and what impact the TTR will have on the respective country.
- Adjustment of the national infrastructure model based on the future (expected state) of the situation on the railway infrastructure considering closures, construction of new infrastructure, etc.
- TTR requires the TCRs to be planned earlier and to be more stable.
- Short-term planning and allocation of paths to be supported by technical integration of data from operations.

5.2.4. TE2: High-level requirements

Identified high-level requirements to reach an improved capacity allocation process are:

- Principles for how to reserve capacity in different time periods (annual, rolling planning etc), in a transparent, social-economic efficient and market-friendly way. (TE2a)
- Principles for valuation of traffic, both between and within segments for conflict solving and reservation of rolling planning capacity. (TE2b)
- Suggestions on how IMs can and need to act in order to have sufficient knowledge of the railway market at any given point in time to be able to allocate and assign capacity throughout the timetable process. (TE2c)
- Capability to integrate data from operations for improving path quality. (TE2d)

5.3. Technical enabler 3: Decision support for short-term planning

Short-term planning (STP) is defined by the process of adjusting the current annual timetable to create a new timetable that considers additional needs and constraints. This process can last from 1 day to few months ahead of the day it goes into operation. Except for simple scenarios (e.g., fitting an additional freight train within an already feasible timetable), most of the current short-term timetabling process is performed manually and usually alternates between (1) making rough modifications to an existing timetable (e.g., planning maintenance activities or adding a new train) and then (2) making small adjustments to regain feasibility or increase robustness (e.g., by modifying the dwell times and/or the running times of some trains along their route). The most time-consuming element of this process is related to the second step, which is to manually eliminate all conflicts that may arise after a timetable has been modified. Currently available decision support tools for short-term timetabling can assist route-planners in various ways, in particular by identifying possible train conflicts generated at step (1). Some tools can also identify a conflict-free schedule for a newly added train, a feature that is usually called "find slot" or "find train path". However, when conflicts are generated by modifying the current timetable, there is no available commercial tool that helps regain feasibility and possibly optimality with respect to defined target KPIs, such as robustness or passenger travel time. The software, methodologies, and algorithms developed for TE3 should contribute to the creation of a decision support tool that helps planners in both steps described above, including conflict identification and resolution.

5.3.1. TE3: Alignment with previous results

The following projects are particularly relevant and should be taken into consideration when developing new technologies for this TE:

- **ON-TIME** (2011-2014). This project studied algorithms for train scheduling that could be used for both LTP and STP. These algorithms were implemented and tested on some European railway lines, such as the Iron-Ore line (Sweden/Norway), the East-Cost Main Line (UK), corridors through s'Hertogenbosch (Netherlands), and the Bologna node (Italy). Innovative solutions algorithms for conflict detection and resolution were developed by different groups: (a) a custom branch & bound algorithm, (b) a tabu search heuristic and (3) a Mixed Integer Programming Model solved by a means of a MILP solver.
- **FR8RAIL II** (2018-2022) and **FR8RAIL III** (2019-2023). These projects were responsible for the development and evaluation of the timetable modification module (TIMO) for short-term replanning. TIMO is based on a ruin-and-recreate heuristic coupled with a greedy insertion algorithm. It can be used to change an existing train path or to insert a new train path in a timetable close to operation. In TIMO, small adjustments to a subset of temporally close train paths are allowed to facilitate the change/insertion. The subset could, for example, be specified to only include other trains from the same railway undertaking. TIMO can be used to replan a timetable in situations where several train paths are affected, but the focus is on one train path or a few train paths. In situations where several train paths are affected (for example when planning for large maintenance work), other replanning methods are believed to be more suitable.

5.3.2. TE3: Current state of practice

In Europe, no two countries share the same planning system. Some countries may have systems from the same vendor, but they have been highly customised to the specifics and needs of a certain country. Some countries have decided to share their experience with such tools:

- **NS (Netherlands).** In daily operation, decision support algorithms are not used to construct adjusted timetables. It is a complete manual process, but planning systems help with conflict detection on a microscopic scale. Currently, a joint project with ProRail is tasked to develop a tool that uses an optimisation algorithm to create an adjusted cyclic timetable (adjusted hourly pattern). In WP6, this algorithm will be further developed.
- **SNCF (France).** For STP and LTP, SNCF Réseau uses a tool for defining the train paths manually. No optimisation method is embedded in this tool, however a function warns the planner when two train paths are conflicting. The robustness of the timetable is improved by adding time margins for problematic trains, and this essentially relies on the expertise of the planner. The validation of the produced timetable may then be carried out via a microscopic simulation with another tool.

- **TRV (Sweden).** In Sweden, there is no optimisation method embedded in the planning tool. All adjustments of the annual timetable have to be made manually. The number of adjustments tends to increase every year and the work is highly time consuming for the planners. TRV has started several research projects for long-term and short-term timetable optimisation, but no model has been implemented yet.
- **DB (Germany).** DB Netz offers to RUs the Click&Ride App. It allows to calculate in less than 3 minutes a valid timetable and the IM offer to the RUs. Inside the IM, the visualisation of the network and possible restrictions is identified as important challenge. The main use is for freight traffic where it is possible to reserve a train slot up to 7 days in advance. It is based on optimisation processes using real-time data (construction work and other known restrictions) and the result is a conflict free timetable.
- **RFI (Italy).** In Italy, the tool provides only a visual support. No component is provided for highlighting and resolving conflicts. Timetable robustness is entrusted to the operators' expertise, who can also make use of their knowledge of the characteristics of the local network. Automatic support for microscopic validation of the timetable is also missing. List of specifications and state-of-the-art can be found in RNE (2023b).
- **ADIF (Spain).** ADIF uses one tool to define the train paths manually, for short-term as well as for long-term planning. No optimisation method is embedded in this tool. However, a function warns the planner when two train paths are conflicting and offers possible solutions to the conflict. The planner may adopt one of the solutions proposed by the tool or may solve the conflict manually under his own criteria. The robustness of the timetable is improved by adding time margins, and this essentially relies on the expertise of the planner. For path requests for train runs with less than 48 hours, a path is created to provide the driver with the driving documents and inform him of the estimated times between locations, but the path is not inserted in the graph. Consequently, there is no commitment from the IM in accomplishing with the scheduled times. For these "immediate" paths the train number has a dedicated range of numbers.
- **DB-internal (Germany).** The Capacity and Traffic Management System (CTMS) is the central, automated planning and control system of the future railway system, currently being developed at DB. CTMS will automate, simplify, and accelerate timetable planning across all planning phases as well as the execution and (re-)scheduling processes. The optimisation of decisions is made possible by deep reinforcement learning, a relatively new field of artificial intelligence. The current CTMS prototype has successfully demonstrated the feasibility and power of the integrated approach on a realistic microscopic railway simulation. This has been demonstrated successfully to railway experts on European level several times. The next steps relate to the step-by-step implementation of further features and the realisation in a section on the German rail network.

5.3.3. TE3: Assigned development needs

From the current state of practice section, is clear that planning tools used today do not include optimisation capabilities, except for very simple scenarios. Therefore, there is a clear need for development of new optimisation capabilities to support the timetable planners.

In France, for example, there is a strong need for a tool that maximises the capacity usage and ensures equity between the concurrent railway companies. The upcoming Olympic Games 2024 organised in Paris are a good example of possible challenging situations that require even more effort from the planners, due to extensive required maintenance work and custom timetables that take into account heavy passenger flow between different venues.

In Italy, the tools used in the planning phase require massive manual activity. For example, the display of the TCR does not have any intelligent in-built decision process, and therefore the timetable construction is left to the experience of the planners who manually make the necessary adjustments, such as adding additional stops, deviations and cancellations. An automatic tool to support this work is necessary to build and present timetables that optimise pre-established KPIs, harmonising programming with the TCRs. Moreover, a drastic simplification and speed-up the process would lead to better punctuality. In the planning phase, it is also strongly felt the need for a tool that supports maximisation of capacity while guaranteeing non-discriminatory access to railway traffic, demonstrating compliance with the equity rules.

In Spain, it is critical to exploit the maximum capacity that the line can provide. To this end, the planning process should produce conflict-free, optimal timetables (with respect to capacity utilisation). Since manual adjustments of the timetable are time consuming, the planners' possibility to re-schedule trains in an adequate way is limited.

In Sweden, there are several practical examples of TCRs that are not planned in the timetable and several examples where simple strategies are used, e.g., adding general runtime supplements to the trains. Often, timetables are not conflict-free during the TCR and/or current planning rules are not followed. This leads to delays and bad punctuality during the TCR. To increase timetable quality, the planners need a decision support tool that automatically creates a modified, conflict free and robust timetable given temporary capacity restrictions.

5.3.4. TE3: High-level requirements

Identified high-level requirements for decision support for short-term planning are:

- Advanced algorithms for the adjustment of timetables to accommodate scenarios with additional/modified train paths, for example, due to change of (forecasted) demand. (TE3a)
- Advanced algorithms for the adjustment of timetables to accommodate scenarios with TCRs (temporary capacity restrictions), for example, planned maintenance. (TE3b)
- Algorithms that are available for usage both by timetable planners as well as traffic management staff. (TE3c)

5.4. Technical enabler 4: Train path and schedule optimisation methods and strategies

Train path and schedule optimisation methods and strategies are necessary for making effective long-term timetable plans optimised for capacity efficiency, robustness and energy saving. Methodological approaches focus on the optimisation of entire networks, as well as on supporting planning in a more detailed, local context based on smaller aspects of the network, and involve analysing different traffic situations as well.

Train path and schedule optimisation methods and strategies consists of process plans, working methods or algorithms incorporated in computer programs. These methods and strategies contribute to transport service attractiveness, capacity efficiency, improving punctuality or energy saving or a combination of it. These methods and strategies should be replicable and provide justification of the results and can be compared with a reference situation.

Long-term planning, which is the focus for TE4, is concerned with the planning scope of the annual network timetabling process (starting annually on the 2nd Sunday of December) and beyond – involving the assessment of timetable concepts and structures. Train path requests and allocation within an annual timetable period, as well as traffic management are considered short-term and handled within TE3.

As we speak about entire networks, we mean nationwide networks. When we mention different parts of it, we refer to parts of a nationwide network. As we speak about different traffic situations, we mean situations that differ in intensity and corresponding level of punctuality, or situations with cyclic or acyclic timetables. The methods and strategies should be applicable in all combinations and situations mentioned, or a combination of methods should cover the different situations.

5.4.1. TE4: Alignment with previous results

While the research community has proposed several optimisation models for timetable planning (see e.g., Gestrelius (2022) for an overview), few have made it into practice. Caimi et al. (2017) mention four European countries that, at some point, have used optimisation to construct (parts of) their timetables. There is no clear explanation as to why this is the case, but the lack of usability focus during algorithm development may be a part of the explanation (compared to the growing field of explainable AI).

At this moment, methods or strategies for long-term train path and schedule optimisation are only existing as research models. Practical models are either non-existing, or very simplified. Furthermore, an objective assessment framework is necessary for assessing the results. As a part of it, a general definition of capacity efficiency and robustness has to be drawn up. The general definitions will enable to compare results of different methods and strategies and can indicate its effectiveness.

Scientific research on new models for railway timetabling is presented in Polinder (2020). This thesis describes the current state of practice for some of the strategic long-term timetable optimisation problems.

- The Strategic Passenger-Oriented Timetabling (SPOT) problem. This problem aims at finding a timetable pattern which is optimal for passengers, explicitly including adaption time into the perceived passenger travel time. The solutions generated by the SPOT model can be used to learn about desirable patterns at key points of the network. This has been demonstrated through case studies.
- Passenger-Oriented Timetabling (POT) problem: Given an infrastructure network with stations and tracks connecting them, and a line plan, specifying line routes, stopping patterns and frequencies: find a timetable including all or a subset of the trains that satisfies the headway restrictions induced by the infrastructure network and minimises average perceived travel time. The outcome consists of a feedback mechanism used to improve the found solutions. Real-life instances, based on the

network operated by NS, obtained satisfying results. Furthermore, the provided feedback indeed leads to (overall) better timetables compared to the initially computed timetable.

- The Periodic Event Scheduling Problem (PESP): Finding a methodology to relax PESP activities to resolve infeasible PESP instances (cyclic timetables). This approach supplements current timetabling algorithms, which suffer from the fact that increased demand for capacity usage as well as quality requirements often lead to (on first sight) infeasible timetabling instances. In the experiments based on parts of or the whole the Dutch railway network, feasible timetables are found in reasonable time in most cases. The model requires the choice of many parameters, namely the allowed deviations of the original bounds and the weights in the objective function, which will steer the algorithm towards a solution. Setting the parameters has been based on expertise and preferences of the railway operator.

5.4.2. TE4: Current state of practice

In the Netherlands, NS has developed a prototype of a timetable optimising model combining passenger flows and a schematised rail network to maximise profit. Profit has been defined as the difference between ticket revenues and costs (rolling stock, staff, infrastructure access charges). The prototype was useful for generating first ideas for timetable design, but more research was needed for wider application. Elements of this prototype are used in the SPOT and POT model.

The original PESP model has been implemented in the nineties in the DONS system used by NS and ProRail. The scientific Research of Polinder (2020) proposed improvements for this approach.

In France, SNCF Réseau uses a planning tool for defining the train paths manually. No optimisation method is embedded in this tool; however, a function warns the timetable planner when two train paths are conflicting. Robustness is improved by adding time margin for the problematic trains, e.g., when the rolling stock is not efficient enough to run at a section in the nominal time. All of this essentially relies on the expertise of the timetable planners. The validation of the produced plan may then be carried out using microscopic simulation with another tool. SNCF Innovation and Research department has developed a prototype of a timetable optimising model taking into account passenger flows, which is not currently used in practice.

In Sweden, there is also no optimisation method embedded in the timetabling tool. The main goal for the timetable planners is to fulfil all train path requests as closely as possible, and this has to be done manually. It is possible to see if trains are planned in conflict in the timetabling tool and there are some planning rules included in the tool to ensure some level of robustness. However, the complex and time-consuming part of the work, the actual synchronisation of train paths, is done manually by the planners. TRV has started several research projects for long-term and short-term timetable optimisation, but no model has been implemented yet.

In Germany, various optimisation methods are used selectively in strategic and operational timetable planning, for example to optimise traffic on certain routes or in stations. However, the overall planning process is still characterised by many coordination efforts between departments and regions, and system discontinuities. The Capacity and Traffic Management System (CTMS), which is currently under development, is expected to reduce the overall planning efforts in the long term. CTMS is the central, automated planning and control system of the future railway system. It is currently being developed in Digital Rail Germany. CTMS will automate timetable planning and the execution of railway operations in a standardised system. CTMS utilises the advantages of digital infrastructure and automated trains. The optimisation of decisions is made possible by deep learning and reinforcement learning.

5.4.3. TE4: Assigned development needs

This task deals with optimisation decision support for long-term timetabling, and the development of advanced algorithms for the generation of timetables to accommodate for scenarios that will occur more than one year ahead (e.g., large variation of train service requests, infrastructure upgrades and investment decisions). The algorithm is usually required to generate new timetables that are different from the existing ones. The algorithm should give the human planners the possibility of testing several scenarios, choosing the right trade-off between different objectives.

The developed algorithms to solve the (Strategic) Passenger-Oriented Timetabling Problems should be combined in a decision support system that can help creating future optimal timetables for different possible scenarios of the railway infrastructure.

A second feature of a decision support system would be guiding investments in infrastructure by focussing on the bottlenecks in the network. Traditionally, the infrastructure network is considered as input to the line planning and timetabling problem. However, work towards passenger-friendly integrated timetable concepts on the national level (e.g., in the Netherlands and Switzerland) has led to a new focus on the feasibility and needs of timetable concepts with respect to the existing infrastructure. This implies that decisions on investments in infrastructure can now, at least partially, be guided by such a timetable, to obtain a better match between passenger demand and the service a network can offer.

In France, given that the planning process essentially relies on the timetable planners' expertise, SNCF Réseau strongly needs a planning tool with optimisation capabilities for maximising the capacity usage while avoiding conflicts, and ensuring equity between the competing railway companies. There is also a need of considering several distinct planning solutions under the same operational constraints, so as to help the timetable planners with KPIs for supporting decisions during negotiations.

The tools to support TOCs in the long-term planning phase, as for short-term, still require a lot of manual work. In the planning phase, is also strongly felt the need for a tool that supports:

- the maximisation of capacity
- guaranteeing non-discriminatory access to railway traffic, demonstrating compliance with the equity rules.

As stated above, TRV has started several research projects for long-term and short-term timetable optimisation. However, in Sweden, support tools with optimisation are still far from being implemented in practice. Research focused on how to make the optimisation models useable for long-term timetable planners, and also in the area of Human, Technology, Organisation (HTO), is therefore needed to understand how optimisation models can be implemented and become part of the planners' everyday work.

5.4.4. TE4: High-level requirements

Identified high-level requirements for train path and schedule optimisation methods and strategies are:

- Algorithms for creating timetables at network, regional and corridor level, including an iterative approach in collaboration with timetable planners. On the station level, an aggregated view is used. (TE4a)
- Methods for station timetable planning based on a detailed representation of the station infrastructure. This includes the analysis of station infrastructure with respect to capacity utilisation and potential bottlenecks. (TE4b)
- Algorithms for creating a macroscopic timetable for a large network, e.g. one country (strategic, 5-10 years ahead) optimised on Generalised Journey Time (GJT). GJT is weighted travel time including waiting times and penalties for transfers. (TE4c)
- Algorithms for identifying critical network areas and links. (TE4d)
- Usability design principles for long-term timetabling decision support systems with optimisation. (TE4e)

5.5. Technical enabler 5: Improved rail traffic simulation models

Rail traffic simulation is a powerful tool for analysing and optimising rail transportation systems. It involves the use of software programs that simulate the simultaneous movement of trains and other rail vehicles through a network, considering various factors such as train characteristics, train schedules, track capacities, signalling systems, traffic control and other variables. The tools can be used to simulate certain processes, subsystems of the environment or a complete use case. The functionality provides the ability to simulate the interaction of trains amongst each other, with some kind of traffic control. It also provides the possibility to evaluate processes separately and not just only monolithic unique process, to dissect the system into their components. This approach is fundamental since the correct architecture of railway systems must be modular and scalable.

Simulation models are essential to be able to estimate the capacity of a given infrastructure and the feasibility and robustness of a timetable. They offer powerful means for analysing and optimising rail transportation systems. By using simulation models to test different scenarios and strategies, railway operators and planners can improve the reliability and efficiency of their networks.

In order to achieve these simulation models, continuous data improvement by continuous feedback of the historical information available for analysis is needed. This will increase the reliability of the railway network simulation both in optimal and degraded states, while always focusing on improving the simulation models.

While railway simulation tools offer many benefits, there are also limitations to their use. Some of the key limitations include:

- Complexity: Railway networks are inherently complex, with many variables and factors that can affect train movement and punctuality. While simulation tools can capture some of this complexity, they may not be able to fully model all the nuances and interactions between different elements of the network.
- Data Availability: Railway simulation tools require accurate and comprehensive data inputs to produce meaningful results. However, data availability can be a challenge in some cases, particularly for older or less well-maintained rail networks or uncontrolled parts of the network. Without accurate data inputs, simulation results may be less reliable. It is a challenge to keep models aligned with the actual state of the network infrastructure which undergoes regularly minor changes that can affect the running times of trains.
- Model Calibration: Simulation models need to be calibrated to accurately reflect the behaviour of the real-world rail network they are simulating. This can be a time-consuming and challenging process, particularly if the network is large or complex. Additionally, calibration requires accurate data inputs, which can be challenging to obtain.
- Sensitivity to Assumptions: Railway simulation models are based on a set of assumptions about how the network operates. However, these assumptions may not always hold true in the real world. As a result, simulation results may be sensitive to changes in assumptions, and users must be careful to interpret results considering the underlying assumptions.

To improve the accuracy of those simulation tools, use cases, pertinent to the operation of modern railway infrastructure, can be selected, that will be used to evaluate improvements in traffic simulation tools. Two examples of such use cases are:

- Simulating primary and secondary delays - This use case involves simulating the effects of primary delays (delays caused by factors such as infrastructure failures, accidents, or severe weather) and secondary delays (delays caused by the knock-on effects of primary delays) on rail traffic. By accurately modelling these delays, the project team can identify areas where delays are most likely to occur and develop strategies to minimise their impact on the network's overall punctuality.
- Simulating drivers vs. ATO over ETCS - This use case involves simulating the performance of trains in scenarios where drivers are manually operating the train versus scenarios where an Automatic Train Operation (ATO) system is controlling the train via the European Train Control System (ETCS). By comparing the performance of these scenarios, the project team can identify opportunities to improve punctuality by optimising the use of ATO systems in the rail network.

5.5.1. TE5: Alignment with previous results

Within the Shift2Rail project PLASA, DB developed a macroscopic simulation tool, formerly named PRISM and now named PROTON. One of the main goals was that the tool should be able to simulate large networks in short computation time. KTH has, together with LU and TRV, used PROTON in various projects, for example within Shift2Rail projects Plasa2 and FR8RailII/III.

A comprehensive overview of the state of the art in timetable planning is made in Plasa D2.1 2017 03 about current micro and macro simulation systems and how they are used for timetable planning purpose. DB is using Proton in its timetable process for national simulations supporting quality in timetabling. TRV focus on Shift2Rail was to transfer Proton to Sweden and do simulations with Proton and Railsys for Swedish network and cross-border Sweden – Denmark. In FR8Rail II focus was Proton – Railsys calibration and validation and in FR8Rail focus was to use Proton combined with a yard departure model for the line Malmö – Hallsberg.

5.5.2. TE5: Current state of practice

Currently, most IMs and RUs are using RailSys (NS, ProRail, TRV, DB) or a modified version of RailSys (SNCF: DENFERT) as the (main) simulation tool. This is a micro simulation tool that can do static, deterministic and stochastic analysis and that does support ETCS, ATO and C-DAS in simulation. NS and ProRail also use OpenTrack, another commercial micro simulation tool and FRISO, a homemade micro simulator that can do deterministic and stochastic analysis for ATO simulation and to integrate traffic control. SNCF is currently developing its own in-house micro simulation tool OSRD and has opened the source of the tool.

Regarding macro models, the picture is more fragmented, as no tool seems to be used widely around partners. NS mentions the use of AnyKoop and Introos (in-house development), TRV uses PROTON and SNCF uses Viriato. CEIT uses OPTICON, another macro simulation tool that is used to do timetable analysis and run time calculation, as well as energy-efficient speed profile generation.

Considering the development of models inside those simulation tools, TRV has a microscopic model of the whole Swedish infrastructure, ETCS L2 and HL3 have been implemented and capacity has been evaluated. In the Netherlands, microscopic infrastructure of the entire country exists in multiple models and NSR has a scalable method to generate macroscopic infrastructure. Stochastic disturbances are used in macroscopic models and developed in microscopic research.

VTI is developing a train driver simulator to evaluate real life capacity, including human factors in the loop. This simulator includes ETCS signalling.

5.5.3. TE5: Assigned development needs

There are several areas where simulation models need improvement. Most of the improvements relate to specific use cases where there are missing functionalities in todays' models. The assigned development needs are:

- Being able to evaluate simulations for large networks.
- Integrate capacity restriction in scheduling.
- Improve calibration and validation of simulation models.
- Improve model of delay distribution.
- Improve the feedback loop between planning and operations, for example using historical data to evaluate timetables.
- Improved simulated driver behaviour compared to real train driver behaviour.
- Integrate energy efficiency in simulations, and understand its impact on other KPIs like punctuality and capacity.
- Integrate crew scheduling in simulations, and move towards doing integral simulation (including crew, rolling stock, infra, etc).
- Improved stochastic micro simulation models based on historical data.
- Introduction of new technologies (ERTMS hybrid level 3, ATO/C-DAS over ETCS) in the simulation models (see details and needs in TE7).

5.5.4. TE5: High-level requirements

Identified high-level requirements for improved railway traffic models are a subset, at an aggregated level, of the above-mentioned development needs:

- Models that can simulate traffic in a large network. (TE5a)
- Support to improve feedback loops between planning and operation and timetable evaluation with historical data and improved delay distributions. (TE5b)
- Improved stochastic simulation models to increase the precision in punctuality prediction. (TE5c)
- Models with integrated crew scheduling. (TE5d)

5.6. Technical enabler 6: Integration of TMS with a) yard capacity planning and b) station capacity planning

TE6 addresses gaps, issues or weaknesses in today's technical communication processes between yard and station, i.e., local track capacity planning and line capacity planning or production systems like Train Path Planning and TMS. It identifies new or enhanced capabilities of the national capacity planning systems to support an improved integration between both, local and line focussed planning and production processes as well as integrated optimisation of operations in stations and their connected shunting areas. This is of importance for the freight transport as a whole and especially the coordination of processes involving freight terminals, logistics centres and companies.

5.6.1. TE6: Alignment with previous results

In Shift2Rail TD5.2, real-time network management knowledge, methods and tools were developed for freight traffic linking yard – network – yard. In TD5.2, main demonstrator was YCS. The developed Yard Coordination System (YCS) was demonstrated in a workshop with experienced participants from the three main actors at Malmö yard Line manager, Marshalling and terminal manager. The demonstration has shown that a tool like YCS can improve transparency and enable cooperative and pro-active planning. The YCS has been developed for real time usage, and in the evaluation workshop the simulated time progressed in normal speed. The results showed that the tool was fast and easy enough to use for re-planning in a real time setting.

In Optiyard, a demonstration was made for a yard in Czech and a yard in Italy, which automatically generated schedule for tracks, shunting locomotives and staff. The schedule quality is evaluated using a microscopic simulation of the yard operations. The optimised schedule is also compared with a real-world example. Note that one of the lessons learned in Optiyard is that it is difficult to define an optimisation problem a priori, as management decisions are sometimes based on knowledge of how the traffic situation may develop, and resources are sometimes used more flexibly than intended during normal operations.

5.6.2. TE6: Current state of practice

Planning the track usage for local operations connected to the passenger trains in stations or depots, is in some countries managed by harmonised processes and one tool. In other countries this is not the case yet. Most of the train paths for freight trains are requested, planned and allocated in STP or even ad-hoc, i.e., at very short-term notice on the day of operation. On the other hand, local track capacity in yards or especially container terminal / harbour areas maybe planned already at earlier stages due to availability of (un-)loading facilities or other processes linked to the supply chains. Moreover, these processes are often triggering freight path requests for line capacity planning departments and related systems at IMs or at RNE for international paths. The integration of local status information or knowledge provided by connected local management systems or local staff in conjunction with rolling stock or load characteristics and related possible restrictions is not communicated back to the line capacity planning.

Conflicts, constraints or needs regarding the choice of appropriate local tracks are usually known only by local staff. The impact of choosing specific local tracks on the given line paths are not communicated back to the line capacity planning systems. This could involve e.g., additional (or less) time required for arrival at stop positions or emergence of hidden conflicts due to implicit routing changes in stations. Additionally, more detailed knowledge of local staff or integrated depot or yard management systems could yield the need for longer (or shorter) technical dwell times within the local tracks impacting the departure times or dwell time allowances included in the planned train path. More reliable information about effective train load, length and possible rolling stock or load restrictions can be expected to result in more realistic operational train paths once they are known to line based capacity planning systems or TMS.

5.6.3. TE6: Assigned development needs

The yard/station level capacity planning systems needs to allow:

- Extended data exchange with terminals, ports and freight forwarders to provide relevant data for customers.
- Using TAF/TAP compliant data exchanges (extensions could be required), where applicable.
- To receive updated capacity plans from line-based Capacity Planning/Management Systems (CMS) (including train paths and TCR).
- To communicate track reservations (stabling, parking, etc.) to CMS and TMS.
- To communicate yard delays and consist/consist changes or rolling stock limitations to TMS.
- To communicate track assignment changes for trains to CMS and TMS.
- To communicate shunting activities with impact on lines to CMS and TMS.
- To communicate path changes (also international, PCS based) down to local planning systems to adapt local planning and feedback constraints/alternative options to line planning.
- To receive updated information from planners of adjacent operations, e.g., operations at multi-modal terminals.
- To support replanning of track allocations in hand-over yards.
- To communicate track allocation changes to planners of adjacent operations, e.g., operations at multi-modal terminals.
- To deal with algorithms for integrated planning of rolling stock stabling and service of passenger units at shunt areas in between passenger trips. They need to be moved from the station to a yard and vice versa, directed to service platforms, properly combined, and be parked efficiently.
- Integrate network and station planning algorithms for long-term timetabling in single algorithms though suitable decomposition algorithms.

- Integrate network and station planning algorithms for short term timetabling in single algorithms though suitable decomposition algorithms.

5.6.4. TE6: High-level requirements

It shall be possible for station or yard capacity planning systems to:

- Perform an extended data exchange with terminals, ports and freight forwarders to provide relevant data for customers. (TE6a)
- Where applicable, make use of TAF/TAP compliant data exchanges (extensions could be required). (TE6b)
- Receive updated capacity plans from line-based CMS/TMS (including train paths and TCR). (TE6c)
- Communicate track reservations (stabling, parking, etc.) to CMS and TMS. (TE6d)
- Communicate yard delays and consist/consist changes or rolling stock limitations to TMS. (TE6e)
- Communicate track assignment changes for trains to CMS and TMS. (TE6f)
- Communicate shunting activities with impact on lines to CMS and TMS. (TE6g)
- Communicate path changes (also international, PCS based) down to local planning systems to adapt local planning and feedback constraints/alternative options to line planning. (TE6h)
- Receive updated information from planners of adjacent operations, e.g., operations at a multi-modal terminal. (TE6i)
- Support re-planning of track allocations in hand-over yards. (TE6j)
- Communicate track allocation changes to planners of adjacent operations, e.g., operations at a multi-modal terminal. (TE6k)
- Compute an integrated rolling stock stabling plan that contains parking of trains, shunting between station and yard (and vice versa), and the capacity scheduling for cleaning and inspection activities in related tracks. (TE6l)

5.7. Technical enabler 7: New planning and operational processes using feedback loops from ERTMS ATO and C-DAS

The functionality of DAS and ATO use the same kind of data about infrastructure, train and timetable, which are used to calculate a driving profile (train trajectory). The difference between the two systems lies in the driving profile's execution. Driver Advisory Systems (DAS) translate the train trajectory to driving advice for the driver while the ATO system uses the calculated train trajectory as reference to provide automatic control commands to the traction and braking systems.

In the case of ATO over ETCS, the ATO on-board system receives from the ATO trackside system the journey information (e.g., timing points with arrival, passing times and/or departure times exist) to pull and brake automatically the train following an optimised speed profile.

DAS and ATO systems consider various types of data, such as train positioning, infrastructure characteristics, the real-time transport plan, rolling stock data, etc.

With the use of the DAS and ATO several benefits are expected to be obtained. Among others, they represent a significant improvement of performance in the short term without the need for a large investment, a contribution to the traction energy saving (generally estimated between 5% and 15% depending on the type of system: S-DAS or C-DAS, a better punctuality and network capacity improvement.

These systems, implemented by the IMs and RUs, should be able to communicate with other systems to receive and provide them information. Therefore, basic guidelines need to be defined to allow this compatibility.

DAS were slowly implemented in Europe over the 2010s, mostly in S-DAS version rather than C-DAS version. C-DAS version has a connection to the TMS to give and receive updates about a train's journey with the aim to maintain a constantly updated understanding of the trip (e.g., conflicts, new timetables etc.). The DAS system constantly recalculates and displays a conflict-free and energy-optimised driving profile based on real-time information about a train's path, infrastructure constraints, topology, timing targets, etc.

In relation to the ATO itself, there has also been progress in recent years. In the XRail-4 project the specification for the ATO over ERTMS GoA2 were developed (in 2019). With a GoA2, a semi-automatic train operation is achieved, in which the train is driven automatically but a train driver is still responsible. The stopping is automated, but the driver is required to start the automatic driving. Additionally, the driver can operate the doors, carry out other manual activities or handle emergencies.

The specifications result of the XRail-4 project for ATO GoA2 were tested in two demonstrators: one in United Kingdom and another in the border between Germany and Switzerland. This was also analysed in OCORA demonstrator project and reviewed by ERA to be included as part of the CCS TSI. These ATO GoA2 over ETCS specification has been finally included and published in the new CCS TSI published by ERA in September/October 2023.

As part of the Flagship Project 2 (FP2) of EU-Rail the specifications of ATO GoA3-4 over ETCS is expected to be developed. These GoAs allow driverless and unattended trains.

Additionally, significant advances have existed in the integration of the TMS with systems such as the C-DAS or ATO. The integration of the ATO with the systems involved in traffic management has demonstrable objective advantages. The ATO and C-DAS linked with the TMS, improves system response times and process automation, while maintaining the possibility of human control if necessary. This results in greater than 99% availability for regulation, improvements in energy consumption and fleet management, increased punctuality, reduced system response time and more options for human intervention in case of possible risks.

At performance level (higher depending on the degree of automation) a significant difference arises between DAS and ATO. In DAS, the staff receives the information and acts manually, but with ATO, the developed solutions will, for sure, be executed accurately. It is then possible to predict the trains current state and also its future movement along the line. This will enable the reduction of timetable supplements applied for operational variance.

5.7.1. TE7: Alignment with previous results

ProRail and NS have experience in modelling future operations by human-in-the-loop simulation. Here train drivers, signallers and dispatchers work together, simultaneously, in simulated operational scenarios. Here, they will focus on insertion of new (innovative) technologies into operation, like ETCS HL3 and ATO in timetables, defining optimal methods and parameters for realistic and robust future plans.

TRV is building up a knowledge node TMS – CDAS/ATO. System suppliers of DAS need agreement with RU running trains in Sweden. RU could connect to TMS/Digital graph – DAS. Digital graph is currently under development by TRV. VTI is developing a train driver simulator to evaluate real life capacity, including human factors in the loop. This simulator includes ETCS signalling and it is foreseen to include ATO and C-DAS in the future.

CAF is working on ATO/TMS on improvements in energy consumption, punctuality, more tools for human intervention in case of possible risks, fleet management, shorter response time of the system (not only in terms of form but also providing the staff with more time to respond to an eventuality that may arise and require their intervention). They also work on simulation systems that allow the replication and improvement of the process.

DB uses ATO in the Stuttgart digital node in automation Level 2 (GoA2). The onboard unit regulates the speed according to the current operating state of the network. During scheduled operations, it drives at the most energy-efficient speed and in the event of a delay, the train drives at the maximum permissible speed. At platforms, ATO enables a high-precision stop. This avoids delays and shortens the distance between two trains. ATO will be directly communicating with CTMS, the future central, automated planning and control system. CTMS will create and update Journey Profiles for ATO dynamically, depending on the current operational situations.

It is required the use of harmonised DAS protocol like described in the SFERA protocol *IRS 90940* (UIC, 2020) in addition to ERTMS/ATO. The *IRS 90940* model comes as close as possible to the ERTMS/ATO standard (UNISIG SUBSET- 125/126). This was intended to keep the effort involved in generating the *IRS 90940* data in parallel to the UNISIG ATO data as small as possible for IMs and to offer similar data for DAS and ATO to RUs. This approach also has the advantage that the *IRS 90940* data contains all the information necessary for ATO operations.

However, unlike ERTMS/ATO, *IRS 90940* aims to support Class B ATP lines. Due to the technical constraints of these legacy lines (e. g. the absence of ETCS balises or ETCS On-Board Units), this IRS was enriched with additional data elements which on ERTMS lines would mostly be supplied by ETCS. These are mainly:

- The Train Characteristics: those used by ERTMS/ATO are either received from the TCMS or hardcoded in the ATO over the ETCS On-Board Unit.
- Additional information about the infrastructure: needed by the DAS for defining a train's location (with ETCS, this information is provided by balises).
- Additional information about the signalling system, such as the position of signals, usual aspects of signals and the signal-induced behaviour of the train driver (the actual signal aspect is unknown at the time the driving advice is calculated).
- Context information about the train journey to help the driver understand the advice given (e.g., kilometre reference points, reasons associated with timetable updates).

- ATO/TMS must guarantee scalability and adaptability. This provides independence from the deployment of physical equipment and facilitates that its functional subsystems can be coupled to any architecture.

5.7.2. TE7: Current state of practice

ERTMS ATO and C-DAS are new technologies for which the practical experience is yet very limited. TRV, SNCF among others, are building up knowledge, but nothing is implemented.

In UK, C-DAS is in use since 2017 in three major types (RDG, 2017):

- Standalone DAS (S-DAS): a driver advisory system which has all data downloaded to the train at or prior to journey starts.
- Networked DAS (N-DAS): a driver advisory system that is capable of communicating with one or more RU control systems, enabling provision of data to the train, including updates for schedule or routing information, although these are generally not in near real time.
- Connected DAS (C-DAS): a driver advisory system with a communications link to external control systems in each controlled area in which the train operates – this is most likely a traffic management system.

In Spain there are no mainline equipped with fully operational and functional ATO. The closest is the C5 commuter line in Madrid, but it is an LZB installation with more than 25 years in service that is planned to be replaced by ERTMS. There is also no ATO/ERTMS. The closest thing is the ERTMS L2 mounted on some lines, but it has no commercial stop data, among others. In on-board systems, Siemens ICE 3 tracks the traction curve, but is not an ATO as such.

5.7.3. TE7: Assigned development needs

The following development needs are found within new planning and operational processes using feedback loops from ERTMS ATO and C-DAS:

- Improved simulation methods for capacity evaluation of different development aspects of ETCS, such as ETCS level 2 optimal braking and ETCS Hybrid level.
- Improved simulation methods for capacity evaluation of C-DAS/ATO.
- ATO-TMS operational test facilities, linking with FA2 ATO demos Human-in-the-loop simulations (train driver-loco-traffic management-TMS-ATO and human-factors research).
- Ensure the compatibility of communications between on-board and field equipment, especially on the part of suppliers, so as to mitigate as much as possible the risk of incompatibilities in communication between trains and infrastructure. The interface between ATO on-board and ATO trackside system should be use for ATO system and could be use as reference for C-DAS system.
- Ensure communication compatibility between the systems for suppliers, users and manufacturers of the adopted solution.
- Adjust the planning to the actual running of the train by means of:
    - Refine the trains running with the use of historical data on train operation
    - Refine the trains running with the introduction of ATO over ETCS
    - Increase the capacity by considering innovative technologies such as ERTMS Hybrid Level 3 or ETCS Level 3 with moving blocks
    - Ensure the feedback from TSR and TCR to planning and CMS to refine the operation plan

- Simplification and optimisation system included in TMS/ATO in both software and hardware.
- Feedback and use from data obtained from the analysis (capacity, punctuality, energy, units in use, station times, speeds, etc) considering ETCS, ATO and C-DAS aspects.

5.7.4. TE7: High-level requirements

High-level requirement for the work with new planning and operational processes are:

- Improved railway traffic simulation models for capacity evaluation of ETCS. (TE7a)
  - Simulation methods for capacity evaluation of different development aspects of ETCS, such as ETCS level 2 optimal braking and ETCS Hybrid level.
- Improved railway traffic simulation models for capacity evaluation of C-DAS/ATO. (TE7b)
  - Modelling of C-DAS/ATO in timetables.
  - Capacity simulation models including different capacity aspects of C-DAS/ATO such as TMS interaction, driver behaviour and energy efficiency.
- Feedback loops between operations and planning considering ETCS, ATO and C-DAS aspects. (TE7c)
  - Improve the timetable planning by considering historical data on train operation and feedback data from new technologies, i.e., C-DAS, ATO over ETCS and ETCS L2 and Hybrid L3.
  - Improve the timetable planning by getting feedback data from capacity simulations of ETCS, ATO and C-DAS.

6. Demonstration descriptions

In Section 6, all demonstrations in Workstream 1.1 are introduced and described, together with related use cases. As mentioned in Section 3, the term *demonstration* is used instead of *demonstrator* in this document. This is because most of the results in WP4-9 will consist of principles, algorithms, methods and models. The frameworks that are planned to be developed and used for the demonstrations can be found in Appendix B. Some frameworks are mature and some frameworks are not mature and therefore, *demonstrations* will be the main results from Workstream 1.1.

There are 13 demonstrations and they relate to the different work packages WP4/WP5, WP6/WP7 and WP8/WP9. For some demonstrations, there are several beneficiaries involved and to make it clear what each of the beneficiary will work with, these demonstrations are divided into sub-demonstrations. For example, Demonstration 7 is divided into 7.1 and 7.2 because there are two beneficiaries that will present two slightly different demonstrations.

All demonstrations and sub-demonstrations are introduced in Section 6.1 and mapped against TEs, TRL levels, use cases and high-level requirements. The high-level requirements for each TE are found in the subsections of Section 5. Defining TRL levels for each sub-demonstration is an ongoing work and for several demonstrations this is not decided yet or might be updated.

There are in total 47 use cases in Workstream 1.1, all presented in a separate table in Appendix A. 17 use cases are related to demonstrations in WP4/WP5, 12 use cases related to WP6/WP7 and 18 use cases related to WP8/WP9.

In Section 6.2, all demonstrations and sub-demonstrations are presented with conceptual ideas of what will be demonstrated and how. In Section 6.3, the demonstrations and sub-demonstrations are mapped against simulation environments and frameworks to be used within WP4/WP5, WP6/WP7 and WP8/WP9.

6.1. Introduction of demonstrations

Table 6.1 Mapping of demonstrations for WP4/WP5

Demo No.	Short description	Participants	Technical enabler	TRL	Use case	High-level requirement
1	Cross-border scheduling	MERMEC	TE1	4/5	UC-FP1-WP3-17	TE1a, TE1b, TE1d, TE1e, TE1f

2	Handling both, national and cross-border traffic with focus on cross-border freight trains. Supporting methods how to identify residual capacity Sweden – Norway. International co-ordination of residual capacity in an early ad hoc stage	TRV A.E. KTH	TE1	4/5	UC-FP1-WP3-7, UC-FP1-WP3-8, UC-FP1-WP3-9	TE1b, TE1d, TE1e, TE1f
3	Interfaces for interaction with external national or central planning applications; cross-border planning including short-term planning and process improvement among actors	HAC	TE1	6/7	UC-FP1-WP3-1, UC-FP1-WP3-2, UC-FP1-WP3-3	TE1a, TE1b, TE1c, TE1e, TE1f, TE1g
4	Collaborative yard capacity planning	TRV A.E. RISE	TE6	4/5	UC-FP1-WP3-10, UC-FP1-WP3-11, UC-FP1-WP3-12, UC-FP1-WP3-13	TE6a, TE6c, TE6i, TE6j, TE6k
5	Improved capacity allocation and new processes. Integration of new planning processes and the production of standard reports.	HAC	TE1, TE2	6/7	UC-FP1-WP3-4	TE1e, TE2a, TE2b, TE2c
6	Integration of traffic management system with network capacity planning. The feedback loop between planning and operation will be jointly demonstrated with WP11 (task 11.3)/ WP12 and WP 13/14.	HAC	TE2, TE6	5/6	UC-FP1-WP3-5	TE2d, TE6e, TE6f
7.1	Integration of network capacity planning with yard and station capacity planning. Integration of nodes and lines using specified interfaces	HAC	TE6	5/6	UC-FP1-WP3-6	TE6b, TE6c, TE6d, TE6f, TE6g, TE6h, TE6j
7.2	Feasibility checks for tactical yard/network planning	TRV A.E. KTH and RISE	TE1, TE6	5	UC-FP1-WP3-14, UC-FP1-WP3-15, UC-FP1-WP3-16	TE1b, TE1d, TE1f, TE6c, TE6d, TE6f, TE6g, TE6i, TE6j, TE6k

Table 6.2 Mapping of demonstrations for WP6/WP7

Demo No.	Short description	Participants	Technical Enabler	TRL	Use case	High-level requirement
8.1	Demonstration of algorithms for generating strategic timetables	NSR, NRD A.E. SINTEF, DLR	TE4	5	UC-FP1-WP3-22, UC-FP1-WP3-23, UC-FP1-WP3-24	TE4a, TE4b, TE4c, TE4d
8.2	Demonstrate how a planner can interact with an optimisation-based timetable planning tool to resolve conflicts in the long-term planning process	TRV A.E. RISE	TE4	4/5	UC-FP1-WP3-21	TE4a, TE4e
9	Timetable optimiser and decision support system for adjusting the annual timetable on a line or network level based on the activities of subtask 6.3.1	HAC	TE3	5/6	UC-FP1-WP3-25	TE3a, TE3b, TE3c
10.1	Demonstration of algorithms for planning of planned maintenance work for the entire Dutch network. Cancellations and alternative routes will be considered.	NSR	TE3	5/6	UC-FP1-WP3-19	TE3b
10.2	Demonstrate the use of short-term planning algorithms for re-scheduling trains in case of TCRs at the Alnabru-Malmö line	TRV A.E. LIU, NRD A.E. SINTEF	TE3	5/6	UC-FP1-WP3-18	TE3b
10.3	Demonstrate the use of algorithms for inserting short-term train paths in a planned timetable	SNCF	TE3	5/6	UC-FP1-WP3-29	TE3a
10.4	Demonstrate the use of short-term planning algorithms that identify and solve conflicts by different means	INDRA	TE3	5/6	UC-FP1-WP3-26	TE3c
10.5	Demonstrate functionalities for short-term planning for rescheduling timetables in case of TCR and managing additions or modifications of new tracks on request	STS, NRD A.E. SINTEF	TE3	5/6	UC-FP1-WP3-27	TE3a, TE3b, TE3c

11.1	Demonstration of algorithms for rolling stock rotation	NRD A.E. SINTEF	TE4	5/6	UC-FP1-WP3-28	TE4a
11.2	Demonstration of algorithms for rolling stock stabling	NSR	TE6	5/6	UC-FP1-WP3-20	TE6l

Table 6.3 Mapping of demonstrations for WP8/WP9

Demo No.	Short description	Participants	Technical Enabler	TRL	Use case	High-level requirement
12.1	Simulate large networks, calibration and validation methodology of simulation model, mainly regarding finding primary delay distribution input (from historical data)	TRV A.E. KTH, TRV A.E. LU	TE5	5/6	UC-FP1-WP3-31, UC-FP1-WP3-32	TE5a, TE5b, TE5c
12.2	Demonstrate a method to evaluate the robustness of a crew plan by a new simulation tool. The simulation focuses on delay propagation between trains by shared crew members.	NSR A.E. SISCOG, PR	TE5	6/7	UC-FP1-WP3-42	TE5a, TE5b, TE5c, TE5d
12.3	Demonstrate a method for processing the historical data and implement the delay distribution into RailSys for stochastic models	SNCF	TE5	TBD	UC-FP1-WP3-32	TE5b, TE5c
12.4	Simulate how the timetable behaves with different topology networks	INDRA	TE5	TBD	UC-FP1-WP3-43	TE5a
13.1	Determining the capacity, wear and energy effects of: ATO, TPE, C-DAS, TMS, HL3, NG Brake on mainlines and shunting/stabling actions	PR, NSR	TE7	4/5	UC-FP1-WP3-41	TE7a, TE7b, TE7c
13.2	Methods to determine the capacity effect of ETCS HL3	SNCF	TE7	TBD	UC-FP1-WP3-30	TE7a, TE7c
13.3	Create timetables considering C-DAS driver mode and determine the effects in capacity	INDRA	TE7	TBD	UC-FP1-WP3-44	TE7b, TE7c
13.4	Create mixed operational plans taking into consideration the hour of the day or the area where the track is placed	CAF	TE7	5/6	UC-FP1-WP3-36, UC-FP1-WP3-37, UC-FP1-WP3-38, UC-FP1-WP3-39	TE7a, TE7b, TE7c

13.5	Analyse the effects of C-DAS on capacity and energy consumption taking into account the effects of on-board communication and positioning	CEIT	TE7	4/5	UC-FP1-WP3-46	TE7b, TE7c
13.6	Modelling of system effects of different GoA. Modelling effects from introducing ETCS HL3 on lines with dense traffic. Modelling effects from varying adhesion conditions and introducing new generation braking system.	TRV A.E KTH	TE7	4/5	UC-FP1-WP3-40, UC-FP1-WP3-45, UC-FP1-WP3-47	TE7b, TE7c
13.7	Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety	TRV A.E. VTI	TE7	4/5	UC-FP1-WP3-33, UC-FP1-WP3-34, UC-FP1-WP3-35	TE7a, TE7c

6.2. Detailed description of the demonstrations

6.2.1. Demo 1 (WP4/WP5)

In Demo 1, MERMEC will use one or several simplified and internal developed CMS planning applications to perform a cross-border path request. The scenario will be applied in a regional context using a line that has to be agreed with RFI. A simplified Path coordinator orchestrator will be developed to allow path requests data exchange. From WP17 the developed Forecast and conflict detection/resolution module will simulate how the new path request fits for the cross-border lines. The related use case is UC-FP1-WP3-17. The expected result is to have a cross-border path definition without any conflicts from both sides of the border.

6.2.2. Demo 2 (WP4/WP5)

In Demo 2, TRV A.E. KTH will demonstrate methods for visualising residual capacity while inserting freight trains in a cross-border application. Use case UC-FP1-WP3-7 will cover a scenario where all other trains are fixed, while UC-FP1-WP3-8 covers a scenario where some trains can be modified. Simulation is used in use case UC-FP1-WP3-9 to assess the robustness of different train path solutions. The test instance will be taken from the line Malmö-Oslo/Alnabru.

6.2.3. Demo 3 (WP4/WP5)

In Demo 3, HACON will use a CMS planning application based on their enhanced TPS.plan product to show interaction with external national or central planning applications and cross-border STP capabilities including process improvement among actors. The use cases UC-FP1-WP3-1 and UC-FP1-WP3-2 are covered for demonstrating international path request alignment facilitated by CMS instances of the neighbouring IMs at different phases. For demonstration of the UC-FP1-WP3-3, the import of TCRs via TAF/TSI as provided by a centralised application (e.g., at RNE) will be shown including conflict detection and required handling of international paths to address the TCR impact.

6.2.4. Demo 4 (WP4/WP5)

In Demo 4, TRV A.E. RISE will use a tool for operational planning of arrival/departure yards (YCS) to show how it can be used for improved coordination between the actors at the yard and for better track allocation plans with improved foresight, that are in-line with the train information in the TMS-system. Use cases UC-FP1-WP3-10 to UC-FP1-WP3-13 are connected to demonstration 4. The demonstration will be showing Malmö shunting yard. The expected result is better yard planning with improved communication between the yard capacity planner, yard manager and terminal manager.

6.2.5. Demo 5 (WP4/WP5)

In Demo 5, HACON will use a CMS planning application based on their TPS.plan product to address use case UC-FP1-WP3-4, by showing an improved capacity allocation and new processes including the integration of new planning processes (according to TTR) and the production of standard reports. The new planning processes to be shown will especially include long term capacity agreements, capacity partitioning and rolling planning process in conjunction with annual capacity allocation.

6.2.6. Demo 6 (WP4/WP5)

In Demo 6, HACON will show the integration of traffic management system with network capacity management/planning system based on their products TPS.plan and TPS.live. The bi-directional integration between capacity planning (CMS) and capacity production (TMS) will be jointly demonstrated with WP11 (task 11.3)/ WP12 and WP 13/14. The demonstrations include use case UC-FP1-WP3-5, addressing the provision of (very) short-term (capacity-)plan to the TMS including TCRs send by line-based and local, i.e., yard or station related capacity planning processes. For better quality and efficiency in the overall processing between planning and operations, operational information including operational status is fed back to planning to provide adjusted plans accordingly.

6.2.7. Demo 7 (WP4/WP5)

Demo 7 is a combined demonstration from Hacon and TRV A.E. RISE and TRV A.E. KTH.

Demo 7.1

In Demo 7.1, HACON will show the use case UC-FP1-WP3-6 covering the integration of network capacity planning application based on their enhanced TPS.plan product with a yard-based capacity planning application for connecting node and line-based planning processes using specified interfaces. The demonstration cases involve sending updated capacity plans managed by national CMS to a local capacity management application in a yard and station as well as communication of capacity plan changes induced by local capacity management needs to the national CMS.

Demo 7.2
In Demo 7.2, TRV A.E. RISE will show how a tool for arrival/departure yard planning can be used in the tactical planning to make provisional track allocation plans and to verify that tactical timetables created in CMS are verified from a yard feasibility perspective. This is handled both for the plan in general (UC-FP1-WP3-14) and for new or changed capacity demands coming from CMS (UC-FP1-WP3-15). New input can also come from the terminal manager or yard manager, which is handled in UC-FP1-WP3-16. Further TRV A.E. KTH will demonstrate how solutions (requests) from the yard planning tool can be used as input to update the timetable to resolve planning infeasibilities between yards and the network.

6.2.8. Demo 8 (WP6/WP7)

Demo 8 is a combined demonstration from NSR, NRD A.E. SINTEF, and TRV A.E. RISE.

Demo 8.1
In Demo 8.1, NSR and NRD A.E. SINTEF will demonstrate decision support algorithms for generating strategic timetables. The algorithms can optimise over different objective functions, depending on the needs of the railway companies. An example is considering the service quality and the operational cost of a timetable, taking into account passenger transfer time. Another example is to consider some of the costs as soft constraints (i.e., that they don't need to be always satisfied) and minimise the number of violated constraints. Moreover, by including infrastructure limitations, the proposed approach can rule out designs that would turn out to be impossible in later stages of the timetabling process. The algorithms can also investigate the feasibility of certain train service levels, for example checking whether an increased frequency of trains between two stations is a viable option or it would require an upgrade of the railway infrastructure.

The goal of the research is to develop generic timetabling algorithms for both network and node level that can be used together to generate timetables from scratch. The proposed algorithms allow for understanding the trade-off between service quality and operational costs, as well as for assessing the benefits of infrastructure expansions. The algorithms will be tested on Dutch and Norwegian data sets.

In the demonstrator, NSR and NRD A.E. SINTEF will show that high-quality timetables can be computed in this way, for example, by asking experienced timetable designers to assess their quality. The use cases related to this demo are UC-FP1-WP3-22, UC-FP1-WP3-23 and UC-FP1-WP3-24.

Demo 8.2
In Demo 8.2, TRV A.E. RISE will show examples of how a planner can interact with an optimisation-based timetable planning tool to resolve conflicts in the long-term planning process. The demonstration is related to use-case UC-FP1-WP3-21. The test instance will be taken from the

Swedish part of the line Malmö-Oslo/Alnabru.

The focus of the demonstration will be on the efficiency-thoroughness trade-off, i.e., helping a planner find a good enough solution fast enough. Timetable planners often work towards strict deadlines, and it is therefore important that a timetable planning support tool help planners reach a solution that they are satisfied with before the deadline. The envision is that the demonstration will show some sort of iterative work process, potentially where planners first find a rough plan, and then add more details in iterations. The expected result from the work with this demonstration is knowledge about how planners can work with optimisation to make good enough timetables fast enough.

6.2.9. Demo 9 (WP6/WP7)

In Demo 9, HACON will show a timetable optimiser and decision support system for adjusting the annual timetable in short-term planning on a line or network level. The demonstration covers use case UC-FP1-WP3-25. It will show how optimisers can be used supporting STP in case of new or changed trains paths or TCRs causing needs for optimal re-alignment of the capacity plan, minimising the impact of the required adaptations. The use of a decision support module demonstrates how different solutions generated based on different sets of configurable parameters can be assessed by a capacity planner pre selecting and implementing the most suitable solution. The resulting capacity plan changes will be synchronised with the capacity production process (TMS) via use case UC-FP1-WP3-5 and related Demo 6.

6.2.10. Demo 10 (WP6/WP7)

Demo 10 is a combined demonstration from NSR, NRD A.E. SINTEF, TRV A.E. LIU, SNCF, INDRA and STS.

Demo 10.1

In Demo 10.1, NSR will demonstrate a decision support algorithm based on an advanced mathematical model for constructing an (almost) conflict-free adjusted hourly timetable (AHT) on a national level. The model and algorithm will be demonstrated on several real-life test cases of the Dutch railway network, with both passenger and freight services, as well as collections of maintenance work that had been scheduled for the same day, see use case UC-FP1-WP3-19.

The goal is to design an AHT that facilitates passenger and freight flows on the available infrastructure; this includes the minimisation of the cancellation of services. In addition, it is preferred to adjust the departure and arrival times as little as possible.

In the demonstrator, NSR will show that the test cases can be solved sufficiently quickly with a desirable level of optimality guarantee, and they will use external simulation tools to verify the quality of the passenger flows. Moreover, timetabling experts will assess the benefits of the proposed model and algorithm for the timetabling process.

Demo 10.2

In Demo 10.2, TRV A.E. LIU in collaboration with NRD A.E. SINTEF, will demonstrate a new algorithm that re-schedules train paths in case of a TCR in a mixed-traffic line. The purpose of the algorithm is to give decision support to a timetable planner in the time-consuming work of creating a temporary timetable. In case of a TCR, some trains might have to be cancelled, and the expected result is an algorithm that can guide the planner in an iterative way, to take decisions in a strategic way. This can be also called *incremental timetabling*.

Interesting TCRs to include in the demonstration are a closure of one of the tracks at a double-track line and a speed restriction on a part of the line (UC-FP1-WP3-18). The annual timetable is the input and the algorithm will use optimisation to create a new, macroscopically feasible, timetable. The chosen instance will be taken from the Malmö - Oslo/Alnabru line where there is mixed cross-border train traffic.

The output timetable will be evaluated using several KPIs, such as travel time, cancellations and robustness. The idea is to evaluate the traffic using microscopic simulation to see that the punctuality is satisfying.

Demo 10.3

In Demo 10.3, SNCF will demonstrate algorithms which optimise the insertion of short-term train-paths (STTP) into a predefined timetable, see use case UC-FP1-WP3-29. RUs demands are studied by the concerned regional and local timetable planners, who have to coordinate together to find a solution. The main problem is that it is necessary to have a lot of back-and-forth work between the planners to succeed in inserting STTPs, but also that a lot of demands are rejected because no solution is found. However, solutions could be possible if a global approach is considered, to slightly re-optimise train speed profiles, routes or platform assignments, without modifying the commercial timetable.

The purpose is to showcase a global and integrated approach considering both regional and local views, taking as inputs the nominal timetable, the planned maintenance and works, and the requested STTPs. The output will be the modified timetable with as many as possible STTPs inserted within it. The validation will be done with the microscopic OSRD simulator provided by SNCF Réseau.

Demo 10.4

In Demo 10.4, INDRA will demonstrate the use of algorithms on conflict detection and resolution (CDR) that make adjustments in the timetable schedule. The purpose of the demonstrator is to deal with scenarios that typically occur such as unexpected TSRs or possessions (UC-FP1-WP3-26) supporting the timetable planner to make good decisions.

Initially, the planner can modify and adjust the schedule, for example adding TSRs or new train paths. When insertion is possible, the schedule will be manually adjusted. However, unfeasible timetables are frequently the consequence of these insertions and modifications. INDRAs CDR software will detect several conflicts and will provide a set of resolution methods that modify and update the train-paths, resulting in a conflict-free timetable. The CDR algorithms will manage several conflict types (crossing, catch-up, insufficient track length, possession conflict). After applying the algorithms, the obtained timetable can be analysed in terms of train-paths affected and the impact on the commercial times.

Demo 10.5

The software component developed by Hitachi/SINTEF will demonstrate functionalities for optimising timetables in the short-term period (from one day to one year ahead) taking into account TCRs, new trains requests and network characteristics.

The scenarios considered in the demonstration will be use cases of possible perturbation, such as track or station TCRs, but also the addition or modification of new tracks on request, see use case UC-FP1-WP3-27. In the use case, the significant area and timetable parts for the single demonstrations of the functionality will be taken into consideration.

The data that will be used by the demonstration will be static configuration data (e.g., network configuration data and train running times) and a base planned timetable. The demonstration will not use actual data from the real system. The extra data needed for the demonstration will be created ad-hoc and will not be traceable to real events.

6.2.11. Demo 11 (WP6/WP7)

Demo 11 is a combined demonstration from NRD A.E. SINTEF and NSR

Demo 11.1

In Demo 11.1, NRD A.E. SINTEF will demonstrate the quick creation of rolling-stock plans for one or more lines in Norway in synergy with Demonstration 8.1, see use case UC-FP1-WP3-28. The algorithm will pair with the system for long-term timetabling developed in Demonstration 8.1, and it will be able to quickly produce a new plan whenever a new timetable is generated. Determining this new plan and, more importantly, showing it through the GUI to timetabling experts, will help the incremental decision process of Demonstration 8.1.

Demo 11.2

In Demo 11.2, NSR will demonstrate a decision support algorithm based on a construction and local search heuristic for constructing a rolling stock stabling plan for a railway node. The algorithm will be demonstrated on node Utrecht, UC-FP1-WP3-20. Utrecht Central is the most central and busiest train station (both in terms of number of passengers and number of trains) of the Netherlands, and has been found to be a hard nut to crack. The node of Utrecht has three stabling yards.

The goal of the research is to improve the quality of the initial plan using more complicated logic which is tailored more towards the characteristics of the infrastructure of the node. It is also expected that the plans can be made more recognisable to planners.
In the demonstration, NSR will show that the test cases can be solved sufficiently quickly.
Moreover, experienced node planners will assess the benefits of the proposed algorithm.

6.2.12. Demo 12 (WP8/WP9)

Demo 12 is a combined demonstration from TRV A.E. KTH, TRV A.E. LU, TRV A.E. VTI, NSR, ProRail, SNCF and INDRA.

Demo 12.1

TRV A.E. KTH and LU will demonstrate the use of macroscopic railway simulation tool PROTON for a large network in a Swedish use case (UC-FP1-WP3-31) and linked to this also demonstrate methodology for creating primary delay distributions from historical data to be used as input for the simulation model (UC-FP1-WP3-32).

Demo 12.2

NSR, together with SISCOG and PR, will demonstrate a new feedback loop for crew planning. The robustness of multiple crew plans is assessed and compared on a robustness indicator by a new simulation model, that combines operations of timetable, rolling stock and crew. A comparison between a current and optimised version of a crew plan will be shown, and the robustness of both plans will be assessed.

The demonstration focuses on delay propagation by shared crew. The case where a driver arrives late from a previous task, UC-FP1-WP3-42, is considered. The focus is on the second train, to ensure this departs on time, where the transfer buffer time (total transfer time minus minimum time required for operations) is calculated. In an iterative step, the optimiser will calculate a second set of duties, with buffer time allocated at connections that are prone to delay or have more impact if the second train departs late.

Demo 12.3

SNCF will demonstrate a method for processing historical data and implement the delay distribution into RailSys for stochastic models, see use case UC-FP1-WP3-32.

The 3 main objectives of the demonstration are:

- Improve the quality of regularity data processing (historical data). At SNCF Réseau, time differences of less than 5 minutes are not documented in the regularity reporting tool (Bréhat/ORE). A first step will be to "reconstruct " the original incidents on the basis of existing regularity data and additional data (track circuit occupancy for instance)
- Better calibration of the "background noise" to improve the performance of stochastic tests. This involves finer parameter setting, or even inputting parameters from an external routine.
- Identify development needs for simulation in RailSys: trains running in advance, regulation rules, etc.

This demonstration will be carried out using RailSys/Denfert.

Demo 12.4

INDRA will demonstrate the use of simulation calculations in the analysis of timetables with different topology networks, see use case UC-FP1-WP3-43. The capacity analysis tool provides reports with train movements, block times, critical block information and conflicts found in the timetable that may lead to rethinking of signalling, relocation of railway elements. The capacity analysis tool will support a model with several ATP systems, applying their behaviours to the calculation and signalling procedures: ETCS Level 1 and ETCS Level 2.

6.2.13. Demo 13 (WP8/WP9)

Demo 13 is a combined demonstration from ProRail, NSR, SNCF, ADIF, INDRA, CAF, CEIT, TRV A.E. KTH, TRV A.E. VTI.

Demo 13.1

NSR and ProRail will develop the method to determine various effects, such as the capacity, of several new railway technologies, such as ERTMS HL3, ATO, Next generation brakes and TMS. The corridor that is selected for this demo is Schiphol – Amsterdam Zuid – Almere – Lelystad (SAAL), with a branch to Hilversum, which will be fitted with ERTMS level 2. This part of the network consists of 2- and 4-track sections with dense mixed traffic of slow and fast passenger trains and freight trains. The corridor is especially suited to investigate the effects of the system developments since the passenger numbers will increase in the future, while adding extra infrastructure is relatively expensive, especially around Schiphol Airport.

The demonstration will be performed with a micro-simulation environment, currently foreseen to be RailSys, wherein a method for the main corridor and adjacent yards will be applied. This demonstration relates to use case UC-FP1-WP3-41.

Demo 13.2

SNCF will develop a demonstrator about ETCS HL3. The aims are:

- Demonstration of a method for implementing ETCS HL3 into RailSys
- Demonstration of methods for determining the capacity effect of ETCS HL3
- Identification of the development needs for ETCS HL3 and ETCS L2 in RailSys (simulation of degraded modes, etc.)

The demonstration is related to use case UC-FP1-WP3-30. The location is not yet confirmed, but an option could be the LNOBPL (Ligne Nouvelle Bretagne Pays de Loire) project: capacity and high-speed rail improvements with ETCS HL3 in Brittany (western France). Some preliminary stochastic studies were carried out a few years ago. SNCF Réseau would like to study the possibility of implementing ETCS HL3 and the associated capacity gains.

Demo 13.3

Demo 13.3, by INDRA, will analyse the optimal capacity in a section of the network when C-DAS driver mode is included in INDRA simulation environment, see use case UC-FP1-WP3-44. It will demonstrate that the route calculation process in the TMS can be improved with the C-DAS linkage. Route calculation can be refined obtaining an optimised timetable.

Demo 13.4

The main objective of CAF demonstration is to be able to generate and validate mixed planning timetables taking into consideration different inputs such as the information generated by the CAF capacity analysis tool.

Our simulation tool will be the responsible of testing that the plans created are feasible. To accomplish the objective just mentioned, CAF will present some use cases in which the plan will be done taking into consideration the train position (space) or the service hour (time):

- In the case of time, there are two different cases; When it is a rush hour, traffic will be planned and regulated by headway. While if it is an off-peak hour, it will be managed by a timetable.
- Considering the space, the area through which the train runs, must be considered. It may be the case that the train changes from an area planned by headway to another that does so by timetable. This can be found on a long line that runs through central areas of the city and through more distant areas or branch lines.

Our planning tool will not be in charge of the transitions between the two management models (headway/timetable), this will be responsibility of the regulation tool that CAF will develop in WP15.

This demonstration is designed to serve different purposes:

1. To have it internally as a testing tool or test ecosystem that allows us to validate the advances, accomplished in TMS.
2. Serve as a tool with commercial value to assess the feasibility of the needs presented by a customer or in the pre-project phase. Here, the focus will be on the planning capacity to see whether or not pre-set conditions are satisfied.

The use cases in which CAF are going to test the planning tool are: UC-FP1-WP3-36, UC-FP1-WP3-37, UC-FP1-WP3-38, UC-FP1-WP3-39.

Demo 13.5

The demonstration developed by CEIT aims at developing a simulation environment to be able to analyse the impact of C-DAS on operations, namely energy consumption and capacity analysis. For that, different existing tools (currently focused on running time and energy analysis, communication performance and railway positioning simulations respectively) will be integrated and further developed into a new micro simulation tool. A special emphasis will be set on the impact on C-DAS performance of on-board communications and positioning using GNSS technologies. These input on communications and positioning parameters comes from FP2 (WP22 and WP28). The specific lines for the use case are still not defined. The use case in which the demonstrator is tested is UC-FP1-WP3-46.

Demo 13.6

The main objective of the TRV A.E. KTH Demo 13.6 is to simulate the system effects of different grades of automation on selected lines on the Swedish and Norwegian national railway networks with micro and macro simulation tools with ATO (see use case UC-FP1-WP3-40). The specific lines will be determined according to the WP8/WP9 planning and FP2 WP32. In addition, effects of introducing ETCS Hybrid Level 3 on a subset of the selected lines will be analysed both from a technical headway perspective and using operational simulation (see use case UC-FP1-WP3-45). The system effects include assessing influence on capacity and punctuality. Another objective of the demonstrator is to model effects of varying adhesion conditions and new generation braking system with improved adhesion management (see use case UC-FP1-WP3-47). This will also include one deterministic part with focus on technical headways and a simulation part to assess the impact on punctuality or other measures.

Demo 13.7

The primary purpose of the TRV A.E. VTI Demo 13.7 is to develop scenarios that make possible, in a train simulator, to study the effects of a new ERTMS implementation strategy called Co-existence (where Swedish national lineside-signalling and ERTMS (in-cab signalling) co-exist). The use cases will include a standard ERTMS implementation strategy (no co-existence) (UC-FP1-WP3-34), co-existence (UC-FP1-WP3-33), and special cases within co-existence (UC-FP1-WP3-35). The objective is to study the effects in terms of drivability, capacity, and safety by using real train drivers that, in a simulated environment, drive scenarios that include co-existence in normal conditions and when different types of special cases occur. All scenarios will take place on a simulated part of the Scandinavian-Mediterranean corridor.

6.3. Monitoring of demonstrators, simulation environments and frameworks in WP4/WP5, WP6/WP7 and WP8/WP9

The framework tools that are planned to be used for the 29 demonstrations (13 main demonstrations) can be found in Appendix B. They consist of simulation tools, modules and algorithms, collectively referred to as frameworks. The frameworks use different datasets, both microscopic and macroscopic. Amongst the participating partners in Workstream 1.1, only Norway provides open-source dataset applicable for the use cases in the demonstrations. Most partners work with native datasets to them. Therefore, they do not require open-source datasets. The datasets have thus not been mapped in detail as this will be done in a later stage in WP2. For details about the datasets to be used, we refer to the WP2 "data plan". However, for the purpose for future interoperability and application in dataset areas not native to the researchers, the datasets should be harmonised and be made readily available for a more efficient data exchange than is required for a one-time static dataset in a research program.

7. Interaction with other work packages and Flagship Projects

In this section the alignment and interactions between WP4-WP9 demonstrations and other FA1 WPs, other Flagship Projects and SP Task 3 CMS/TMS and RNE are mapped.

Table 7.1 Alignment and interactions of demonstrations for WP4/WP5

Demo No.	Short description	Participants	Other FP1 WPs	Flagship Projects	SP Task 3 CMS/TMS, RNE
1	Cross-border scheduling	MERMEC	WP10/WP11 and WP17		SP/RNE cross-border
2	Handling both, national and cross-border traffic with focus on cross-border freight trains. Supporting methods how to identify residual capacity Sweden – Norway. International co-ordination of residual capacity in an early ad hoc stage	TRV A.E. KTH			SP/RNE cross-border
3	Interfaces for interaction with external national or central planning applications; cross-border planning including short-term planning and process improvement among actors	HAC	WP6/WP7, WP11/WP12	FP5 (seamless planning work packages)	SP/RNE cross-border
4	Collaborative yard capacity planning	TRV A.E. RISE	WP11/WP12	FP5 (data integration via FP5 WP32) FP5 (seamless planning work packages)	SP/RNE cross-border
5	Improved capacity allocation and new processes. Integration of new planning processes and the production of standard reports.	HAC			SP/RNE: Timetable Re-Design (TTR)
6	Integration of traffic management system with network capacity planning. The feedback loop between planning and operation will be jointly demonstrated with WP11 (task 11.3)/ WP12 and WP 13/14.	HAC	WP11/WP12, WP13/WP14		SP/RNE: Timetable Re-Design (TTR): TCR ad-hoc paths
7.1	Integration of network capacity planning with yard and station capacity planning. Integration of nodes and lines using specified interfaces	HAC	WP11/WP12	FP5 (seamless planning work packages)	SP/RNE: Timetable Re-Design (TTR): TCR ad-hoc paths

7.2	Feasibility checks for tactical yard/network planning	TRV A.E. KTH and RISE		FP5 (data integration via FP5 WP32) FP5 (seamless planning work packages)	SP/RNE cross-border

Table 7.2 Alignment and interactions of demonstrations for WP6/WP7

Demo No.	Short description	Participants	Other FP1 WPs	Flagship Projects	SP Task 3 CMS/TMS, RNE
8.1	Demonstration of algorithms for generating strategic timetables	NSR, NRD A.E. SINTEF, DLR			
8.2	Demonstrate how a planner can interact with an optimisation-based timetable planning tool to resolve conflicts in the long-term planning process	TRV A.E. RISE	WP8/WP9		
9	Timetable optimiser and decision support system for adjusting the annual timetable on a line or network level based on the activities of subtask 6.3.1	HAC	WP4/WP5		
10.1	Demonstration of algorithms for planning of planned maintenance work for the entire Dutch network. Cancellations and alternative routes will be considered.	NSR			
10.2	Demonstrate the use of short-term planning algorithms for re-scheduling trains in case of TCRs in the Alnabru-Malmö line	TRV A.E. LIU, NRD A.E. SINTEF	WP8/WP9		
10.3	Demonstrate the use of algorithms for inserting short-term train paths in a planned timetable	SNCF			
10.4	Demonstrate the use of short-term planning algorithms that identify and solve conflicts by different means	INDRA	WP17/WP18		

10.5	Demonstrate functionalities for short-term planning for rescheduling timetables in case of TCR and managing additions or modifications of new tracks on request	STS, NRD A.E. SINTEF			
11.1	Demonstration of algorithms for rolling stock rotation	NRD A.E. SINTEF			
11.2	Demonstration of algorithms for rolling stock stabling	NSR			

Table 7.3 Alignment and interactions of demonstrations for WP8/WP9

Demo No.	**Short description**	**Participants**	**Other FP1 WPs**	**Flagship Projects**	**SP Task 3 CMS/TMS, RNE**
12.1	Simulate large networks, calibration and validation methodology of simulation model, mainly regarding finding primary delay distribution input (from historical data)	TRV A.E. KTH, TRV A.E. LU	WP6/WP7		
12.2	Demonstrate a method to evaluate the robustness of a crew plan by a new simulation tool. The simulation focuses on delay propagation between trains by shared crew members.	NSR A.E. SISCOG, PR			
12.3	Demonstrate a method for processing the historical data and implement the delay distribution into RailSys for stochastic models.	SNCF			
12.4	Simulate how the timetable behaves with different topology networks	INDRA			
13.1	Determining the capacity, wear and energy effects of: ATO, TPE, C-DAS, TMS, HL3, NG Brake on mainlines and shunting/stabling actions	PR		FP2 WP17: Next Generation Brake Systems with adhesion management functions – Phase 1: Demonstrator preparation and pre-validation FP2 WP32: DATO Assessment and Potential identification	

				FP2 WP37: ETCS HL3 Deployment Strategies FP2 WP39: ATO over ERTMS demonstration on mainline	
13.2	Methods to determine the capacity effect of ETCS HL3.	SNCF		FP2 WP32: DATO Assessment and Potential identification FP2 WP37: ETCS HL3 Deployment Strategies	
13.3	Create timetables considering C-DAS driver mode and determine the effects in capacity.	INDRA	WP11 and WP15		
13.4	Create mixed operational plans taking into consideration the hour of the day or the area where the track is placed	CAF	WP15	FA6: FUTURE	
13.5	Analyse the effects of C-DAS on capacity and energy consumption taking into account the effects of on-board communication and positioning	CEIT	WP15	FP2 WP22 and WP28	
13.6	Modelling of system effects of different GoA. Modelling effects from introducing ETCS HL3 on lines with dense traffic. Modelling effects from varying adhesion conditions and introducing new generation braking system.	TRV A.E KTH		FP2 WP17: Next Generation Brake Systems with adhesion management functions – Phase 1: Demonstrator preparation and pre-validation FP2 WP32: DATO Assessment and Potential identification FP2 WP37: ETCS HL3 Deployment Strategies FP2 WP39: ATO over ERTMS demonstration on mainline	

13.7	Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety	TRV A.E. VTI			

8. Conclusions and next steps

In this deliverable, the high-level specifications of requirements, high-level design and high-level use cases for capacity planning, are aligned, prepared and delivered. They are all connected to the development of the Technical Enablers 1 to 7:

1. European cross-border scheduling with international train path planning.
2. Improved capacity allocation using rolling planning and TTR.
3. Decision support for short term planning.
4. Train path and schedule optimisation methods and strategies.
5. Improved rail traffic simulation models for selected Use Cases to forecast punctuality in the network.
6. Integration of TMS with a) yard capacity planning and b) station capacity planning.
7. New planning and operational processes using feedback loops from ERTMS ATO and C-DAS.

The document can be seen as a conceptual deliverable where the scope within FA1 Workstream 1.1 is described. It is the foundation for future demonstrations in WP5, WP7 and WP9. All involved beneficiaries from Workstream 1.1 have collaborated in the writing of this deliverable and the result can be seen as the basis for the forthcoming work in WP4/WP5, WP6/WP7 and WP8/WP9. All descriptions are high-level and more details will be presented in each of the WPs own deliverables.

Each of the 13 predefined demonstrations are presented together with related use cases. All demonstrations are mapped against technical enablers, TRL levels, use cases and high-level requirements. They are also mapped against simulation environments and frameworks to be used within WP4/WP5, WP6/WP7 and WP8/WP9. To conclude, WP4/WP5 will work with integration of planning systems and new planning processes, including yard and station capacity planning and cross-border planning. WP6/WP7 will work with decision support and optimization for generating long-term and short-term timetables, strategic planning and rolling stock planning are also included. WP8/WP9 will work with improving simulation methods and models to improve the feedback between planning and operation and also to improve capacity evaluations of new technologies such as ETCS, C-DAS and ATO.

Due to ongoing alignment sessions with RNE and the SP and their work, changes to the use case and demonstration details for improved alignment of final development results cannot be excluded.

8.1. Next steps

The subsequent deliverables detailing the D3.1 work further are D4.1, D6.1, D8.2 and D8.3. In D4.1, the high-level requirements will be further specified into detailed requirements for European cross-border scheduling, capacity allocation using rolling planning and improved station/yard capacity planning (technical enablers 1, 2 and 6). Also, the use cases from D3.1 related to demonstrations 1-7, will be further described, in order to set precise expectations for each of the demonstrations. In D6.1, a review of the state-of-the-art within timetable optimization, will be presented. Also, decision support algorithms will be presented for both long-term and short-term planning, including strategic planning, station planning, rolling stock planning and TCR adjustments, as described in the use cases from D3.1 related to demonstration 8-11. In D8.2, micro and macro simulation environments will be presented for the specific use cases from D3.1 related to demonstration 12 along with methods for analysing historical data to improve capacity evaluations. In D8.3, models and methods for analysing capacity with ETCS, C-DAS and ATO will be presented according to the use cases from D3.1 related to demonstration 13.

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10. Appendices

Appendix A – Use cases

Appendix B – Mapping of simulation models and frameworks for Workstream 1.1 demonstrations

Appendix A – Use cases
Deliverable D3.1

Project acronym:	MOTIONAL
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High-level uses cases in WP4/WP5

UC-FP1-WP3-1 – International late path request placed between X-8 and X-2

Name	*International late path request placed between X-8 and X-2*
ID	*UC-FP1-WP3-1*
Partner	*HACON*
Demonstration associated	*Demo 3*
Description	*International capacity allocation process is (in general) not agile enough for the market needs (too long time to construct an international path). This happens in all time horizons, but especially for late and short-term requests. There are several problems, for example, IMs have different processes and deadlines and there is no immediate access to one IMs information for another IM. In this use case the focus is on solving the problem for international late path requests placed between X-8 and X-2.*
Related to task/subtask(s)	*Tasks 4.3, 5.2.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic, FP5*
Actor(s)	*IMs, RUs (as a capacity applicants)*
Notes	*General considerations:* • *The nature of the networks, types of borders, etc. need to be considered.* • *Track availability in border stations (interchange points) needs to be considered.* • *Consider variations of the paths depending on the period of the year or the weekday (Applicants may want different timetable or even route, O/Ds in different periods or weekday for the same "service", TCR periods).*

UC-FP1-WP3-2 – International path request placed after X-2 and before X+12)

Name	*International path request placed after X-2 and before X+12)*
ID	*UC-FP1-WP3-2*
Partner	*HACON*
Demonstration associated	*Demo 3*
Description	*International capacity allocation process is (in general) not agile enough for the market needs (too long time to construct an international path). This happens in all time horizons, but especially for late and short-term requests. There are several problems, for example, IMs have different processes and deadlines and there is no immediate access to one IMs information for another IM. In this use case the focus is on solving the problem for international path requests placed after X-2 and before X+12.*
Related to task/subtask(s)	*Tasks 4.3, 5.2.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic, FP5*
Actor(s)	*IMs, RUs (as a capacity applicants)*
Notes	*General considerations:* • *The nature of the networks, types of borders, etc. need to be considered.* • *Track availability in border stations (interchange points) needs to be considered.* • *Consider variations of the paths depending on the period of the year or the weekday (Applicants may want different timetable or even route, O/Ds in different periods or weekday for the same "service", TCR periods).*

UC-FP1-WP3-3 – Showing and handling of impact of imported TCR

Name	*Showing and handling of impact of imported Temporary Capacity Restrictions (TCR) on the currently planned international train paths.*
ID	*UC-FP1-WP3-3*
Partner	*HACON*
Demo associated	*Demo 3*
Description	*The CMS planning application shows new or changed TCRs received from a central service. The impact of the changed TCRs on international freight trains can be identified and handled by the Capacity Planner.* 1. *Local TCR causes changes to path(s) at/behind the border (handover) location* 2. *Behind-the-border TCR causes changes to path(s) in local network* 3. *Freight Corridor (RFC) view on impact and changes resulting from a) and b)*
Related to task/subtask(s)	*Tasks 4.2, 5.2.1*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic, FP5*
Actor(s)	*CMS operator*
Notes	*Expected identification of harmonization needs of national Planning rules – shared view (IMs / RNE)* *Expected input to SP/RNE in relation to TCR specification*

UC-FP1-WP3-4 – Planning and allocation of capacity for different planning horizons

Name	*Planning and allocation of capacity for different planning horizons*
ID	*UC-FP1-WP3-4*
Partner	*HACON*
Demo associated	*Demo 5*
Description	*The national CMS planning application demonstrates the support of new planning processes by using it for planning and allocation of capacity for different planning horizons involving* *1. RNE train path envelopes and TCR;* *2. Long-term capacity agreements and capacity partitioning;* *3. Rolling planning process and conjunction to annual allocation;* *4. Interface prototype supporting ECMT/capacity hub (RNE) integration;* *5. Modelling and (capacity-)handling of planned changes of the infrastructure;* *6. Generation of standard reports.*
Related to task/subtask(s)	*Tasks 4.3, 5.2.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1, TE2*
Interactions SP/FP	*SP/RNE: Timetable Re-Design (TTR)*
Actor(s)	*CMS operator*
Notes	*Expected identification of harmonization needs of national planning rules or paradigms in national planning*

UC-FP1-WP3-5 – Data exchange between TMS and national CMS

Name	*Data exchange between traffic management system (TMS) and local or national capacity management/planning system (CMS)*
ID	*UC-FP1-WP3-5*
Partner	*HACON*
Demo associated	*Demo 6*
Description	*The national and local (yard) based CMS planning application demonstrate the exchange of data with TMS showing new planning process involving the use of operational feedback information. The following sub-Use Cases are covered:* 1. *New or changed plan in national CMS sent to TMS a) train path b) TCR;* 2. *New or changed local plan of yard based local CMS sent to TMS, a) train consist b) later arrival in departure track c) earlier arrival in departure track d) track assignment change e) changed or new track reservation f) changed or new shunting activities with impact on lines;* 3. *New or changed operational TCR in TMS sent to national and local yard-based CMS;* 4. *Up-to-date train position feed-back from TMS to national CMS for deviation detection (track/time);*
Related to task/subtask(s)	*Tasks 4.4, 5.2.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE2, TE6*
Interactions SP/FP	*SP/RNE: Timetable Re-Design (TTR): TCR, ad-hoc paths*
Actor(s)	*CMS operator* *CMS operator* *TMS operator*
Notes	*Expected identification of harmonization needs of national planning rules or paradigms in national planning*

UC-FP1-WP3-6 – Data exchange between CMS and local CMS

Name	*Data exchange between national capacity management/planning system (national CMS) and local, yard-based capacity management/planning system (local CMS)*
ID	*UC-FP1-WP3-6*
Partner	*HACON*
Demo associated	*Demo 7.1*
Description	*The national CMS planning application demonstrates the exchange of data with local (yard) based CMS showing new planning process capabilities. The following sub-Use Cases are covered:* *1. New or changed plan in national CMS sent to yard based local CMS a) train path b) TCR;* *2. New or changed local plan of yard based local CMS sent to national CMS, a) train consist b) later arrival in departure track c) earlier arrival in departure track d) track assignment change e) changed or new track reservation f) changed or new shunting activities with impact on lines;*
Related to task/subtask(s)	*Tasks 4.5, 5.2.4*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*SP/RNE: Timetable Re-Design (TTR): TCR, ad-hoc paths, R-CDM, FP5*
Actor(s)	*CMS operator* *CMS operator*
Notes	*Expected identification of harmonization needs of national planning rules or paradigms in national planning*

UC-FP1-WP3-7 – Cross-border ad hoc planning 1

Name	*Cross-border ad hoc planning 1*
ID	*UC-FP1-WP3-7*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 2*
Description	*Timetable planners need support to take decisions when processing requests for ad hoc train path insertions or change requests, minor or major, for existing train paths. In this use case, we consider a static scenario in which none of the existing trains can be adjusted or modified while searching for residual capacity for inserting a single train path. The use case will be demonstrated between Malmö and Alnabru freight yards or on a subsection of this line.*
Related to task/subtask(s)	*Tasks 4.2, 4.5, 5.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*Timetable planners at IMs and RUs (as a capacity applicants)*
Notes	*N/A*

UC-FP1-WP3-8 – Cross-border ad hoc planning 2

Name	*Cross-border ad hoc planning 2*
ID	*UC-FP1-WP3-8*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 2*
Description	*Timetable planners need support to take decisions when processing requests for ad hoc train path insertions or change requests, minor or major, for existing train paths. In this use case, we consider a dynamic scenario in which existing trains can be adjusted or modified when searching for residual capacity for inserting a single train path. Other freight trains may be adjusted to some degree, also passenger trains may get smaller adjustment but subject to any delivery commitments. The use case will be demonstrated between Malmö and Alnabru freight yards or on a subsection of this line.*
Related to task/subtask(s)	*Tasks 4.2, 4.5, 5.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*Timetable planners (at IMs and RUs -as a capacity applicants)*
Notes	*N/A*

UC-FP1-WP3-9 – Cross-border ad hoc planning and simulation

Name	*Cross-border ad hoc planning and simulation*
ID	*UC-FP1-WP3-9*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 2*
Description	*Timetable planners need support to make judgements when processing requests for ad hoc train path insertions or change requests, minor or major, for existing train paths. This use case builds on the previous ones, but simulation is added as a tool for assessing the robustness of different train path insertion alternatives. Either a macroscopic or microscopic simulation tool will be used here.*
Related to task/subtask(s)	*Tasks 4.2, 4.5, 5.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*Timetable planners (at IMs and RUs -as a capacity applicants)*
Notes	*N/A*

UC-FP1-WP3-10 – YCS: Update the initial A/D-yard plan

Name	*YCS: Update the initial A/D-yard plan and make it conflict free for the next few hours.*
ID	*UC-FP1-WP3-10*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 4*
Description	*The LM, YM and TM update the initial plan for the next few hours.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*TMS Operator for the hand-over yard, also called Line Manager – LM, active* *Yard Manager – YM, active* *Terminal Manager -TM, active* *Train driver, passive* *TMS Operators for adjacent lines, passive* *RU, passive*
Notes	*This use case represents the planning work done during e.g. the beginning of a shift, or after a large disruption has occurred.* *The actors may need to, e.g., call each other and discuss in order to find a solution they all find satisfactory.* *The updated ready-to-depart times may be later than the current planned departure time. However, the departure times are not changed in YCS but rather in the TMS system.* *Small updates are handled in use case UC-FP1-WP3-11, UC-FP1-WP3-12 and UC-FP1-WP3-13.*

UC-FP1-WP3-11 – YCS: Update planned arrival times

Name	*YCS: Updated planned arrival times*
ID	*UC-FP1-WP3-11*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 4*
Description	*Information regarding updated planned arrival times is received from TMS, replanning is triggered. Information propagated to TM/YM, who make secondary responses to this.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*TMS Operator for the hand-over yard, also called Line Manager – LM, active* *Yard Manager – YM, active* *Terminal Manager -TM, active* *Train driver, passive* *TMS Operators for adjacent lines, passive* *RU, passive*
Notes	*The actors may need to, e.g., call each other and discuss in order to find a solution they all find satisfactory.* *The updated ready-to-depart times may be later than the current planned departure time. However, the departure times are not changed in YCS but rather in the TMS system.*

UC-FP1-WP3-12 – YCS: Wagons for outbound train not ready for departure on time

Name	*YCS: Wagons for outbound train not ready for departure on time*
ID	*UC-FP1-WP3-12*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 4*
Description	*Replanning triggered by information from terminal about cars not being ready for departure on time.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*TMS Operator for the hand-over yard, also called Line Manager – LM, active* *Yard Manager – YM, active* *Terminal Manager -TM, active* *Train driver, passive* *TMS Operators for adjacent lines, passive* *RU, passive*
Notes	*The actors may need to, e.g., call each other and discuss in order to find a solution they all find satisfactory.* *The updated ready-to-depart times may be later than the current planned departure time. However, the departure times are not changed in YCS but rather in the TMS system.*

UC-FP1-WP3-13 – YCS: New shunting need from YM

Name	*YCS: New shunting need from YM*
ID	*UC-FP1-WP3-13*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 4*
Description	*Replanning triggered by new information from Yard Manager regarding shunting operations that requires track capacity on A/D-yard.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*TMS Operator for the hand-over yard, also called Line Manager – LM, active* *Yard Manager – YM, active* *Terminal Manager -TM, active* *Train driver, passive* *TMS Operators for adjacent lines, passive* *RU, passive*
Notes	*The actors may need to, e.g., call each other and discuss in order to find a solution they all find satisfactory.* *The updated ready-to-depart times may be later than the current planned departure time. However, the departure times are not changed in YCS but rather in the TMS system.*

UC-FP1-WP3-14 – YCS: Cleanup of short-term track allocation plan

Name	*YCS: Cleanup of short-term track allocation plan*
ID	*UC-FP1-WP3-14*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 7.2*
Description	*The track allocation for an arrival/departure yard is updated for short-term planning in YCS. A (long-term) track allocation plan exists. The cleanup takes the special requirements for the considered time period into consideration. Train arrival and departure times are considered as given and fixed.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*Timetable planner for the hand-over yard, active* *Timetable planner for adjacent lines, passive* *Yard Manager – YM, passive* *Terminal Manager -TM, passive* *Train driver, passive* *RU, passive*
Notes	*Time perspective for this use case is about 1 month before day of operation. An initial track allocation plan is assumed to exist from the long-term planning.*

UC-FP1-WP3-15 – YCS: Adjust track allocation plan according to changes from CMS

Name	*YCS: Adjust track allocation plan according to changes from CMS*
ID	*UC-FP1-WP3-15*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 7.2*
Description	*The timetable in the CMS is updated and the track allocation plan in YCS should be adjusted to match the updated timetable.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*Timetable planner for the hand-over yard, active* *Timetable planner for adjacent lines, passive* *Yard Manager – YM, passive* *Terminal Manager -TM, passive* *Train driver, passive* *RU, passive*
Notes	*Time perspective for this use case is about 1 month before day of operation. An initial track allocation plan is assumed to exist from the long-term planning.*

UC-FP1-WP3-16 – YCS: Adjusted handling capacity of yard operations

Name	*YCS: Adjusted handling capacity of yard operations*
ID	*UC-FP1-WP3-16*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 7.2*
Description	*The short-term track allocation plan for the arrival/departure yard needs to be updated to match adjusted handling capacity of terminal operations or marshalling.*
Related to task/subtask(s)	*Tasks 4.5, 5.1, 5.2.4, 5.3*
Impact on other task(s)	*WP 11/12: Tasks 11.3.8, 12.2.8.*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*FP5 (data integration via FP5 WP32)*
Actor(s)	*Timetable planner for the hand-over yard, active* *Timetable planner for adjacent lines, passive* *Yard Manager – YM, passive* *Terminal Manager -TM, passive* *Train driver, passive* *RU, passive*
Notes	*Time perspective for this use case is about 1 month before day of operation. An initial track allocation plan is assumed to exist from the long-term planning.*

UC-FP1-WP3-17 – CMS decision supporter to plan a cross-border path

Name	*CMS decision supporter to plan a cross-border path*
ID	*UC-FP1-WP3-17*
Partner	*MERMEC*
Demonstration associated	*Demo 1*
Description	*The planning operator performs a cross-border path request. All the involved CMSs harmonize the final timetable evaluating their local availability and TCRs.*
Related to task/subtask(s)	*Tasks 4.2, 5.2, 5.2.1*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE1*
Interactions SP/FP	*SP/RNE: cross-border topic*
Actor(s)	*Local or national planner,* *CMSs,* *Path Coordinator orchestrator,* *Forecast and conflict detection/resolution module,* *CMS operators.*
Notes	*Forecast and Conflict detection/resolution module as output of WP17-WP18*

High-level use cases in WP6/WP7

UC-FP1-WP3-18 – Decision support for timetable planning with a temporary single-track section

Name	*Decision support for timetable planning with a temporary single-track section*
ID	*UC-FP1-WP3-18*
Partner	*TRV A.E. LIU, NRD A.E. SINTEF*
Demonstration associated	*Demo 10.2*
Description	*A timetable planner needs support to make good decisions in case of a TCR. The TCR is of such magnitude that it has a significant impact on the traffic and will lead to large delays if we don't make a new plan. It is time-consuming to make temporary timetables which in practice often results in the trains running according to the original timetable, with delays. With an algorithm that returns a new timetable given the new prerequisites, the timetable planner could get input to which decisions to make according to some KPIs.* *Two TCRs of different characters will be analysed: 1) A TCR that is located on a double-track line where one of the tracks is closed, and 2) A TCR that is located on a single-track line where some part of the line has a speed reduction for all trains.*
Related to task/subtask(s)	*Tasks 6.3, 7.4*
Impact on other task(s)	*Task 8.3*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at IMs)*
Notes	*N/A*

UC-FP1-WP3-19 – Decision support for constructing adjusted hourly timetables

Name	*Decision support for constructing adjusted hourly timetables*
ID	*UC-FP1-WP3-19*
Partner	*NSR*
Demonstration associated	*Demo 10.1*
Description	*Preventive maintenance of the railway infrastructure necessitates the closure of some parts of the networks for a few days, forcing adjustments on the generic timetable. The problem of finding an adjusted timetable arises quite often: almost every weekend has maintenance works at multiple locations.* *The use case focuses on the cyclic case with a cycle time of 1 hour, i.e., the timetable is repeated every hour. In particular, it deals with producing a conflict-free adjusted hourly timetable (AHT) in which the services of the generic timetable may be adjusted, fully cancelled, partially cancelled or shifted in time.* *The AHT is valid for duration of a given set of infrastructure maintenance works. Moreover, the maintenance works are scattered throughout the country and tend to affect the flow on multiple corridors of a highly inter-connected railway network. Therefore, it is desirable to consider the entire country's AHT, rather than splitting up the problem geographically.*
Related to task/subtask(s)	*Tasks 6.3, 7.4*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at RU and IM)*
Notes	*N/A*

UC-FP1-WP3-20 – Decision support for rolling stock stabling

Name	*Decision support for rolling stock stabling*
ID	*UC-FP1-WP3-20*
Partner	*NSR*
Demonstration associated	*Demo 11.2*
Description	*We will demonstrate a decision support algorithm based on a construction and local search heuristic for constructing a rolling stock stabling plan for a railway node. The algorithm will be demonstrated on node Utrecht. Utrecht Central is the most central and busiest train station (both in terms of number of passengers and number of trains) of the Netherlands, and has been found to be a hard nut to crack. The node of Utrecht has three stabling yards.* *The goal of the research is to improve the quality of the initial plan using more complicated logic which is tailored more towards the characteristics of the infrastructure of the node. It is also expected that the plans can be made more recognizable to planners.* *In the demonstrator, we will show that the test cases can be solved sufficiently quickly. Moreover, experienced node planners will assess the benefits of the proposed algorithm.*
Related to task/subtask(s)	*Tasks 6.4, 7.5*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*N/A*
Actor(s)	*Node planners (at RU)*
Notes	*N/A*

UC-FP1-WP3-21 – Usability of an optimization-based decision support system for long term timetabling

Name	*Usability of an optimization-based decision support system for long term timetabling*
ID	*UC-FP1-WP3-21*
Partner	*TRV A.E. RISE*
Demonstration associated	*Demo 8.2*
Description	*When constructing the annual timetable, planners have to modify train paths to resolve conflicts. There are many ways that the train paths can be modified to obtain a conflict-free timetable, but planners rarely have time to explore different solutions as there are strict deadlines. There are optimization algorithms that could be used to support the planners, and this use case focuses on how to make an interactive usable optimization-based decision support system. Specifically, the use case considers a planner who wants to solve the conflicts for a train, or a set of trains, in the long-term planning process.*
Related to task/subtask(s)	*Tasks 6.2, 7.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE4*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at IMs)*
Notes	*N/A*

UC-FP1-WP3-22 – Decision support for strategic timetabling

Name	*Decision support for strategic timetabling*
ID	*UC-FP1-WP3-22*
Partner	*NSR*
Demonstration associated	*Demo 8.1*
Description	*For strategic timetabling, decision support algorithms that can optimize the trade-off between service quality and operational cost of a timetable need to be developed.* *In this use case, we focus on cyclic timetables with a cycle time of 1 hour. In addition, we want to minimize the total generalized travel time for all passengers together. This includes waiting time, in-train time and transfer time.*
Related to task/subtask(s)	*Tasks 6.2, 7.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE4*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable designers (at RUs/IMs)*
Notes	*N/A*

UC-FP1-WP3-23 – Decision support for strategic station routing

Name	*Decision support for strategic station routing*
ID	*UC-FP1-WP3-23*
Partner	*DLR*
Demonstration associated	*Demo 8.1*
Description	*Network-level planning algorithms cannot guarantee that their generated timetables are viable when taking the microscopic station infrastructure into account. A timetable planner may, therefore, want to validate the feasibility on important station nodes before proceeding to the next stages of the timetabling process.* *For a given macroscopic timetable, we will demonstrate an algorithm that finds a robust station routing or reports its inability to do so. We also want to investigate whether this algorithm may return additional feedback to aid the network-level planning.* *Furthermore, when provided with predefined infrastructure variants containing small modifications (e.g., an additional switch), the algorithm will be able to assess their benefit for implementing the specific given timetable.*
Related to task/subtask(s)	*Tasks 6.2, 7.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE4*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable designers (at RUs/IMs)*
Notes	*N/A*

UC-FP1-WP3-24 – Decision support for tactical timetabling

Name	*Decision support for tactical timetabling*
ID	*UC-FP1-WP3-24*
Partner	*NRD* A.E. *SINTEF*
Demonstration associated	*Demo 8.1*
Description	*In this Use Case, we will focus on one or more lines in Norway, where we will generate new timetables from scratch using an interactive approach. Route planners will be able to add one or more train services at a time and decide their periodicity. The algorithm will employ the concept of quasi-periodic timetabling, where we allow small deviations from the very restrictive periodic departures, while guaranteeing a perfectly periodic published timetable for the passengers.*
Related to task/subtask(s)	*Tasks 6.2, 7.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE4*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable designers (at RUs/IMs)*
Notes	*N/A*

UC-FP1-WP3-25 – Using timetable optimizer and decision support for STP

Name	*Using timetable optimizer and decision support for STP*
ID	*UC-FP1-WP3-25*
Partner	*HACON*
Demo associated	*Demo 9*
Description	*The national CMS planning application demonstrates the Use of a timetable optimiser as a part of a decision support module for timetable adjustments (STP). The following sub-Use Cases are covered:* *1. Introduction of new or changed paths triggering the need for re-optimization of the capacity plan;* *2. Introduction of new or changed TCRs triggering the need for re-optimization of the capacity plan;* *3. Studying an optimized plan before implementing the change in the plan (decision support module);* *4. Synchronization of the resulting optimized plan update with TMS;*
Related to task/subtask(s)	*Tasks 6.3.1, 7.4.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*CMS operator* *TMS operator*
Notes	*N/A*

UC-FP1-WP3-26 – Decision support for timetabling by conflict detection and resolution (CDR) algorithms

Name	*Decision support for timetabling by conflict detection and resolution (CDR) algorithms.*
ID	*UC-FP1-WP3-26*
Partner	*INDRA*
Demo associated	*Demo 10.4*
Description	*The objective is to develop a decision tool that identify the conflicts that arise after perturbations and generate a new free-conflict timetable without modifying the commercial timetable. The conflict detection and resolution (CDR) software offers a list of possible resolution methods for specific conflict types (such as crossing conflict) and the planner can choose among them in order to resolve these conflicts, modifying the timetable.* *The following sub use cases are covered:* *1. Create a TSR in a track that affects the capacity of the network* *2. Create a possession in a track* *3. Changes in train-paths in the timetable schedule motivated by exceptional situations* *4. Create new train-paths in the timetable schedule*
Related to task/subtask(s)	*Tasks 6.3.1, 7.4.1, 7.4.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at RU and IM)*
Notes	*N/A*

UC-FP1-WP3-27 – Use of timetable optimizer and decision support for STP

Name	*Use of timetable optimizer and decision support for STP*
ID	*UC-FP1-WP3-27*
Partner	*Hitachi/NRD A.E. SINTEF*
Demo associated	*Demo 10.5*
Description	*The software component developed by Hitachi/SINTEF will demonstrate functionalities for optimizing timetables in the Short-term Period (from one day to one year ahead) taking into account TCRs, new trains requests and network characteristics.* *It will be configured in the Genoa SCCM area, a plant currently in operation with a variety of cases including single and double track lines, the presence of route alternatives, and stations of significant complexity.* *The following possible sub-Use Cases are considered:* *1. A scheduled work that completely interrupts a stretch of line or puts a station out of service for a period* *2. An accidental event such as flooding of a station or derailment of a train. The trains must be redirected to an alternative route for a period of time that cannot be determined in advance* *3. Interruption due to works on only one track of a double-track line* *4. Changes to station layout, e.g., platform not available for a period* *5. Add a new train to the timetable schedule, given specific constraints*
Related to task/subtask(s)	*Tasks 6.3.1, 7.4.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at RU and IM)*
Notes	*N/A*

UC-FP1-WP3-28 – Automatic rolling stock planning

Name	*Automatic rolling stock planning*
ID	*UC-FP1-WP3-28*
Partner	*NRD A.E. SINTEF*
Demonstration associated	*Demo 11.1*
Description	*This Use Case is complementary to the Use Case UC-FP1-WP3-24 about long-term timetabling. For every new timetable generated in UC-FP1-WP7-7, we will compute an optimal (or almost optimal) rolling stock plan, with the objective of minimizing the number of locomotives necessary to fulfill the timetable.*
Related to task/subtask(s)	*Tasks 6.4, 7.5*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE6*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable planners (at RU)*
Notes	*N/A*

UC-FP1-WP3-29 – Optimized insertion of short-term train-paths into a predefined timetable

Name	*Optimized insertion of short-term train-paths into a predefined timetable*
ID	*UC-FP1-WP3-29*
Partner	*SNCF and EMSE*
Demonstration associated	*Demo 10.3*
Description	*In this use-case, we will demonstrate algorithms which optimize the insertion of short-term train-paths (STTP) into a predefined timetable.* *We propose a global and integrated approach to address the problem by slightly reoptimizing train speed profiles, routes or platform assignments, without modifying the commercial timetable.* *The purpose is to showcase a global and integrated approach considering both regional and local views, taking as inputs the nominal timetable, the planned maintenance and works, and the requested STTPs. The output will be the modified timetable with as many as possible STTPs inserted within it. The validation will be done with the microscopic OSRD simulator provided by SNCF Réseau.*
Related to task/subtask(s)	*6.3*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE3*
Interactions SP/FP	*N/A*
Actor(s)	*Regional and local timetable planners (at IM)*
Notes	*N/A*

High-level uses cases in WP8/WP9

UC-FP1-WP3-30 – Improved railway traffic simulation models for capacity evaluation of ETCS

Name	*Improved railway traffic simulation models for capacity evaluation of ETCS*
ID	*UC-FP1-WP3-30*
Partner	*SNCF*
Demonstration associated	*Demo 13.2*
Description	*Simulation methods for capacity evaluation of different development aspects of ETCS, such as ETCS level 2 optimal braking and ETCS Hybrid level 3* *Specific line to be determined according to the upcoming project at SNCF Reseau and the WP8/9 planning.*
Related to task/subtask(s)	*Tasks 8.4.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FP2 WP32: DATO Assessment and Potential identification* *FP2 WP37: ETCS HL3 Deployment Strategies*
Actor(s)	*IMs, RUs (as a capacity applicants)*
Notes	*General considerations:* • *Future developments of ETCS need to be considered.* • *ETCS Hybrid L3 is not already defined, then a most appropriate set simulation parameters need to be defined.*

UC-FP1-WP3-31 – Feedback loop from simulation to planning for large scale networks

Name	*Feedback loop from simulation to planning for large scale networks*
ID	*UC-FP1-WP3-31*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 12.1*
Description	*Railway traffic creates dependencies between trains running for long times and at different lines. To get a complete evaluation of the traffic, IMs need to be able to capture all these dependencies and perform stochastic traffic simulations in large networks. Microscopic models are at a high level-of-detail, which makes it complicated and time consuming to simulate traffic in large networks. There is a need for model with lower level-of-detail, that can handle large datasets but still give reliable results.*
Related to task/subtask(s)	*Tasks 8.3.1, 9.1*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE5*
Interactions SP/FP	*N/A*
Actor(s)	*IMs and RUs (that want to evaluate current or future traffic)*
Notes	*The idea is to demonstrate the existing simulation tool PROTON in a Swedish use case and simulate a large network.*

UC-FP1-WP3-32 – Historical data analysis to improve traffic simulations and traffic planning

Name	*Historical data analysis to improve traffic simulations and traffic planning*
ID	*UC-FP1-WP3-32*
Partner	*TRV A.E. LU and SNCF*
Demonstration associated	*Demo 12.1 + Demo 12.3*
Description	*In stochastic simulations, primary delays are inserted to capture timetable performance indexes such as punctuality and arrival delay. To get accurate output from the simulations, it is important that the input is correct and corresponds to real world historical data. Therefore, we 1) need to perform analyses of historical data and 2) calibrate primary delay distributions, to turn the data into realistic disturbance distributions which can be used in operational railway simulations.* *In the use case, there are of two datasets, one Swedish and one French, that can be assessed in respective demonstrations.*
Related to task/subtask(s)	*Tasks 8.3.2, 9.1*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE5*
Interactions SP/FP	*N/A*
Actor(s)	*IMs and RUs (performing stochastic simulations)*
Notes	*N/A*

UC-FP1-WP3-33 – Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – co-existence

Name	*Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – co-existence*
ID	*UC-FP1-WP3-33*
Partner	*TRV A.E. VTI*
Demonstration associated	*Demo 13.7*
Description	*Develop a demonstrator in a train-driver simulator where the effects of a new ERTMS roll-out strategy can be studied. A method called co-existence (ERTMS marker boards and lineside signalling co-exist) will be implemented in the simulator, which includes parts of the Scandinavian Mediterranean corridor.*
Related to task/subtask(s)	*Tasks 8.4.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE 7*
Interactions SP/FP	*N/A*
Actor(s)	*Train driver*
Notes	*N/A*

UC-FP1-WP3-34 – Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – normal ERTMS implementation strategy

Name	*Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – normal ERTMS implementation strategy*
ID	*UC-FP1-WP3-34*
Partner	*TRV A.E. VTI*
Demonstration associated	*Demo 13.7*
Description	*Develop a demonstrator in a train-driver simulator where the effects of a standard ERTMS roll-out-strategy can be studied. In this strategy, lines are equipped with either lineside signalling or ERTMS marker boards (and in-cab signalling).*
Related to task/subtask(s)	*Tasks 8.4.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE 7*
Interactions SP/FP	*N/A*
Actor(s)	*Train driver*
Notes	*N/A*

UC-FP1-WP3-35 – Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – special cases

Name	*Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety – special cases.*
ID	*UC-FP1-WP3-35*
Partner	*TRV A.E. VTI*
Demonstration associated	*Demo 13.7*
Description	*Develop a demonstrator in a train-driver simulator where the effects of a new ERTMS roll-out strategy can be studied. A method called co-existence (ERTMS marker boards and lineside signalling co-exists) will be implemented in the simulator, which includes parts of the Scandinavian Mediterranean corridor. Scenarios that include special cases are developed in order to be studied.*
Related to task/subtask(s)	*Tasks 8.4.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE 7*
Interactions SP/FP	*N/A*
Actor(s)	*Train driver*
Notes	*N/A*

UC-FP1-WP3-36 – Generating plans through different inputs

Name	*Generating plans through different inputs*
ID	*UC-FP1-WP3-36*
Partner	*CAF*
Demonstration associated	*Demo 13.4*
Description	*Through this use case, we want to be able to generate a plan, taking into account different parameters. One of the most important things to consider is the time of day or the area where the track is located in order to define through one or the other if the planning is done as a headway or as a timetable.* *This would be done as follows:* • *If we take into account the time of day, if it is an off-peak time, the planning will be by timetable and if it is a rush hour it will be done by headway.* • *If we take into account the space through which the track runs, the planning will be done in the following way: if it is an urban area, the planning will be by headway; if on the contrary it runs through an area of branch lines, the planning will be by timetable.*
Related to task/subtask(s)	*Tasks 8.3, 8.4, 9.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FA6: FUTURE*
Actor(s)	*TMS Operator*
Notes	*N/A*

UC-FP1-WP3-37 – Validation of planning

Name	*Validation of planning*
ID	*UC-FP1-WP3-37*
Partner	*CAF*
Demonstration associated	*Demo 13.4*
Description	*The objective of this use case is to validate the planning generated with the simulation environment to see if it meets the needs presented*
Related to task/subtask(s)	*Tasks 8.3, 8.4, 9.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FA6: FUTURE*
Actor(s)	*TMS Operator*
Notes	*N/A*

UC-FP1-WP3-38 – Planning simulation and acceptance

Name	*Planification simulation and acceptance*
ID	*UC-FP1-WP3-38*
Partner	*CAF*
Demonstration associated	*Demo 13.4*
Description	*The objective of this use case is to compare different plans that have been generated and validated in steps before. Then the TMS operator will choose the one that best fits the needs and implement it.*
Related to task/subtask(s)	*Tasks 8.3, 9.1, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FA6: FUTURE*
Actor(s)	*TMS Operator*
Notes	*N/A*

UC-FP1-WP3-39 – Planning changes based on data analytics

Name	*Planning changes based on data analytics*
ID	*UC-FP1-WP3-39*
Partner	*CAF*
Demonstration associated	*Demo 13.4*
Description	*The objective of this use case is to be able to make changes in the planning, generating a new one, based on the results obtained from the analysis of historical data that we have carried out through big data.*
Related to task/subtask(s)	*Tasks 8.3, 8.4*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FA6: FUTURE*
Actor(s)	*TMS Operator*
Notes	*N/A*

UC-FP1-WP3-40 – System effects of different grades of automation

Name	*System effects of different grades of automation*
ID	*UC-FP1-WP3-40*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 13.6*
Description	*Analyse system effects of ATO with different grades of automation on selected lines on the Swedish and Norwegian national railway network with macro and micro simulation tools. Preliminary RailSys and PROTON will be used as tools. The lines will be of different types: single track/double track, mixed traffic/only passenger/mainly freight and urban/rural environments.*
Related to task/subtask(s)	*Tasks 8.4.2, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FP2 WP32: DATO Assessment and Potential identification* *FP2 WP39: ATO over ERTMS demonstration on mainline*
Actor(s)	*IMs and RUs*
Notes	*N/A*

UC-FP1-WP3-41 – System effects of DATO concepts

Name	*System effects of DATO concepts*
ID	*UC-FP1-WP3-41*
Partner	*ProRail*
Demonstration associated	*Demo 13.1*
Description	*Demonstrate by use cases the system effects of different DATO concepts, such as HL3 and ATO GoA2 or higher, on a corridor of the national railway network with a micro simulation tool.*
Related to task/subtask(s)	*Tasks 8.4, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE5, TE7*
Interactions SP/FP	*FP2 WP17: Next Generation Brake Systems with adhesion management functions – Phase 1: Demonstrator preparation and pre-validation* *FP2 WP32: DATO Assessment and Potential identification* *FP2 WP37: ETCS HL3 Deployment Strategies* *FP2 WP39: ATO over ERTMS demonstration on mainline*
Actor(s)	*IMs and TOCs*
Notes	*N/A*

UC-FP1-WP3-42 – Feedback loops between crew plan and operation

Name	*Feedback loops between crew plan and operation*
ID	*UC-FP1-WP3-42*
Partner	*NSR*
Demonstration associated	*Demo 12.2*
Description	*Determine the robustness of a crew plan using simulation modelling based on representative delay distributions*
Related to task/subtask(s)	*Task 8.3*
Impact on other task(s)	*Task 9.1*
Technical Enabler(s)	*TE5*
Interactions SP/FP	*N/A*
Actor(s)	*Timetable designer/planner at RU*
Notes	*A new simulation software will be developed for this purpose. Existing crew planning tool will be modified and linking interfaces are built.*

UC-FP1-WP3-43 – Assess the feasibility of a change in the network topology

Name	*Assess the feasibility of a change in the network topology*
ID	*UC-FP1-WP3-43*
Partner	*INDRA*
Demonstration associated	*Demo 12.4*
Description	*In this use case we will demonstrate the performance of a capacity analysis tool with several topologies and timetables. In case of poor performance by simulating with a specific topology, the capacity tool is used to accurate identify bottlenecks that can be solve by topology changes. Iterative simulations with different topologies facilitate timetabling.*
Related to task/subtask(s)	*Tasks 8.3.1, 9.1*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE5*
Interactions SP/FP	*N/A*
Actor(s)	*IMs and RUs.*
Notes	*N/A*

UC-FP1-WP3-44 – Effects of C-DAS in capacity

Name	*Effects of C-DAS in capacity*
ID	*UC-FP1-WP3-44*
Partner	*INDRA*
Demonstration associated	*Demo 13.3*
Description	*INDRA will evaluate the capacity of the infrastructure with new elements such as C-DAS and/or ETCS level 2.* *The objective is to analyse the changes in capacity with C-DAS.*
Related to task/subtask(s)	*Task 8.4.2, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*N/A*
Actor(s)	*IMs and RUs*
Notes	*N/A*

UC-FP1-WP3-45 – Effects of introducing ETCS Hybrid Level 3 on lines with dense traffic

Name	*Effects of introducing ETCS Hybrid Level 3 on lines with dense traffic*
ID	*UC-FP1-WP3-45*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 13.6*
Description	*Analyse and compare the effect on capacity and operations on selected lines on the Swedish network by moving from ETCS L2 to a ETCS HL3 setup. The selected lines will be a subset of those used in UC-FP1-WP3-40. Deterministic simulation is first used to compute the effect on technical headways with varying combinations of virtual (HL3) block lengths. Further, stochastic simulation is used for assessing the effects on, e.g., capacity/robustness and punctuality.*
Related to task/subtask(s)	*Tasks 8.4.2, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FP2 WP37: ETCS HL3 Deployment Strategies*
Actor(s)	*IMs and RUs*
Notes	*N/A*

UC-FP1-WP3-46 – Simulation tool including the effect of communications and positioning to asses energy consumption and capacity

Name	*Effects of C-DAS on energy consumption and capacity*
ID	*UC-FP1-WP3-46*
Partner	*CEIT*
Demonstration associated	*Demo 13.5*
Description	*Analyse the effects of C-DAS on operations (e.g., energy consumption, capacity, punctuality), taking into account the effects of on-board communication and positioning. Input on communications and positioning parameters comes from FP2.*
Related to task/subtask(s)	*Tasks 8.4.2, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FP2 WP22 & WP28*
Actor(s)	*IMs and RUs*
Notes	*N/A*

UC-FP1-WP3-47 – Effects from varying adhesion conditions and introducing new generation braking system

Name	*Effects from varying adhesion conditions and introducing new generation braking system*
ID	*UC-FP1-WP3-47*
Partner	*TRV A.E. KTH*
Demonstration associated	*Demo 13.6*
Description	*Analyse the effects on capacity and operations (e.g., punctuality, robustness) under varying adhesion conditions and from introducing new generation braking system with improved adhesion management. The idea is to use a representative and suitable line for this use case, preferably one from the set of lines that will be used in UC-FP1-WP3-40. Deterministic simulation is used first to compute the effect on technical headways under conditions both with and without new generation braking system. Further, stochastic simulation, is used for assessing the effects on, e.g., capacity/robustness and punctuality. Input on brake parameter modelling comes from FP2.*
Related to task/subtask(s)	*Tasks 8.4.2, 9.2*
Impact on other task(s)	*N/A*
Technical Enabler(s)	*TE7*
Interactions SP/FP	*FP2 WP17: Next Generation Brake Systems with adhesion management functions – Phase 1: Demonstrator preparation and pre-validation*
Actor(s)	*IMs and RUs*
Notes	*N/A*

Appendix B – Mapping of simulation models and frameworks for Workstream 1.1 demonstrations Deliverable D3.1

Project acronym:	MOTIONAL
Starting date:	01-12-2022
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Dissemination level:	PU
Status:	Final version for external review

Reviewed: (yes)

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Definitions of mapping

The simulation environments/frameworks are coordinated and supported amongst the WPs in Workstream 1.1 (Planning). Open-source simulators, commercial simulators and inhouse developed simulators/frameworks being used have been monitored. The following specifications have been mapped:

Name of simulation environment/framework proposed to be used by WP
Name proposed simulation environment/tool to be used for the demonstration. If no name exists, "new developed module/algorithm" is used.

Maturity of simulation environment/framework proposed to be used by WP:

- planned: the framework does not exist yet
- available: the framework has been developed, but is not in operational use
- operational: the framework is in operational use at one partner

Dataset level required:

- macro (aggregated): operational point as nodes, line/main track as edges
- micro: switch as nodes, track as edges
- meso: aggregation level between macro and micro

Dataset area required:

- international: any cross-border lines
- regional: a national regional network
- corridor: several lines in same corridor
- line: one isolated railway line
- station: one operational point of type station
- track: one or several tracks part of an operational point.

Demo dataset area / Suggested Location
Suggested geographical location of dataset area for the demonstration

Mapping of simulation models and frameworks

Demo No.	Short description	WP	Partners	Name of framework	Maturity of framework	Dataset level	Dataset area	Dataset location
1	Cross-border scheduling	WP4, WP5	MERMEC	new developed module/algorithm	planned	macro	regional, line	Civitanova-Albacina (to be agreed with RFI/FS)
2	Handling both, national and cross-border traffic with focus on cross-border freight trains. Supporting methods how to identify residual capacity Sweden – Norway. International co-ordination of residual capacity in an early ad hoc stage	WP4, WP5	TRV A.E. KTH	Railsys, Proton	operational	micro	international	Malmø-Alnabru
3	Interfaces for interaction with external national or central planning applications; cross-border planning including short-term planning and process improvement among actors	WP4, WP5	HAC	TPS.plan	operational	micro	international, corridor	Malmø - Oslo/Alnabru
4	Collaborative yard capacity planning	WP4, WP5	TRV A.E. RISE	YCS - Yard coordination tool	available	micro	station	Malmø
5	Improved capacity allocation and new processes. Integration of new planning processes and the production of standard reports.	WP4, WP5	HAC	TPS.plan	operational	micro	international, corridor	Malmø - Oslo/Alnabru

Demo No.	Short description	WP	Partners	Name of framework	Maturity of framework	Dataset level	Dataset area	Dataset location
6	Integration of traffic management system with network capacity planning. The feedback loop between planning and operation will be jointly demonstrated with WP11 (task 11.3)/ WP12 and WP 13/14.	WP4, WP5	HAC	TPS.plan	operational	micro	international, corridor	Malmø - Oslo/Alnabru
7.1	Integration of network capacity planning with yard and station capacity planning. Integration of nodes and lines using specified interfaces.	WP4, WP5	HAC	TPS.plan	operational	micro	international, corridor	Malmø - Oslo/Alnabru
7.2	Feasibility checks for tactical yard/network planning	WP4, WP5	TRV A.E. KTH and RISE	YCS - Yard coordination tool	available	macro (lines), micro (yard)	regional	Malmø
8.1	Demonstration of algorithms for generating strategic timetables	WP6, WP7	NSR, NRD A.E. SINTEF, DLR	new developed module/algorithm	planned	micro/meso/macro	regional, station	TBD, locations in the Netherlands and Norway
8.2	Demonstrate how a planner can interact with an optimization-based timetable planning tool to resolve conflicts in the long-term planning process	WP6, WP7	TRV A.E. RISE	M2	available	macro	international/ regional	Malmø-Alnabru (part of)
9	Timetable optimiser and decision support system for adjusting the annual timetable on a line or network level based on the activities of subtask 6.3.1	WP6, WP7	HAC	TPS.plan	operational	micro	international/ regional	Malmø-Alnabru (part of)

Demo No.	Short description	WP	Partners	Name of framework	Maturity of framework	Dataset level	Dataset area	Dataset location
10.1	Demonstration of algorithms for planning of planned maintenance work for the entire Dutch network. Cancellations and alternative routes will be considered.	WP6, WP7	NSR	RAAD	available	meso	regional	Netherlands, main network
10.2	Demonstrate the use of short-term planning algorithms for re-scheduling trains in case of TCRs in the Alnabru-Malmö line	WP6, WP7	TRV A.E. LIU, NRD A.E. SINTEF	new developed module/algorithm	planned	macro	international	Malmø-Alnabru (part of)
10.3	Demonstrate the use of algorithms for inserting short-term train-paths in a planned timetable.	WP6, WP7	SNCF	new developed module/algorithm	planned/ available	micro/meso	regional	South France
10.4	Demonstrate the use of short-term planning algorithms that identify and solve conflicts by different means	WP6, WP7	INDRA	TTCMS	planned/ operational	micro	regional	TBD
10.5	Demonstrate functionalities for short-term planning for rescheduling timetables in case of TCR and managing additions or modifications of new tracks on request	WP6, WP7	STS, NRD A.E. SINTEF	new developed module/algorithm	planned	meso	regional	Genova
11.1	Demonstration of algorithms for rolling stock rotation	WP6, WP7	NRD A.E. SINTEF	new developed module/algorithm	planned	meso	regional	part of the Norwegian network

Demo No.	Short description	WP	Partners	Name of framework	Maturity of framework	Dataset level	Dataset area	Dataset location
11.2	Demonstration of algorithms for rolling stock stabling	WP6, WP7	NSR	HIP	available	micro	station	Utrecht Centraal
12.1	Simulate large networks, calibration and validation methodology of simulation model, mainly regarding finding primary delay distribution input (from historical data).	WP8, WP9	TRV A.E. KTH	Proton	operational	micro/macro	regional	Larger part of the Swedish network
12.2	Demonstrate a method to evaluate the robustness of a crew plan by a new simulation tool. The simulation focuses on delay propagation between trains by shared crew members.	WP8, WP9	NSR A.E. SISCOG, PR	AnyCrew	planned	macro	regional	All trains of NS within the Netherlands
12.3	Demonstrate a method for processing the historical data and implement the delay distribution into RailSys for stochastic models.	WP8, WP9	SNCF	Railsys (DENFERT)	operational	micro	regional	TBD
12.4	Simulate how the timetable behaves with different topology networks.	WP8, WP9	INDRA	TMS_CAP	operational	micro	regional	TBD
13.1	Determining the capacity, wear and energy effects of: ATO, TPE, C-DAS, TMS, HL3, NG Brake on mainlines and shunting/stabling actions	WP8, WP9	PR, NSR	Railsys	operational	micro	corridor	Schiphol-Amsterdam Zuid-Almere-Lelystand (and a branch to Hilversum)

Demo No.	Short description	WP	Partners	Name of framework	Maturity of framework	Dataset level	Dataset area	Dataset location
13.2	Methods to determine the capacity effect of ETCS HL3.	WP8, WP9	SNCF	Railsys (DENFERT)	operational	micro	line or regional	TBD
13.3	Create timetables considering C-DAS driver mode and determine the effects in capacity.	WP8, WP9	INDRA	TMS_CAP	operational	micro	line or regional	TBD
13.4	Create mixed operational plans taking into consideration the hour of the day or the area where the track is placed	WP8, WP9	CAF	CAF Tool	operational	micro	line	1st Call: lab environment (location TBD)
13.5	Analyse the effects of C-DAS on capacity and energy consumption taking into account the effects of on-board communication and positioning	WP8, WP9	CEIT	RailVOS	planned/ available	micro	line	TBD
13.6	Modelling of system effects of different GoA._Modelling effects from introducing ETCS HL3 on lines with dense traffic. Modelling effects from varying adhesion conditions and introducing new generation braking system.	WP8, WP9	TRV A.E KTH	Railsys/PROTON	operational	micro/macro	international/ regional	Multiple lines in Sweden and Norway
13.7	Demonstrate effect of ETCS level 2 roll-out strategy in terms of drivability, capacity and safety	WP8, WP9	TRV A.E. VTI	VTI Driver simulator	operational	micro	regional line	Scanmed, corridor B