ERJU SYSTEM PILLAR

T3-SystemConcept

SYSTEM CONCEPT R2 EUROPE RAIL CMS & TMS

Disclaimer

Chapters 4 and 5 will be aligned with the future EU "Capacity regulation" " of which the first draft was published on 11 July 2023 ((https://transport.ec.europa.eu/news-events/news/green-deal-greening-freight-more-economic-gain-less-environmental-impact-2023-07-11_en)**.**

Differences in concepts/terminology between chapters 4 and 5 which are -due to national versus international defined specificities- will be aligned

Author(s)	Völcker Marcus (I-NAT-GST-CCS-EXT - Extern) , NANNI Marco , Krista Matthias (I-NAT-GST-CCS-EXT - Extern) , Peter Šišolák , Mohamed Raghda (I-NAT-GST-CCS-EXT - Extern) , Oostveen, R.F.H. (Ramon) , Simona Di Loreto , Uhlich Sebastian (I-NAT-GST-CCS-EXT - Extern)
Abstract	The document describes the European ambitions for the railway system in Europe, coordination between countries for cross-border trains, the function and operating models of capacity and traffic management systems, their system capabilities along with a high level architecture. The document also describes some topics related to communications, system interfaces, and shed light on the out of scope topics from Task 3 perspective along with the non functional considerations.
Config Item	System Concept
Document ID	30 Deliverables/TMS_SYCON_ES_014_00#714346 T3-SystemConcept
Classification	Public
Status	Open (draft)
Version	1.7
Revision	714344
Last Change Date	24.09.2025
Copyright	Brussels: Europe's Rail Joint Undertaking, 2025

INFO: History table is not displayed, because this document is in status **doc_open**.
RULE: History table is not displayed, in statuses: { draft doc_open doc_inprogress doc_contentApproval doc_contentDecision }
CONTACT: For more information contact Administrator

1 History of Changes

Nr.	Changes	Leaders/Authors
1.1	First draft for internal review	Afra Zumbrunn Matthias Krista, Raghda Mohamed
	Comments	Marco Nanni, Marcus Völcker, Ramon Oostveen
1.2	Second draft for internal review	Raghda Mohamed, Matthias Krista
	Comments	Marco Nanni, Marcus Völcker, Ramon Oostveen, Simona Di Loreto
1.3	Draft for First Delivery	Matthias Krista, Raghda Mohamed, Simona Di Loreto
	Revision	Marco Nanni, Marcus Völcker, Matthias Krista, Peter Sisolak, Ramon Oostveen, Simona Di Loreto
1.4	First Internal Delivery	Marco Nanni, Marcus Völcker, Matthias Krista, Raghda Mohamed
	Contributors' Review	Mirko Ghersi, Patrick Konix, Ramon Oostveen, Simona Di Loreto, Valter Pettinati, Peter Šišolák
1.5	First Delivery Version	Raghda Mohamed confirmed by Marco Nanni & Marcus Völcker
1.6	• Addition of Restriction Area and Warning Area aspects. • Removed occurrences of type "Reference" for those WI where this type was misused according to the Reference Usage Guideline published by EET team.	Matthias Krista, Sebastian Uhlichm Marco Nanni
	Review	"Add your name here"

2 System Concept Capacity & Traffic Management System (CMS & TMS)

This document is the CMS & TMS System Concept. Its structure largely follows that described in EN 50126 for system concepts although the current version of this document may not yet contain all chapters required therein. This document in its current form focusses on the scope of the proposed European CMS & TMS. Further chapters may be added as needed and as aligned with the steering board.
[SPT3TMS-9260 **]**

3 CMS & TMS Purpose and General Functional Overview

3.1 European Ambitions for CMS & TMS

To create a capacity plan and an operational plan for all trains in general and for border-crossing trains in specific and corridors, which fulfils customer needs in an optimised way, and which includes a high complexity of work. This includes but is not limited to the interaction between several involved "planning partners" (several cross-border/cross-company RIM, ROC, maintenance departments / workshops/ depots, shunting yards, terminals, stations, non-railway planning partners etc.), and a wide array of supervised production factors such as the involved train. **[**SPT3TMS-9259 **]**

For example, at present, large departments are required to accomplish the planning process and its communication. The duration of the cooperative planning process leads to long lead times for solutions to enter running production (i.e., norm for freight train path requests for corridors > 40 days). It is envisaged that an algorithm and automation-based system should address at least some of this complexity and accelerate changes, reducing human dependencies and the need for large teams. **[**SPT3TMS-9262 **]**

The quality of plans (optimise capacity utilisation, reduce the rate of missing connections, increase train punctuality, improve forecast capabilities and more accurate capacity planning) depends- to a big extent- on the limit of the affordable coordination between planning partners. Reduced plan quality may lead to higher production resource consumption, capacity needs or planning reserve and less predictability/ reliability for the end-customers (passengers and shipping agents). Reduced quality may also lead to lower KPIs. The replanning process in case of production deviations (always called "dispatching" in this document) takes too long and the negative impact of any deviation grows for as long as it remains unresolved, with response times for long-range deviations on freight corridors lasting for as long as several hours, during which loads are idling on tracks. **[**SPT3TMS-8411 **]**

Figure 1 shows the whole Railway network, representing the ecosystem and the involved partners.

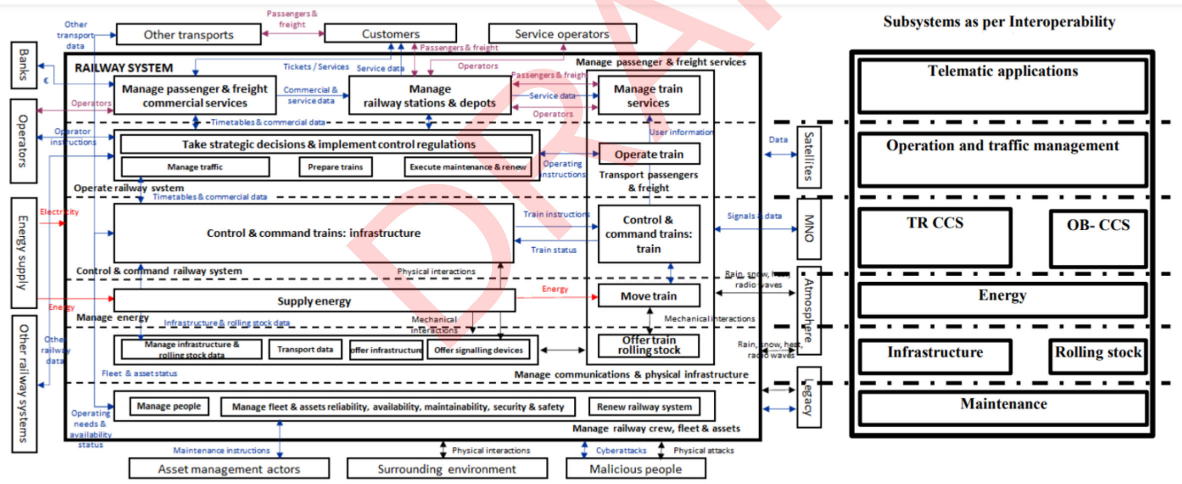
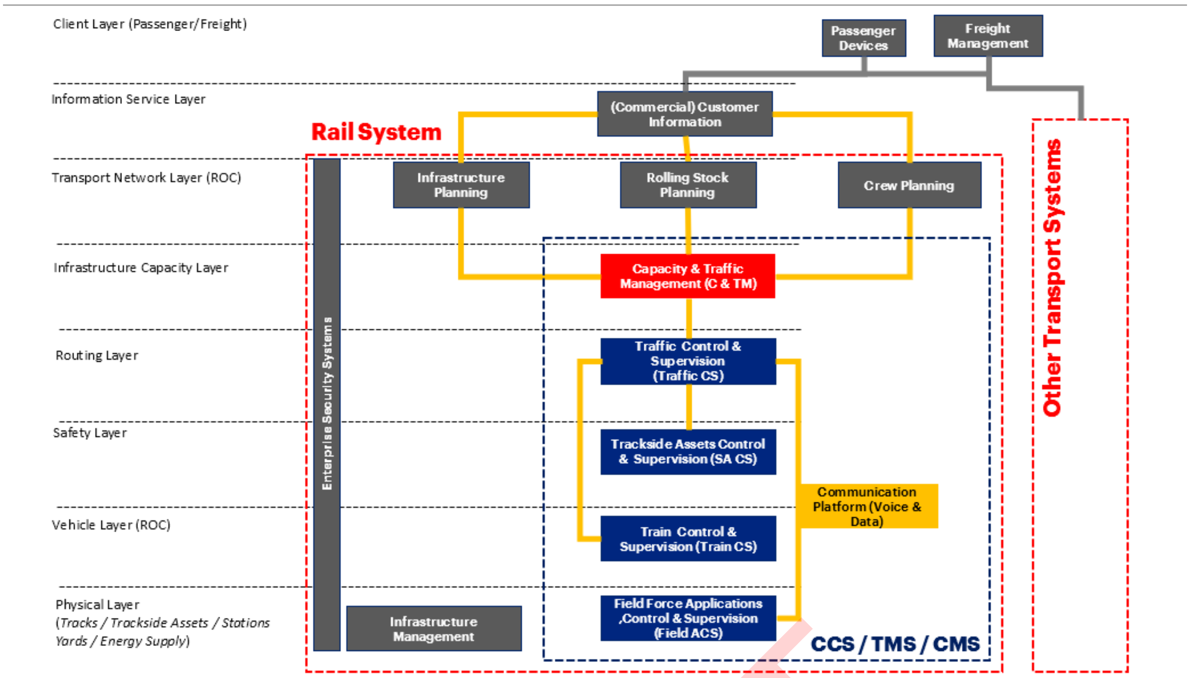


Figure 1: The Railway System *(European Commission, 2022, p.13)*

[SPT3TMS-8412 **]**

Considering the scope and processes given by the previous working groups, the scope for TMS can hence be illustrated as follows in Figure 2. Data flows are not complete, they are for illustration only:



[SPT3TMS-9261]

Figure 2: System Architecture - Railway System - CMS & TMS Scope

3.2 CMS & TMS Functional Overview

Capacity and Traffic Management are the domains responsible for **all planning activities** including producing an **operational plan**, based upon the RT- operational state and RT-operational events of a railway infrastructure provider. [SPT3TMS-9256]

The two main areas of **activities** are:

*** Capacity planning (CMS)**

- Capacity planning (infrastructure planning, planning resulting from Temporary Capacity Restrictions (TCRs)) and,

[SPT3TMS-9255]

*** Capacity production (TMS)**

- Capacity production based on capacity plan including any potential dispatching.

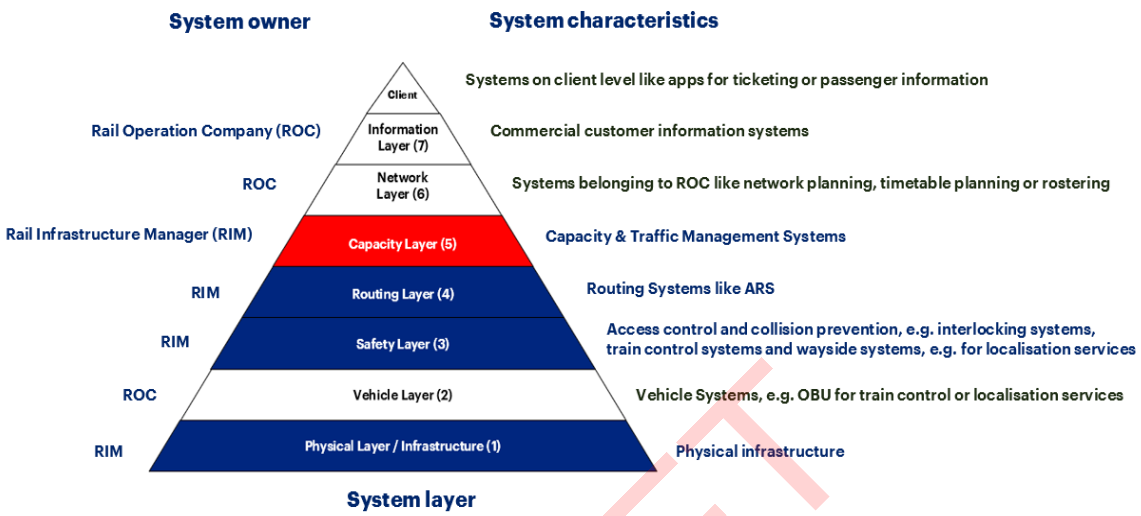
[SPT3TMS-9258]

A predominantly conflict free operational plan would be sent to “Traffic Control and Supervision”.

The capacity planning is performed on a detailed level including the capacity information and specification along with any capacity restrictions planned in asset management and maintenance systems and imported into the capacity plan. Changes of operational plan may affect any time period ranging from the next minutes up until sometime into the future. A plan may include (depending on its timing) regular as well as incident-related commands for infrastructure users (e.g., trains, capacity restriction), including measures to mitigate deviations or to stabilise the traffic flow in the short term (recovery from a disruption). Capacity & Traffic Management as a large set of external information flows from and to a variety of enterprise systems for coordinating planning, deviation management, and sending information about the production status. [SPT3TMS-9257]

In a system to support Capacity & Traffic Management, the above activities are defined as a small set of standard interfaces, that for example “inform” about current production status. CMS & TMS components typically have no safety requirements. ((Europe´s, Annex 2 CCS_TMS Systems Architecture: Annex 2 CCS/TMS/

CMS Systems Architecture, 2022)). According to the commonly used layers model as Figure 3 shows, CMS & TMS belongs to the capacity layer (5) only, communicating with adjacent layers via interfaces (network layer (6) systems / routing layer (4) systems). The figure displays the system layer model from a RIM's perspective **[**SPT3TMS-8414 **]**

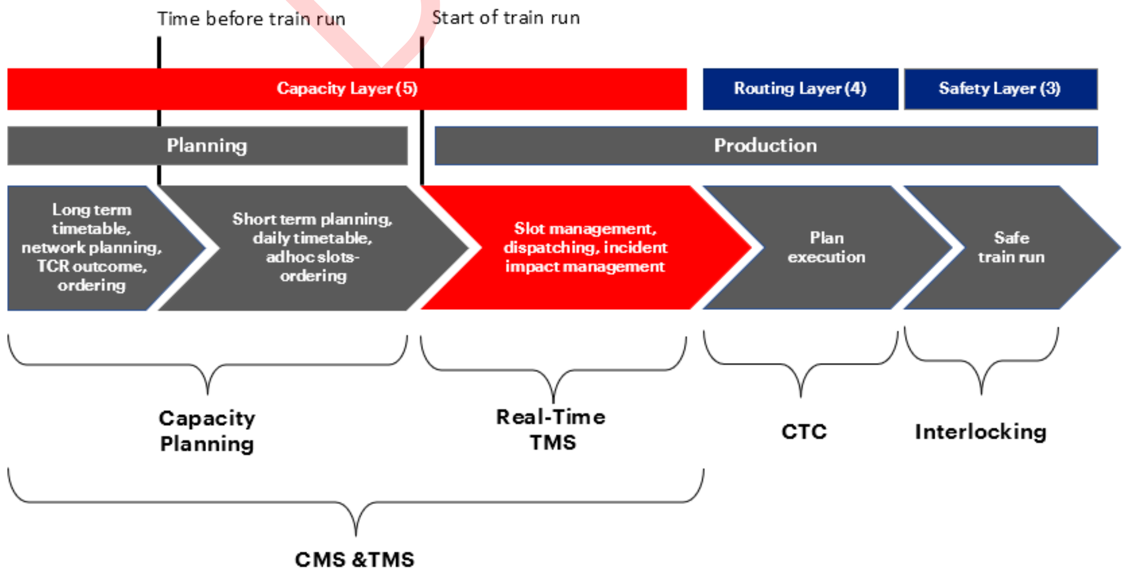


[SPT3TMS-9268 **]**

Figure 3: System Layer Model

The distinction between planning and production is defined by the point in time at which the first event of an operational plan is scheduled to be executed . **[**SPT3TMS-10158 **]**

Figure 4 below, visualises the CMS & TMS scope within the context of the overall timeline of the rail production process from a RIM's point of view.



[SPT3TMS-9278 **]**

Figure 4: Capacity Planning & Production

4 Analysis Of Variants For European CMS & TMS

Refer to the document "Analysis Of Variants For CMS & TMS, whos elink is the following:
[SPT3TMS-15940 **]**

Analysis Of Variants For European CMS & TMS

5 European Roof CMS & TMS Core Scope

The idea behind a European roof CMS & TMS is to strengthen the cooperation in the traffic planning and management in the form of a European network. The network is based on the full commitment of each RIM to implement guidelines which will allow a major improvement in the quality of international traffic management. On one hand, this is realised by improving the quality of information sharing along the whole train journey as well as increasing the availability of information and on the other hand by assuring the quick communication and coordinated actions between RIMs. Overall, this improved cooperation will bring significant benefits to the international train run. **[**SPT3TMS-9276 **]**

This European network acts in a decentralised manner based on commitment of all traffic cells to one goal, on guidelines for daily cooperation (Process of International Traffic Management), information exchange (providing relevant traffic management-related data to the neighbouring RIM), and for communication (single communication module connecting all Traffic Control Centres (TCCs)), to be prepared for the spectrum of traffic situations between regular traffic and International Incident Impact Management. A traffic cell represents the unit defined by an RIM to dispatch the traffic within an area. They can reach from border areas to regional or national areas of responsibility and are controlled by a dedicated TMS. For TMS this means that a RIM consists of minimum one traffic cell but depending on the size of the RIM, there is usually more than one. The core of a functioning European traffic management network is that traffic cells are connected by standardised ways of information sharing, the availability of common communication tools and commonly agreed procedures to handle minor deviations from plan as well as larger disruptions. **[**SPT3TMS-9274 **]**

For TMS this means that train-related data is shared digitally, as specified in the SAD document, automatically and is available for all RIMs in the network. These concerns are not only data like current position, timestamps, delay along the train run and train properties like maximum speed, weight and length but also train running forecast information (for this guideline: ETx, i.e., Estimated time of arrival, departure, handover, run-through) as the essential information. **[**SPT3TMS-8416 **]**

For TMS this means that event-related data for deviations from the plan as well as obstructions and disruptions with an international impact shall be shared digitally in a standardised format and if deemed necessary by making direct communication with the concerned parties (neighbouring RIM(s) or RIMs farther away depending on the current case). The aim is to move towards more digital information sharing over time, in accordance with TAF/TAP TSI and mutually agreed information exchange. In this regard, the further development of a European roof TMS will improve the availability and accessibility of information. However, is still open if the European roof TMS shall not substitute or compete with the national TMS, but rather serve as a complementary tool that enables RIMs to access information beyond the national TMS from the whole network. **[**SPT3TMS-9286 **]**

The concept of a European and a national TMS is the same, the major difference is that for a European TMS the coverage, coordination and data exchange among the different RIMs are much bigger and more complex and it serves a bigger purpose than planning infrastructure for a specific control area, but to provide a harmonised planning across Europe and considering the effect of infrastructure usage, planned and unplanned events on the rest of the network to improve the cross border train operations. **[**SPT3TMS-8417 **]**

For TMS, risk management is based both on sharing digital information, e.g., on TCRs and situations that might develop into risks and other means of communication. This allows early detection and communication of risks and includes the development of commonly agreed plans. Risk management should be performed by regular data exchange on progress and conference calls based on the available information on e.g., inclement weather conditions, strikes and TCRs. **[**SPT3TMS-9284 **]**

For TMS. the real benefit of the European network comes from actually operating as one unit without borders. The enabling elements described above allow TCCs to carry out cooperated traffic management in all situations, from handling delayed trains to dealing with obstructions and incidents in a way that brings benefits to international train runs. **[**SPT3TMS-9283 **]**

For TMS, the new network is focused on national TCCs in synergy with regional centres involved in cross border cooperation of neighbouring areas. To build a reliable European Network RIMs need to have strong contribution ties with other involved stakeholders e.g., RUs, terminals, ports. The goal of the proposed concept is to strengthen current practices and solutions on a more harmonised and developed level. [SPT3TMS-9282]

To summarise, the main principles of the European TMS network are:

- All trains that cross at least one border are considered international trains and require coordination with the neighbouring RIMs.
- Developing European mindset by taking a wider approach from national to international perspective.
- Digital and automated information sharing as much as possible. As long as or where this is not applicable, manually typed data methods of sharing information are encouraged.
- Domestic systems are exchanging data based on TAF/TAP TSI and mutually agreed information exchange formats.
- European roof TMS serves as a complementary tool and offers additional information.
- RIMs prepare and consider forecasts of train runs and events.
- Cross-border monitoring is based on this information.
- The European Traffic Management Network (ETMN) elements allow the RIMs to complement their existing processes and rules.
- RIMs agree to procedures and processes to perform internationally coordinated traffic management in a wide range of deviations from plan (from single delayed trains to major disruptions).
- Common risk management is based on information sharing and cooperation.
- Regular meetings for risk management and improving the overall cooperation are established.
- Supporting tools usage and European network status makes the cooperation more effective.
- Communication and data sharing platform integrates dispatchers into common network.

[SPT3TMS-9289]

5.1 European Capacity Planning

5.1.1 Introduction

For the purpose of this document, the scope of a European CMS will describe the functions that shall be performed in order to guarantee a more effective and efficient Capacity Management both at local and European scale. The CMS description will tackle all the issues/functions that, because of several reasons that will be explained case by case, call for a European harmonisation or standardisation, while, all those issues for which a better management might be needed but no European harmonisation/standardisation is required will not be taken into account. [SPT3TMS-9288]

In general, the need for a new, smarter capacity management system, with harmonised/standardised solutions all over Europe, meets many of the Common Business Objectives, among others in particular:

- new technologies, harmonized processes -> CBO024
- flexible use of infrastructure capacity -> CBO019
- increase capacity -> CBO021
- optimize timetables -> CBO026
- continuous supervision -> CBO014
- rapid response to capacity request -> CBO028
- rapid return of experience -> CBO029
- reduce noise, reduce vibration, reduce carbon emissions -> CBO031
- standardized architecture(1) -> CBO034
- standardized architecture(2) -> CBO035

[SPT3TMS-8420]

It has to be underlined that the CMS scope will have to be multi-stakeholder (i.e., taking into account different stakeholders both as far as the type of partners – Railway Infrastructure Manager, Railway Operating Company, other customers) and the geographical scope are concerned) and multidisciplinary, i.e. it will have to cover:

- Processes
- Tools and interfaces
- Enabling factors

[SPT3TMS-9291]

All these aspects, need to be analysed for each aspect or function of the Capacity Planning process. The capacity planning process, simply stated, is the sum of actions which lead to the creation of the Capacity Plan. For the purposes of this document "capacity" means: the total overall capability of the infrastructure that is available for traffic, infrastructure works for building new/upgrading existing infrastructure and/or for ordinary/extraordinary maintenance. Capacity may apply to specific geographic sectors like stations or lines, or can be referred to an entire network.)
The Capacity Plan comprises the following components: any planned capacity usage (traffic and construction works) at any point in time during the planning period. The aim is a consistent and conflict free capacity plan. **[**SPT3TMS-9302 **]**

For a more precise definition, the Capacity Planning is a process aimed at determining the total theoretically available capacity supply. Capacity planning covers the planning along all-time horizons (strategic to short term, more precisely from X-60 to X+12) based on the expected demand. The capacity plan or supply represents the offer. X refers to the timetable change, while the digit afterwards indicates the months prior to this change, where X-# represents the number of months before the day of timetable change. **[**SPT3TMS-9300 **]**

In order to ensure a conflict-free offer, the Capacity restrictions also shall be taken into consideration.

A Capacity restriction is a temporary, full or partial, unavailability of network infrastructure due to construction works, maintenance, inspection works or due to unforeseen events (such bad weather, incidents, authority's closures) and disruptions. For the purposes of capacity planning, the term "Temporary Capacity Restrictions" is used, and it only refers to planned capacity unavailability, thus excluding the cases of unforeseen events and disruptions. **[**SPT3TMS-9298 **]**

The outcome of capacity application/allocation processes at any moment in time is the timetable (annual, short term/ad hoc, late path …). The combination of capacity planning processes (long term strategy, medium term model, short term supply) and capacity application/allocation (and related modification/alteration/cancellation) define the overall Capacity Management System. **[**SPT3TMS-9296 **]**

Therefore, in summary, the scope of the CMS will consider the following main functions:

- Advanced planning:
  - Capacity Strategy
  - Capacity Model
  - Capacity Supply
- TCR (Temporary Capacity Restrictions)
- Timetabling:
  - Path/Request (Timetable planning, Rolling planning, Ad-hoc planning)
  - Path/Capacity Allocation (Timetable planning, Rolling planning, Ad-hoc planning)
  - Path Modification/Alteration/Cancellation/Optimisation

For each of these functions, the CMS system will specify:

- Situation as of today:
  - Processes harmonised at European level and applied at national level
  - IT tools: common European IT tools (if any) and functional specification for interfaces to enable communication of national tools with common tools – no technical specifications will be described, nor functional/technical specifications for functional tools;
  - Enabling factors, such as commercial conditions, legal framework, etc …
- Future developments:
  - Analysis of how processes could be improved taking into account return of experience and business cases;
  - Future scenario for a more automatised and/or standardised IT environment European wide
  - Obstacles to future developments

[SPT3TMS-8421 **]**

5.1.2 Purpose Of The Future CMS

The strategy for the future CMS is founded upon the market needs. This framework encompasses various aspects, including but not confined to the interplay among multiple engaged "planning partners" (cross-border/cross-company RIMs, ROCs, maintenance departments / workshops/ depots, shunting yards, terminals, stations, non-railway planning partners etc.). Additionally, it encompasses an extensive range of monitored production factors, notably the participating trains. The current limitations of capacity planning can be outlined as follows: **[**SPT3TMS-8423 **]**

With a few exceptions, traffic on the network is mixed, i.e., passenger and freight traffic share the same tracks. The disparities between the two types of traffic pose significant challenges for capacity-optimised planning of the infrastructure. The dynamic driving behaviour (acceleration, braking and uphill driving) of passenger and freight trains diverges significantly. In addition, passenger trains typically have significantly more stops. To avoid conflicts, suitable overtaking opportunities need to be arranged, and more generous time reserves between trains of different types must be allocated. Other shortcomings of the present capacity management can be summarised as follows: **[**SPT3TMS-8424 **]**

- Planning primarily occurs within the medium-short term; in particular, the current timetabling process focusses strongly on annual requests. However, This early initiation of path requests lacks in the dynamic and agility that some businesses, notably freight rail, need to remain competitive. This results in surplus bookings, elevated expenses, and diminished capacity. Additionally, with final timetables being published in September, passenger ROCs cannot sell tickets well in advance of the December timetable change, putting them at a competitive disadvantage compared to road and air travel

[SPT3TMS-8425 **]**

- International path harmonisation is often impeded by national processes and behaviours that are not aligned internationally

[SPT3TMS-8426 **]**

- Capacity planning and timetabling do not primarily follow to market demands, instead considering various constraints like limited infrastructure capacity, technical specifications, operational rules, and more:
  - The majority of passenger train services operate on regular timetables that are established well in advance. In contrast, the definitive assignment of a freight path to a specific train often only occurs at short notice. Path-determining train parameters such as length, weight, etc. are often only available late adjusted or require late adjustments. This necessitates that slots for freight traffic are designed with greater flexibility, e.g., via the use of margins.
  - Matching planned arrival and departure times at every stop to the minute is of great importance in passenger transport – especially when there are connections to other trains. Passenger trains tend to exhibit a high degree of predictability, with minimal daily variations in their operational patterns

[SPT3TMS-8427 **]**

Freight trains, on the other hand, often only have time specifications for their departure and arrival times, with even these being considered flexible within a time frame. Many trains in freight traffic are international. Due to their significantly longer travel distances the actual behaviour of the trains depends more on the planning. The dynamic driving behaviour of a freight train, on the other hand, depends on the load and length. Consequently, even freight trains that follow regular schedules frequently experience notable fluctuations in travel times. In addition, load and length are typically not known at the time of planning. For this reason, the slots prepared for freight traffic must allow for larger bandwidths, which may then be adapted to the actual circumstances at short notice if necessary.
Passenger traffic peaks occur primarily in the morning and, to a lesser extent, during the afternoon and

evening, with freight traffic typically peaking starting in the afternoon and continuing into passenger off-peak hours. Thus, total capacity utilisation adds up.

- To address the scarcity of capacity, infrastructure investments are imperative (both to construct new infrastructure and to upgrade the existing infrastructure). Presently, however, the management of Temporary Capacity Restrictions (TCRs) requires better planning, communication, and harmonisation to avoid risks to the competitiveness of the rail sector. Today, TCRs lead to unexpected costs, sometimes even the loss of business for ROCs, reduced reliability towards the market and unnecessary unavailability of lines.
- A fundamental prerequisite for internationally harmonised timetabling processes is a high level of synchronised digitalisation, integrated by corresponding national IT systems. All too often, this is not yet the case. Additionally, there is a rightful call for heightened focus on rapid, digitalized ad hoc request management

[SPT3TMS-8428 **]**

To overcome the above-mentioned hindrances, a future, more efficient, CMS, should be based on the following factors:

- Market driven planning
- Advanced planning and earlier path allocation when needed (earlier ticket sales)
- Possibility to request capacity all over the year
- Differentiated capacity products and different requests method (no “one –size fits all" approach)
- Optimised and coordinated timetable planning, using data provided by TAF/TAP TSI, and incorporating EU strategies

[SPT3TMS-8429 **]**

5.1.3 Main concepts of an improved CMS

- An improved CM process yields several benefits that support the shift to rail:
  - Planning time horizons ensuring both safeguarded capacity and flexibility
    - Earlier detection of congestions and capacity needs, providing additional time for countermeasures and better solutions than today
    - Earlier confirmation of allocations to ROCs, enabling earlier ticket sales to passengers
    - Safeguarded access to reliable and high-quality capacity at times when transport specific needs are established, promoting a heightened level of flexibility. This negates the necessity for today’s requests based on speculative needs

[SPT3TMS-8431 **]**

- Harmonisation between RIMs/Allocation Bodies: European harmonisation of fragmented national processes to simplify access to capacity, international train operation and potential expansion to other networks

[SPT3TMS-8432 **]**

- Market oriented capacity planning and allocation rules:
  - Differentiation of offered capacity products, meeting different market needs
  - Different request/allocation methods
  - Introduction of the possibility to place a single capacity request valid for several years. Presently, this kind of capacity often necessitates up to four separate requests across three different timeframes

[SPT3TMS-8433 **]**

- Efficiency of the whole process and sub-processes via increased digitalisation:
  - Development of enabling factors (commercial conditions, regulatory framework)
  - Minimising redundancies between RIMs, and ROCs stemming from the need to repetitively rework the timetables due to market and works planning instability. The objective is to strike a balance between establishing stable timetables and permitting a certain degree of flexibility for Temporary Capacity Restriction (TCR) planning

[SPT3TMS-8434 **]**

5.2 Functional Capabilities Of The European Framework of CMS

The future CMS should encompass a series of processes and an array of tools, designed to enable a streamlined planning and effective management of available railway capacity, spanning both national and international domains, catering to all types of traffic. In this context, "effective" signifies a comprehensive consideration of all influential factors, including market demands, infrastructure availability, operational constraints, and commercial conditions, among others. **[**SPT3TMS-8436 **]**

A future and more effective CMS aims at:

- Harmonising planning and management processes (still performed at RIM level)
- Expanding use of IT tools and the level of automation.

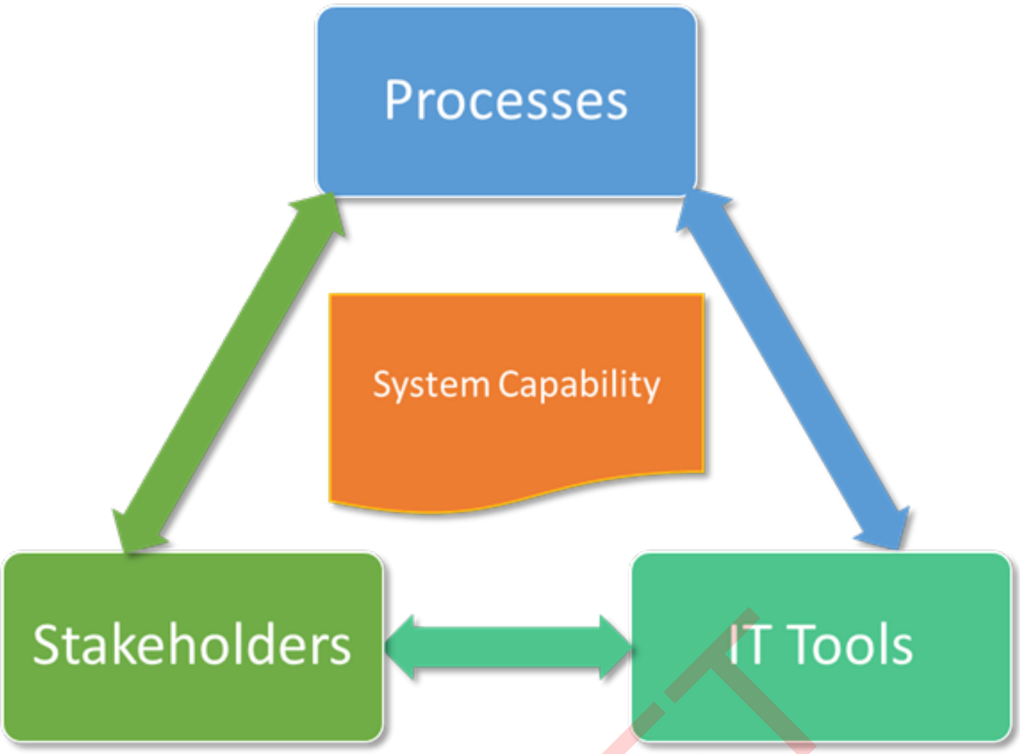
[SPT3TMS-8437 **]**

The approach outlined above can be described as a “federated” approach. Within this framework, the primary functions and tools employed for capacity planning and management remain within the purview of individual RIMs, whereas processes for cross-border traffic are harmonised. This approach ensures that coordination and compatibility between national/local and international traffic are upheld, while simultaneously enhancing the quality of international capacity provisions. **[**SPT3TMS-8438 **]**

For the purposes of this document, only the capacity management activities performed by the RIMs will be considered in detail. In-depth descriptions of capacity management within shunting yards, terminals, ports, and similar contexts will not be provided in this document. However, descriptions might be given of the interfaces bridging "railway" capacity and "terminal" where appropriate. **[**SPT3TMS-8439 **]**

5.2.1 Foreword

- Capability Meaning
For the purposes of this document, a capability, in the framework of CMS, is considered as an interaction between processes, stakeholders and (IT) tools as illustrated in figure 5: **[**SPT3TMS-8441 **]**



[SPT3TMS-8442 **]**

Figure 5: Capacity Planning Interactions

The following paragraphs will address a general description of the CMS System Capabilities.

The subsequent paragraphs will then provide the detail the processes enabling each capability. Processes are to be considered as nationally applied but internationally harmonised and valid for all types of traffic. **[**SPT3TMS-8443 **]**

IT tools will be described in the System Architecture Design (SAD) document. Where relevant, a general description of the needed interfaces from national systems will be mentioned. **[**SPT3TMS-8444 **]**

As far as the stakeholders' point of view is concerned, except what will be included in the description of the process, no further recommendation for European harmonisation will be made. If the processes are applied as internationally agreed and IT tools are used as agreed as well, the internal RIMs/ROCs/ Allocation Bodies or other stakeholders' organisation does not need to be harmonised and it is, therefore, out of scope of this document. **[**SPT3TMS-8445 **]**

5.2.2 Advanced Capacity Planning

Advanced capacity planning is an essential element of a future, more effective capacity planning. Its primary objective is to proactively facilitate conflict-free scheduling by anticipating infrastructure availability over the medium to long term. This proactive approach enables the transition from aligning on core planning principles in the Capacity Strategy to constructing the Capacity Model, which centres on projected traffic volumes and the capacity required for Temporary Capacity Restrictions (TCRs). Such a methodology aids in the early detection of potential capacity conflicts and congestions, affording additional time to counteract these issues through appropriate measures. The final phase of advanced planning involves preparing the capacity supply, where various capacity elements such as paths, bandwidths, and TCRs are synthesized into a comprehensive 365-day capacity diagrams.
Advanced Capacity Management hence consists of three integral system capabilities/components: **[**SPT3TMS-8447 **]**

- Capacity Strategy
- Capacity Model
- Capacity Supply

[SPT3TMS-8448]

The following tables describe these capabilities in more detail.

5.2.2.1 Capacity Strategy

Capacity Strategy Name	**CAPACITY STRATEGY**
Short Description	Capacity planning for specific routes or a part of the network or the entire network. First rough analysis traffic flows, list of all planning partners *per* line, common overview on x-border traffic flows. (X-60 to X-36)
Purpose	A capacity strategy is needed to allow for a more precise planning of timetables. Such a strategy should provide insight into the IMs' and applicants' intentions for the upcoming timetable periods, including the management of traffic streams. It is also necessary to analyse traffic flows, taking into account the available infrastructure. Therefore, the careful planning of TCRs shall result in a well-balanced strategy in which IMs', applicants' but also the national economic interests are harmonised at an international level.
Current issue	Currently, timetabling strategies exist at a national level only. Although, there is a small degree of international harmonisation concerning specific lines, these harmonised strategies only have limited priority in case of national path conflicts and are not mandatory at a European level.
Target	A capacity strategy – including a timetabling strategy and TCR planning – is available, serving as a baseline for the creation of specific timetables. This strategy should be implemented top down, from general European traffic flows to specific lines. RIMs, RFCs and ROCs cooperate in order to create such a strategy for the entire international network, provide insight into expected traffic developments and improve timetable approaches in order to procure a larger share of the modal split for railways. This strategy needs to be based on the available as well as planned new infrastructure.
Content	**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 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 (TCRs)** 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

Stakeholders involved	International leading entity* RIMs ROCs Ministries of Transport Regions, local governments, transport associations, industries Terminals and service facilities
Contributing process(es)	Capacity Strategy Process as described in Create Capacity Strategy
Deliverable	At X-36, the final Capacity Strategy shall be published in the standardised format accompanied by the English translation. The English translation is already needed for the draft Capacity Strategy (harmonization with other IMs, involvement of other stakeholders).
IT tool(s)	none
Notes	none

[SPT3TMS-8450 **]**

5.2.2.2 Capacity Model

Capacity Model Name	**CAPACITY MODEL**
Short Description	Breakdown of total capacity into TCR (“negative capacity”) and commercially usable parts (“traffic part – 24hour overview reflecting market needs). Partitioning of capacity in capacity available for Annual timetable paths, safeguarded capacity for Rolling Planning, TCR and unplanned reserves; capacity models must be internationally harmonised. Based on the Capacity Strategy, Capacity Needs Announcements (CNA) and other source of information (e.g., data about train services operated in the current or previous year, estimation and own hypothesis of future market developments, framework agreements) (X-36 to X-18)
Purpose	Consolidation of all known capacity elements (available capacity, expected traffic volume, etc.) into a single entity: the capacity model. In this model, all data regarding a specific timetable period will be available by X-12 and based on this data, the creation of the actual timetables should start. Being the core element of the pre-planning phase, its main function is to display available capacity, partition the expected traffic according to its attributes. It also safeguards capacity for Rolling Planning requests and provides basic information to all stakeholders of the timetabling process.
Current issue	A general capacity model is currently not available. Safeguarding of capacity is being done to a certain degree via Pre-arranged Paths and catalogue paths. However, such approaches are currently limited to either the Rail Freight Corridors or to bilateral agreements between RIMs.

Target	The capacity model exists at European level, based on the common capacity strategy. It covers all traffic expected on lines relevant to international traffic and is shared among European infrastructure managers and RFCs. Applicants participate in the creation of the model prior to X-12 through their capacity needs announcements, base their planning on this model and submit requests according to available capacity. The capacity model also provides the information needed for pre-planning paths together with end customers
Content	Based on the principles defined in the Capacity Strategy, the RIMs continue in the consolidation of all known and expected capacity volumes, the output of this work is visualised in 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 **Traffic part** RIMs need to calculate the expected demand for capacity in the various market segments and display it in form of volumes in a 24-hour overview. The input for the Capacity Model can come from: • information provided by the competent authorities in the capacity strategy phase, • placed multi-annual Rolling Planning requests, • data about train services operated in the current or previous year, • estimation and own hypothesis of future market developments, • capacity needs announcements, • framework agreements. It is advisable to start with only a 1-hour overview, which can be expanded to a 24-hour overview during the development of the capacity model. **TCR part** Notwithstanding Annex VII of Directive 2012/34/EU the, Capacity Model variants should be prepared for major and high impact TCR periods. Furthermore, the IM should publish and iteratively update the TCR duration overview from X-21 until X+12. **Capacity partitioning** After international harmonisation, the published final version of the capacity model serves for the so-called capacity partitioning. By applying this capacity partitioning procedure, the capacity of a origin/destination connection is set aside in the Capacity Model for dedicated purposes. As a minimum requirement, the capacity partitioning should be set for: • passenger traffic • freight traffic • other • TCR It is also possible that the RIMs prepare the portioning in a more detailed way, taking into consideration the product types: • Annual requests for both passenger and freight (stable traffic) • Rolling Planning requests • Ad hoc requests This will be the input for the Capacity Supply

Stakeholders involved	International leading entity* RIMs ROCs Ministries of Transport Region, local government, transport association, industry Terminal and service facility
Contributing process(es)	Capacity Strategy Model as described in Create Capacity Model
Deliverable	The following items should be included in a central system (currently ECMT, future capacity hub): • Pressure points and bottlenecks are identified early with alternatives being provided • 24-hour overviews of traffic volumes (at least standard non-TCR day) • Information on Major, High impact TCRs • Estimated volumes of capacity to be consumed by other TCRs and TCR Windows (over complete TT period)

IT tool(s)	**Relevant Central IT Modules** **-**TCR To manage the coordination and inclusion of TCRs in the Capacity Model as capacity volumes -Capacity Hub (ECMT) To collect and display the capacity volumes -Messaging Module To connect the afore mentioned modules with each other, with national (legacy) IT and with central databases
Notes	

[SPT3TMS-8452 **]**

5.2.2.3 Capacity Supply

Capacity Supply Name	**CAPACITY SUPPLY**
Short Description	Internationally harmonised capacity supply. In a 365-day overview capacity diagram, objects such as pre-planned paths and or wider bandwidths including TCRs and TCR windows. Publication of available capacity to applicants. (X-18 to X-11)
Purpose	Showing a feasible timetable according to axis characteristics published as Capacity Supply. The Capacity Supply is a 365- day overview that shows all the elements in the capacity diagram – TCRs, maintenance windows, pre-planned paths, bandwidths, and empty spaces for tailor-made requests. All objects shall be harmonised between RIMs
Current issue	Today only one timetable product is available (Annual Timetable train path) at one hard request deadline and method for all traffic; later only residual capacity is available for other products
Target	Differentiated products are available according to market needs; accordingly, timeline and methods for application/allocation are differentiated
Content	Based on the final Capacity Model, RIMs 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 available to Applicants the details on the useable capacity for each purpose (passenger, freight). **Commercial share (traffic part)** The supply consists of a 365-days capacity diagram, where object as pre-planned paths, system paths and or wider bandwidths with the number of available slots and/or empty space for tailor made paths are displayed. This shall also take into account which capacity is not available for booking (e.g., due to existing Framework Agreements or multi-annual RP commitments). **TCRs in Capacity Supply phase part** The aim of thorough TCR planning is to eliminate changes in the Capacity Models and minimise impact on allocated paths. Creating the Capacity Supply,

all major, high and medium impact TCRs have to be included in this phase of the Capacity Supply development (X-11). As it is too early for exact details for minor impact or late TCRs, RIMs can establish regular TCR Windows to be able to react. For days when the traffic will be affected by TCRs, RIMs should jointly prepare harmonised sufficient Capacity Supply on diversionary lines. Alignment of the TCR Windows is also part of this harmonisation.

Updates after X-11

The Capacity Supply after its publication at X-11 shall be stable and accessible for all applicants. However, there are several triggers due to which the supply is in a certain term dynamic until X+12. As a general rule, this means that capacity which has not been used in a certain step (e.g., capacity originally foreseen for ATT but not booked until deadline for LPR) is made available to subsequent steps (e.g., to RP or ad-hoc).

Stakeholders involved	International leading entity* RIMs ROCs Ministries of Transport Region, local government, transport association, industry Terminal and service facility
Contributing process(es)	Capacity Supply Planning process as described in Create Capacity Supply
Deliverable	The following items should be included in a central system (currently ECMT, future capacity hub): -365-days 24-hour capacity diagrams showing paths, bandwidths, already allocated capacities, empty space, and blocked space for TCRs, for every day of the timetable year -Views on which capacity is available for which product (ATT, RP, ad-hoc)

IT tool(s)	**Relevant Central IT Modules** **-**TCR To manage the coordination and inclusion of TCRs in the Capacity Supply as blocks/negative capacity -Capacity Hub (ECMT) To collect and display capacity diagrams, harmonise with other RIMs -Messaging Module To connect the afore mentioned modules with each other, with national (legacy) IT and with central databases
Notes	

[SPT3TMS-8454 **]**

5.2.3 Temporary Capacity Restrictions (TCRs)

Temporary Capacity Restrictions (TCRs)

Name	**PLANNED TEMPORARY CAPACITY RESTRICTIONS MANAGEMENT**
Short Description	Planning, coordination, and optimisation of Temporary Capacity Restrictions, impacting international traffic according to market needs and (but not only) on the basis of Annex VII of Directive 2012/34, as well as timely and user-friendly communication to affected stakeholder. The process must be commonly applied by all European RIMs
Purpose	TCR Process harmonisation among neighbouring RIMs starting at X-60; Involvement of stakeholders regarding TCRs; improvement of stakeholders' involvement, including all relevant departments within the RIMs; harmonisation of the application of Annex VII; improvement of the means of publication; improvement of stakeholders' consultation also for minor impact TCRs
Current issue	Temporary capacity restrictions (hereinafter defined as TCRs) are necessary to keep the infrastructure and its equipment in good condition and to allow infrastructure development in accordance with market needs. Annex VII of Directive 2012/34 has set the basic elements to be considered in order to enable the implementation of a TCR process throughout Europe, namely: - Defined criteria into which TCRs should be clustered based on their impact on traffic; - Set common deadlines for RIMs to complete each process step for each type of TCR. However, Annex VII is not uniformly implemented in Europe and out of Annex VII, also late TCRs should be incorporated into the process, in order to avoid that the planning of minor impact TCRs (which continues after X-12) unforeseen excessively impact on the capacity management. There is still a need of a better coordination and communication among international stakeholders

Target

TCRs are planned and communicated well in advance. RIMs consult applicants to identify their commercial needs in sufficient time. The impact of each TCR on timetables is analysed, with increased maturity in each iteration, until they are fixed in the Capacity Model. After TCRs have been fixed, only minor changes should be made. This should ensure the reliability of available capacity and optimal usage of international rail capacities. An international tool enables the coordination and communication of TCRs.

Content

	Consecutive days	Impact on traffic (estimated traffic cancelled, re-routed, or replaced by other modes of transport)	First publication deadline according to Annex VII
Major impact TCR[1]	More than 30 consecutive days	More than 50% of the estimated traffic volume on a railway line per day	X-24
High impact TCR	More than 7 consecutive days	More than 30% of the estimated traffic volume on a railway line per day	
Medium impact TCR	7 consecutive days or less	More than 50% of the estimated traffic volume on a railway line per day	X-12
Minor impact TCR	unspecified	More than 10% of the estimated traffic volume on a railway line per day	X-4
Less than minor impact TCR	unspecified	Maximum 10% of the estimated traffic volume on a railway line per day	The IMs are recommended to comply with the Path Alteration requirements: ➢ *Passenger: T-4* ➢ *Freight: T-1*

Stakeholders involved

International leading entity*
RIMs - incl. leading/coordinating RIM
ROCs - - incl. leading ROC
Regulatory Bodies
Terminal and service facilities

Contributing process(es)

TCRs process as described in Coordinating and Publishing TCR

Deliverable

The following items should be provided:
- Capacity Strategy: Basic principles for TCR planning
- Capacity Model: Capacity Model variants for major and high impact TCR periods
- Capacity Supply: Capacity Supply incorporating major, high, and medium impact TCR periods
- Final Offer: Adjusted according to the available TCR information
- Altered Path: Coordinated alteration process in line with Annex VII.

IT tool(s)	**Relevant Central IT Modules** **-**TCR tool For international harmonization of all known TCRs; for the visualisation of the TCRs and to help RIMs in the coordination process; for RUs to comment TCRs in a consultation phase before the TCRs are published; to act as a single place with all information about available TCRs. This tool will be fed by data from RIMs' national systems -Capacity Hub (ECMT) National TCR tools (where existing) and related interfaces to central IT Tool (for data exchange, for data upload, or other...)
Notes	

[SPT3TMS-8456 **]**

5.2.4 Feasibility Studies

Feasibility Studies

Name	**FEASIBILITY STUDIES**
Short Description	Iterative process, performed for applicants who wish a good understanding and indication of how their paths could fit in TT, based on the capacity partitioning displayed in the capacity model, before an official path request. (X-18--> X-11)
Purpose	Meet the wishes of applicants h to have a good understanding and indication on the manner how their paths could fit in the timetable before they place their official path requests
Current issue	A ROC might find himself in the following situations: the published Capacity Supply does not provide enough information to ROCs, or the published Capacity Supply does not coincide with ROCs' demand.
Target	Provide an instrument aimed at accommodating market needs without changing the capacity partitioning provided with the Capacity Model
Content	A non-binding response if the request made by the ROC can be accommodated (annual timetable and ad-hoc path)
Stakeholders involved	RIMs - incl. leading/coordinating RIM ROCs - incl. Leading ROC
Contributing process(es)	Feasibility Process as described in Perform Feasibility Studies
Deliverable	Coordinated Feasibility Study Result
IT tool(s)	**Relevant Central IT Modules** • Capacity Hub (ECMT) To collect and display the capacity volumes • Capacity Broker/Path Request Management (PCS) To handle and coordinate international feasibility studies • Messaging Module To connect the before mentioned modules, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8458]

5.2.5 Capacity Requests And Allocation

5.2.5.1 Annual Timetable

Annual Timetable Request & Allocation

Name	**ANNUAL TIMETABLE REQUEST AND ALLOCATION**
Short Description	Applicants can request pre-constructed products (paths) published by RIMs as part of the Capacity Supply. Unplanned capacity or bandwidth can also be applied for. In case of conflicts of requests, RIMs will coordinate requests to ensure best possible matching of requirements. Minor/Major changes to initial requests are possible. As the last resort, after the coordination phase, European wide applicable Allocation Rules should be applied.
Purpose	Construction of the Annual Timetable made of pre-constructed train paths, requested on time
Current issue	Some market segments call for more flexibility in the offer of railway capacity product, but there is still the need of guaranteeing, as far as part of the available capacity is concerned, the robustness of a timetable, a precondition is to have a relevant proportion of trains with a static timetable. There are various market needs in the segments of passenger and freight traffic that are compliant with this prerequisite
Target	Build an Annual Timetable by coordinating incompatible requests and finding optimised solutions
Content	Allocation of path request at X-5.25 of annual requests placed on time, i.e., at X-8,5 (new path requests); requests can apply to pre-constructed products or to tailor-made solutions
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM Regulatory Bodies Terminal and Service Facilities
Contributing process(es) Deliverable	Annual Timetable and Late Paths Management as described in Handle Annual Timetable The following items should be included in a central system (future capacity hub): • Available capacity supply for ATT • Already allocated capacity • Allocated coordinated ATT paths
IT tool(s)	**Relevant Central IT Modules** • Capacity Hub (ECMT) • Capacity Broker/Path Request Management (PCS) To handle and coordinate international feasibility studies • Messaging Module To connect the before mentioned modules, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8461]

5.2.5.2 Late Path

Late Path Request & Allocation

Name	**LATE PATH REQUEST AND ALLOCATION**
Short Description	Requests placed until X-8,5 are treated according to ATT procedures, the rest (until X-2) are processed only after the final offer deadline on a first come-first served base. Products that can be applied for: pre-constructed ATT paths or unplanned capacity or bandwidth
Purpose	Construction of the Annual Timetable made of pre-constructed train paths, requested after deadline
Current issue	Some market segments call for more flexibility in the offer of railway capacity product, but there is still the need of guaranteeing, as far as part of the available capacity is concerned, the robustness of a timetable, a precondition is to have a relevant proportion of trains with a static timetable. There are various market needs in the segments of passenger and freight traffic that are compliant with this prerequisite
Target	Build an Annual Timetable by coordinating incompatible requests and finding optimised solutions
Content	Allocation of path request at X-5.25 of annual requests place after the path request deadline, i.e., between X-8.5 and X-2 (late path requests); requests can apply to pre-constructed products or to tailor-made solutions
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating IM Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Annual Timetable and Late Paths Management as described in Handle Late Path Requests
Deliverable	The following items should be included in a central system (future capacity hub): • Available capacity supply for ATT • Already allocated capacity • Allocated coordinated ATT paths
IT tool(s)	**Relevant Central IT Modules** • Capacity Hub (ECMT) • Capacity Broker/Path Request Management (PCS) To handle and coordinate international feasibility studies • Messaging Module To connect the before mentioned modules, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8463 **]**

5.2.5.3 Rolling Planning Request And Allocation

Rolling Planning Request & Allocation

Name	**ROLLING PLANNING REQUEST AND ALLOCATION**
Short Description	A request placed between four and one month before first day of operation for a maximum duration of 36 months. These are handled on a first come – first served base. Applicants can apply for pre-constructed rolling planning capacity (slots) or bandwidth (T-(4-1) ® +36)
Purpose	Allowing ROCs to request paths at any time and RIMs to be able provide high quality paths, as the Rolling Planning is based on safeguarded capacity, which is dedicated to later requests, and which is assigned to this purpose in the capacity model.
Current issue	There is an urgent need, for some market segment for a requesting method for traffic with details known at a later time.
Target	Quick response times and multi-annual request validity should provide the flexibility necessary in order to react to the volatile market while at the same time still providing stability for upcoming timetable periods.
Content	Rolling Planning is available as a request method at any time. Safeguarded capacity – which has been designed by RIMs in cooperation with applicants and other stakeholders - provides high quality paths according to market needs. Multi-annual requests are possible. The applicants make use of the possibility to consult RIMs in the creation process to bring safeguarded capacity as close to real needs as possible
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM ROC - incl. leading ROC Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Rolling Planning Management as described in Handle Rolling Plan Requests
Deliverable	Allocated coordinated Rolling Planning path Updated capacity supply (according to allocated or cancelled capacity)
IT tool(s)	**Relevant Central IT Modules** • Capacity Hub (ECMT) To collect and display the capacity volumes • Capacity Broker/Path Request Management (PCS) To handle and coordinate international path request coordination system for path applicants • Messaging Module To connect the before mentioned modules with each other, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8465 **]**

5.2.5.4 Short-Term And Ad-Hoc

Short-Term & Ad-Hoc

Name	**AD-HOC/SHORT TERM REQUEST AND ALLOCATION**
Short Description	A capacity request placed after X-2 until operations day within the current timetable year. Handled on a first come-first served base. Harmonised between RIMs. Products that can be applied for: unplanned capacity, residual pre-constructed ATT paths or rolling planning capacity, pre-constructed ad-hoc capacity (if applicable) (X-2 ®X+12)
Purpose	Satisfying the requests of ROCs placed after X-2 up until the end of the running timetable
Current issue	This kind of product already exists, but the capacity used to accommodate the related requests is only the residual capacity, not a special product. Moreover, there are no agreed point procedures for the ad hoc requests to treat them in a harmonised way and agree on the operational details that have to be respected in all networks
Target	In the new approach the difference is that the capacity used to accommodate the related request is reserved for this purpose (unplanned capacity, not used pre-defined Annual Timetable paths, any delimited capacity for ad-hoc, if existing) and will not affect the capacity reserved for rolling planning. In addition, the RIMs will apply harmonised procedures as mentioned above
Content	The Ad hoc product covers the following market needs: • Transport need for an extended period (shorter than a TT year), but the deadline for placing ATT Late path requests (X-2) has expired and the published Rolling Planning capacity does not correspond with the required path characteristics. • Transport need for an individual, single train run in the current TT year but the published Rolling Planning capacity does not correspond with the required path characteristics. • Customer has a one-time transport need at short notice (short-term ad hoc request).
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM ROCs - incl. leading ROC Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Rolling Planning Management as described in Handle Ad-hoc Requests
Deliverable	Allocated Harmonised Ad hoc path(s) Updated Capacity Supply

IT tool(s)	**Relevant Central IT Modules** • Capacity Hub (ECMT) To collect and display the capacity volumes • Capacity Broker/Path Request Management (PCS) To handle and coordinate international path request coordination system for path applicants • Messaging Module To connect the before mentioned modules with each other, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8467 **]**

5.2.6 Paths Management After Allocation

5.2.6.1 Path Alteration

Path Alteration

Name	**PATH ALTERATION AND OPTIMISATION**
Short Description	Change or withdrawal of already allocated capacity needed by one initiating RIM (X-5.25® X+12)
Purpose	Managing the cases when the allocated path must be altered by the RIMs reducing the impact on the customers
Current issue	Based on the path agreements, applicants can expect that an allocated path is available up to its operation. However, in several cases, it may be necessary for RIMs and allocation bodies to alternate, adjust, replace, or withdraw already allocated paths. This activity is the so-called “Path Alteration”. The need for path alteration shall be reduced to a minimum.
Target	the Path alteration and optimisation processes are harmonised among RIMs and reduce the impacts on the stability of traffic and on the business of the customers, who are informed in due time. RIM shall make all effort to find a viable alternative solution to the initially allocated path
Content	**MODIFICATION:** Immediately information to the applicant and all potentially affected stakeholders of intention or possibility that a path alteration process will be started by the initiating RIM, who will also take care of any update on the status. Evaluation of the impact of the process (to check if it wil affect more network). In this case, the initiating RIM has to analyse a possibility to provide an immediate economically viable alternative that causes no multi-network impact. The initiating RIM always has the right to withdraw the alteration request. The path alteration can also result to a situation where there is no alternative available, in such a case the affected running days are withdrawn. The RIMs should set up joint procedures for the alterations to treat them in a harmonised way and agree on the operational details that have to be respected in all networks as for instance, the harmonised response time, acceptance timeline and allocation principles. OPTIMISATION: The Path Optimisation process is a special case of the path alteration. The original path is still available for the train operation and active for the applicants holding the rights to this allocated path. The RIMs trigger the path optimisation process to ensure the best possible matching of all path requests

	and or to increase the line capacity by timetable optimisation. The communication has to include the information that the process is driven by the optimisation and not by the fact that the original path is not available anymore. If no response is provided by ROCs in the time frame given by RIMs, the optimised path offer is considered as rejected and the original path remains active and allocated.
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM ROCs - incl. leading ROC Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Path Alteration and Optimisation Management as described in Handle Path Altertion
Deliverable	Altered and coordinated or Optimised and coordinated Path(s) Updated Capacity Supply
IT tool(s)	**Relevant Central IT Modules** Capacity Hub (ECMT) • Capacity Broker/Path Request Management (PCS) • TCR tool • Messaging Module: To connect the aforementioned modules with each other, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8470 **]**

5.2.6.2 Path Modification

Path Modification

Name	**PATH MODIFICATION**
Short Description	Change or withdrawal of already allocated capacity induced by ROC (X-5.25® X+12)
Purpose	Managing the request of change or withdrawal of an allocated path, placed by an ROC after allocation and before the end of the running Timetable period
Current issue	Requests of modification or withdrawal are of course already handled, but they are not harmonised at European level, causing mismatching in case of international paths; moreover, the procedures applied should be differentiated according to the type of requested modification, that can be major or minor. These two types must be defined in an agreed manner.
Target	-The types of modification requests are well defined and recognised by all stakeholders - subsequent processes will be harmonised - impacts/effects on the overall capacity planning duly taken into account

Content	Two types of modifications should be recognised: major and minor modifications. In general, major modifications are changes in parameters of an allocated train path that have a substantial impact on the allocated timetable, therefore, making it impossible to respect the allocated train path. Requesting such change shall be harmonised by the involved ROCs and subsequently by the affected RIMs. Modification for multiannual Rolling Planning will have two steps: normal modification for the current timetable; subsequent timetable period: can be requested during the preparations for converting a slot into a path.
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM ROC - incl. leading ROC Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Path Modification Management as described in Handle Path Modification
Deliverable	Modified and coordinated Path(s) Updated Capacity Supply
IT tool(s)	**Relevant Central IT Modules** Capacity Hub (ECMT) • Capacity Broker/Path Request Management (PCS) • TCR tool • Messaging Module: To connect the aforementioned modules with each other, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8472 **]**

5.2.6.3 Path Cancellation

Path Cancellation	
Name	**PATH CANCELLATION**
Short Description	Handle the full or partial cancellation of paths allocated in Annual Timetable, Rolling Planning, and ad hoc/short-term processes by ROC
Purpose	Managing the request of cancellation of an allocated path, placed by ROC
Current issue	ROC may always cancel an allocated path. Requests of cancellations are of course already handled, but they are not harmonised at European level, sometimes causing business damage to the case when more than one applicant is involved in an international train path of which only one part is cancelled. Harmonisation is an urgent need in this topic
Target	the cancellation processes are harmonised among RIMs and reduce the impacts on the stability of traffic and on the business of the customers, especially ROC's partners who cancelled its part of the path and wish to run their part of traffic

Content	This process applies to paths in the Annual Timetable, Rolling Planning, and ad hoc/short-term processes. ROC may always cancel an allocated path. This path cancellation may refer to one single day, several days, or all remaining operation days. It is also possible to cancel the entire train run (all path sections) or just one or more sections of the train run (one path section). However, if more than one applicant is involved in the path sections, it may be possible for one of the involved ROCs to keep its allocated path section and reuse it for another traffic with identical parameters. In such a case, the path modification request shall be placed (following the cancellation process for the not needed path sections) by ROC that still wishes to use its path section for another train service. Partial cancellation of an allocated path is not recommended without harmonisation with partner applicants, in order not to destroy the path. In case there is no connected path in the preceding or subsequent network, RIM has right to shorten the allocated remaining national path to a reasonable infrastructure point to avoid traffic jams and other issues in traffic management area.
Stakeholders involved	International leading entity* RIMs - incl. leading/coordinating RIM ROC - incl. leading ROC Regulatory Bodies Terminal and Service Facilities
Contributing process(es)	Path Alteration and Optimisation Management as described in Handle Path Cancelations
Deliverable	Cancelled (and coordinated where the case) Paths Updated Capacity Supply
IT tool(s)	**Relevant Central IT Modules** Capacity Hub (ECMT) • Capacity Broker/Path Request Management (PCS) • TCR tool • Messaging Module: To connect the aforementioned modules with each other, with national (legacy) IT and with central databases
Notes	Any other relevant information

[SPT3TMS-8474 **]**

* to be revised according to the outcome of the current legislative procedure **[**SPT3TMS-8475 **]**

5.2.7 Note To CMS Capabilities - Enabling Factors

5.2.7.1 Allocation Principles

Allocation Rules become imperative whenever a RIM faces a capacity shortage, e.g., during the timetabling process when there are conflicting requests/applications. In such cases, allocation priority rules need to be applied. **[**SPT3TMS-8478 **]**

Today, such rules are applied to international traffic in the allocation of pre-arranged paths by the Rail Freight Corridors and are defined in the so-called “Framework for Capacity Allocation (FCA)”. **[**SPT3TMS-8479 **]**

At a national level, each RIMs also applies its own rules, which are not harmonised across different networks. This leads to significant complexity in the case of conflicts, the resolution of which is very time consuming. **[**SPT3TMS-8480 **]**

5.2.8 Requirements For CMS

5.2.8.1 General Requirements

An effective future CMS, should be complemented with allocation rules, whose requirements are:

- Harmonisation and application throughout Europe
- Ease of use
- Based on different criteria, among others, if possible, socio-economic criteria, as opposed to the ones mostly used today ("Winner takes it all" approach). A "scenario approach" (where the idea is to identify several scenarios and pick up the one which is the best solution for the society) should be the preferred one considering its advantages:
    - Positive practical experiences in SF, NO & SE
    - Application of socio-economic criteria do not require extra planners
    - Creation of the model and the «costs» is a one-time task
    - Application will be with pre-defined costs and simple calculation in no extra time

The goal in case of conflicting requests is to find solutions for all requesting ROCs. Rejection due to a lack of capacity should be avoided. **[**SPT3TMS-8483 **]**

5.2.8.2 Commercial Requirements

The CMS delineated thus far envisions a capacity planning process initiated well in advance to facilitate the efficient and swift allocation of rail infrastructure capacity. However, practical experience underscores the necessity for heightened oversight to avert the squandering of rail capacity and the consequent occurrence of superfluous or redundant efforts. These concerns primarily arise from:

- Constant changes made to planning parameters
- Capacity blocked but not used by stakeholders

[SPT3TMS-8485 **]**

To encourage stakeholders to use the process and capacity products as efficiently as possible, commercial conditions must be applied to avoid misuse of capacity. **[**SPT3TMS-8486 **]**

Although commercial conditions are currently in use across Europe, their lack of harmonisation poses significant challenges: ROCs involved in requesting international train paths are confronted with divergent approaches at various stages and varying rules for different national segments of a singular international train route. The efficacy of a future CMS hence hinges on the application of standardised commercial conditions, fostering capacity-friendly behaviour. The realisation of capacity benefits through a new CMS necessitates the capacity sector's ability to influence this conduct both on the ROC and RIM fronts. This implies that ROCs should only reserve the capacity they genuinely require, and RIMs can effectively ensure that track maintenance works (TCRs) are synchronised to maximise capacity availability. **[**SPT3TMS-8487 **]**

The commercial conditions shall:

- Support an increase in commercially usable capacity
- Support the TTR process
- Support stability of allocated paths
- Follow a European approach to process and timelines
- Incentivise capacity-friendly behaviour in both RIMs and ROCs
- Reduce capacity waste

[SPT3TMS-8488 **]**

- Capacity waste means:

- Paths are ordered without proper need, allocated and modified after allocation so that other ROCs cannot sensibly make use of them
- Allocated paths are changed by RIMs after allocation due to the impact of TCRs by RIMs (same one allocating the path or another one on a different network)
- An unnecessary number of paths are not allocated or are cancelled by RIMs due to poor alignment of several planned TCRs
- Paths are not allocated or are cancelled by RIMs due to planned TCRs at times when little or no work is actually being carried out
- Paths are not allocated or are cancelled by RIMs due to planned TCRs that were cancelled
- Paths are not usable (or re-usable) due to the changes being communicated too late (i.e., due to paths being cancelled too late, TCRs cancelled, etc.)

[SPT3TMS-8489 **]**

- Capacity-friendly behaviour means:

- A path confirmed is a commitment from both ROC and RIM, which should be kept after it has been allocated and accepted
- Ordering capacity only when the market need for it need has been confirmed (ROC)
- Give back the capacity as soon the market need changes, or other external requirements are known (ROC)
- Defining the capacity for TCRs in a way that no more capacity than necessary is blocked – in dialogue between ROCs and RIMs
- Planning the majority of TCRs and their impact to paths before path allocation (RIM)
- Reducing TCRs in operational timetable to the minimum and planning their impact to paths/trains as early as possible (RIM)
- Stabilising TCR planning - avoiding TCR cancellations that lead to a double loss of business, as well as massive re-planning of scheduled TCRs, which results in high efforts in operational planning (RIM)

[SPT3TMS-8490 **]**

Scope of application: in TTR, Commercial Conditions shall:

- apply in the planning phase, after a path has been ordered but at the very latest during the planning phase after a path has been allocated and accepted
- apply to planning (i.e., modifications, alterations, cancellations, withdrawals according to the same timelines) and non-usage of allocated paths (i.e., without cancellation)
- not apply to operations (delays etc.), to avoid overlap with real-time traffic management performance

[SPT3TMS-8491 **]**

Desired effects of a balanced, well incentivised, and effective mechanism

- ROCs shall order capacity when needed
- ROCs shall make required changes as early as possible to release unneeded capacity for others
- RIMs shall ensure lean TCR planning in a way that minimises the amount of capacity blocked and make required changes as early as possible to release unneeded capacity
- RIMs shall plan TCRs, and paths affected by them as early as possible to avoid changes to customers and production chains
- It shall not lead to ROC modification or cancellation being prohibited (and ROCs hence forced to keep capacity the market doesn't need) since market demand may change and/or ROCs may need to adapt their production to the market environment
- It shall not lead to forbid RIMs from implementing TCRs since RIMs are permanently responsible for ensuring the safety of operations
- Commercial conditions shall incentivise ROCs and RIMs alike to engage in capacity-friendly behaviour. Issues or undesirable behaviours (modification/alteration, suppression/cancellation, non-usage) must be addressed via either financial or non-financial incentives for both parties. Commercial Conditions need to be designed to influence RIMs' and ROCs' behaviour effectively (Source "Commercial Conditions – RNE-FTE Common Understanding" 13/06/2022)

[SPT3TMS-8492 **]**

5.2.8.3 Additional Requirements (Clarifications)

- Commercial conditions are an incentive to foster capacity-friendly behaviour
- Commercial conditions are not meant to make profit or cover costs of the receiving party
- Principles and timelines for commercial conditions shall be aligned across Europe
- Fee levels / price tags do not need to be aligned
- Every change of a train / path may damage the market; changes shall therefore be disincentivised
- Force Majeure should be excluded from the scope of commercial conditions. A definition of “Force Majeure” is required, but will not be defined in the context of commercial conditions
- Commercial conditions shall not prohibit required changes of paths or additional (urgent) TCRs. These shall however be planned and communicated as early as possible
- ROCs and RIMs are the parties to the path contract and thus are the stakeholders who shall be targeted by commercial conditions. Common requests for improvements among other stakeholders (e.g., ministries, PSO authorities, freight forwarders) may be raised based on the acquired knowledge
- Use cases of the commercial conditions’ subject focus on incentivising capacity-friendly behaviour and plannable scenarios in path allocation. Other subjects (e.g., force majeure, track access charges, etc.) should be handled as separate subjects

[SPT3TMS-8494 **]**

5.2.8.4 Legal Requirements (For Network Statement)

- The CMS described in this document will introduce a new way of planning and allocating railway capacity. To fully implement this innovative process, adherence to the pertinent legal frameworks (European and national) becomes imperative. The prevailing legal structure reflects existing capacity management procedures but no longer aligns completely with evolving market needs. As of July 2023, a proposal for a new EU Regulation has emerged ("on the use of railway infrastructure capacity in the single European railway area, amending Directive 2012/34/EU and repealing Regulation (EU) No 913/2010"). The congruence between the outcomes of this legislative proposition and the delineated Definition of the CMS System merits careful consideration.
- From a regulatory standpoint, similar to the current practice, the national Network Statements will have to reflect both the relevant legislation and the CMS rules as described in this document (capabilities, processes, tools).

[SPT3TMS-8496 **]**

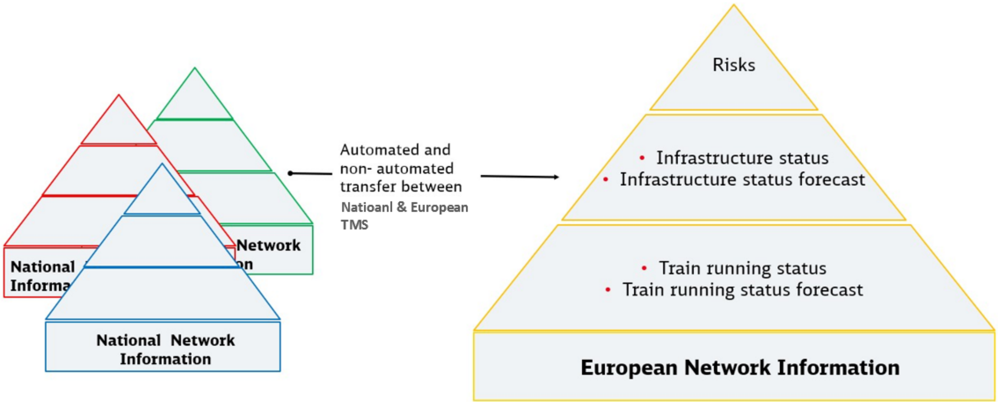
5.3 European Capacity Production (Real-Time TMS (Dispatching))

5.3.1 European Network Status Comprising Status Of All RIMs

In order to unfold the leap forward by the interaction between the network members, it must be secured that three categories of information are made available as in Figure 6:

- Train running status and forecast for all trains from origin to destination,
- Current and planned Infrastructure status,
- Risks.

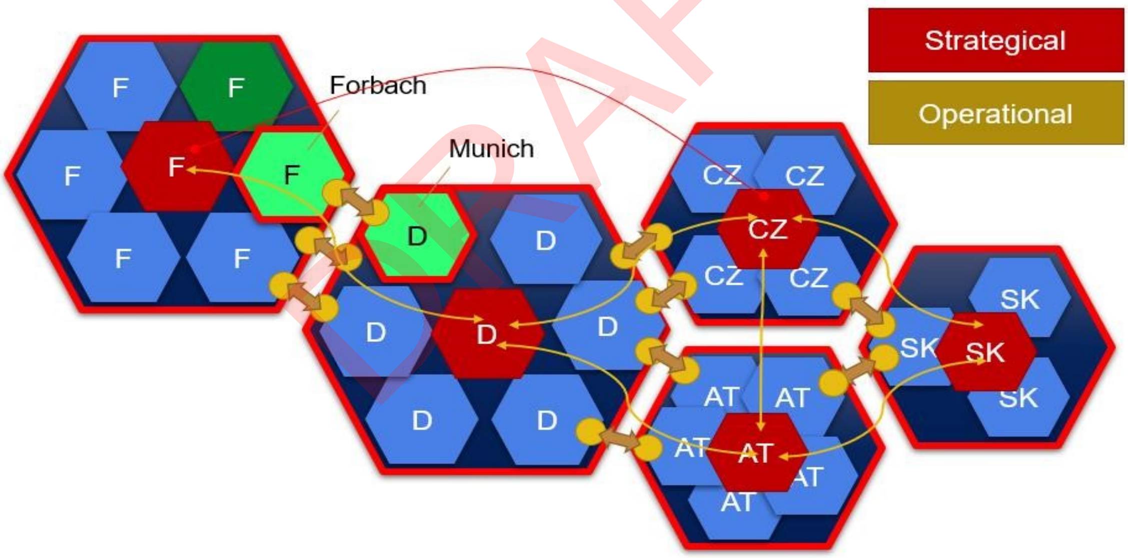
[SPT3TMS-8499 **]**



[SPT3TMS-9307 **]**

Figure 6: Integration Between National & European Operations

A permanent and regular information flow is the backbone of the network approach and is supplemented by the European network status. This means that the RIM can not only observe trains on its own traffic cell, but also on neighbouring traffic cells and cells that are even further away (over-the-cell-vision) as shown in Figure 7. **[**SPT3TMS-8500 **]**

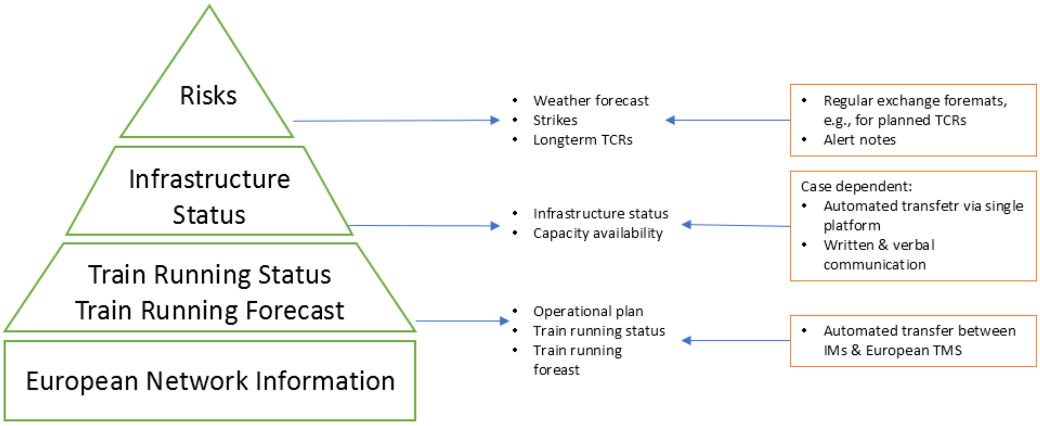


[SPT3TMS-9306 **]**

Figure 7: Traffic Cells - Over The Cell Cooperation

5.3.2 Train Running Status And Forecast; Infrastructure Status, Risks

For ETMN, three information categories can be defined. The categories are described below in Figure 8:



[SPT3TMS-9305 **]**

Figure 8: European Network Information

5.3.2.1 Train Data to Be Made Available In The Network's Operational Plan

The train runs are organised based on the customers' requirements and available capacity of the lines. The agreed timing and capacity utilisation is presented in the operational plan. The operational plan contain the essential information for effective train run management for the dispatchers in their shift. In the network approach the dispatchers should have access to the full international operational plan for the concerned trains they are involved in managing on their network. Keeping the train running according to the operational plan creates precondition for effective traffic management. Exchange on any change must be mandatory within the network. **[**SPT3TMS-9304 **]**

5.3.2.2 Train Running Information

Train running information provides essential information about the current occupation of the allocated train path giving an indication for the train's current location and deviation from the operational plan. Having this information, dispatchers can assess the traffic situation (e.g., traffic density, deviation, etc.) in their responsible traffic cell and intervene if necessary. **[**SPT3TMS-9309 **]**

5.3.2.3 Train Composition

Train properties are always essential to better manage the trains, especially in case of dispatching measures and other deviations from the allocated path. It is important for RIMs to know when train properties deviate from what was indicated in the path request or during the train run. During operation, the exact knowledge of the train properties, especially train length and weight, allows are more efficient overall traffic management as it prevents unnecessary capacity wastage (e.g., in case of overtaking or parking of trains). TMS can obtain the current information from ROCs using an interface, the interface is fully specified in TSI specifications (already given). **[**SPT3TMS-8505 **]**

5.3.2.4 Train Forecast Information

Train forecast information is key to an efficient traffic management in the network. It allows a foresighted dispatching of trains as it is constantly clear when trains will enter and leave the traffic cells. The forecasting contributes to better capacity utilisation especially in cases when trains are deviating from their operational plans. That is why, a key element in the ETMN-concept and various procedures developed in it, is the broadcasting of ETx between RIMs. Especially, in order to create the network effect, ETH is the core information that connects traffic cells indicating when the train approaches the border and giving the neighbouring cell the opportunity to coordinate. **[**SPT3TMS-9219 **]**

The list below shows the detailed information , that is required for international coordination and cooperation. This information is shared and passed from one TMS to another, and updated and imported from the systems generating this data whenever there is a change:

- Operational Plan
- Train Running Information
  - Current location,
  - Deviation from the Operational Plan,
  - Deviations at previous locations.
- Train properties
  - Length,
  - Weight,
  - Maximum speed,
  - Traction,
  - Train composition.
- Train running forecast
  - ETH available for each border crossing once the train departed from its origin. ETH is the crucial minimum timestamp for the functioning of the network,
  - ETx for any location during the train run, especially for larger networks where the train runs through several regional TCCs. The ETx can substitute internal ETH between regional TCC inside one RIM's network,
  - For the final destination.

[SPT3TMS-8507 **]**

5.3.2.5 Infrastructure Data

A common data model with CCS based on TCCs' proposals for effective international traffic management is the availability of the current status of the infrastructures surrounding one traffic cell. In other words, in some situations it is beneficial from a RIM's perspective to know what the status of the infrastructure of the neighbouring RIM(s) is, especially, information about ongoing disruptions affecting international traffic is important for other traffic cells so that RIMs can prepare for effects on their own network. Where necessary, this information can also initiate further contact and coordination between infrastructure managers. **[**SPT3TMS-8509 **]**

The list below shows the detailed information that is required for international coordination and cooperation:

- Infrastructure status
  - Disruptions
    - Location/section/area,
    - Impact on capacity,
    - Expected duration,
    - Type (e.g., accident, technical malfunction, weather, urgent TCR)
  - Unplanned TCRs
    - Location/section/area,
    - Impact on capacity,
    - Estimated end
- Capacity availability

[SPT3TMS-9217 **]**

5.3.2.6 Infrastructure Restrictions (planned and actual)

Risk management is based on information about expected conditions in the upcoming days or weeks. In this context, infrastructure restrictions and unplannable events are particularly worth mentioning. An example is that in case of a planned TCR, train runs should be adapted accordingly. However, the traffic flow during a planned TCR is more vulnerable to disturbances and unexpected events than regular traffic with full capacity. Furthermore, TCRs – contrary to how they are included in the operational plan – may be delayed. This can have negative effects on international trains runs. Risk management also considers other circumstances like inclement weather condition or planned strikes that can heavily affect traffic flows. Sharing information about these risks is important for IMs to coordinate common actions or prepare common plans for a possible reaction to these risks. **[**SPT3TMS-9229 **]**

Circumstances that may have an impact on international traffic (risks in the upcoming days and weeks)

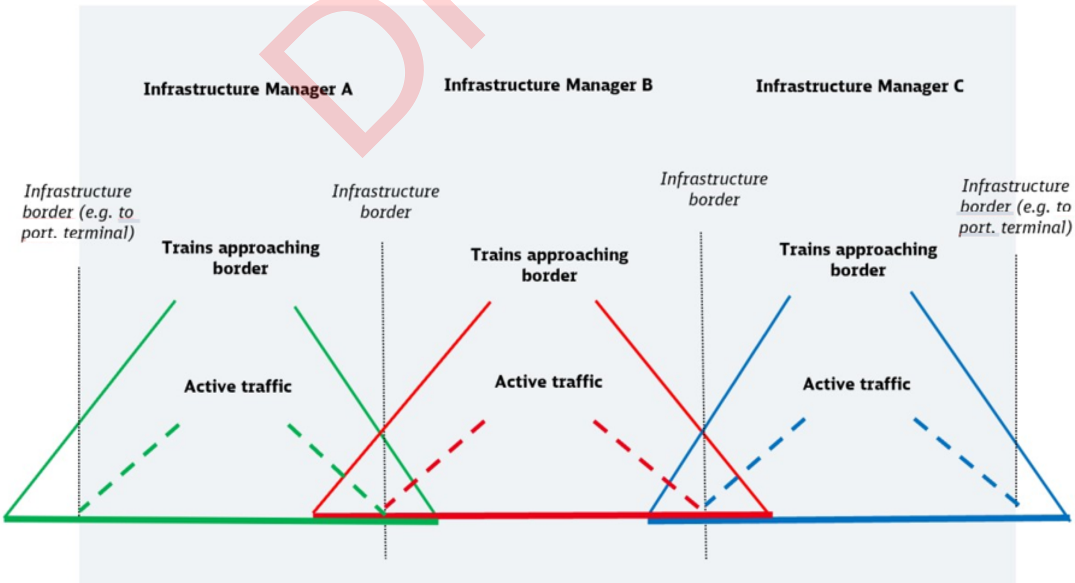
- Type (weather, strikes, other),
- Expected impact,
- Expected duration.

Long term TCRs

- Effects related to the planned TCRs (in the upcoming days and weeks)
    - Timeframe of TCR,
    - Location/section/area of the TCR,
    - Estimated impact on capacity.

[SPT3TMS-9227 **]**

Figure 9 shows the mechanism of the information flow between the different RIMs when communicating traffic information at the borders. It is important to note that the forecast (train approaches border) is provided before active traffic.



[SPT3TMS-9225 **]**

Figure 9: Traffic Management Through Cross-Border Information Flow

5.4 Functional Capabilities of The European TMS

5.4.1 Real-Time Monitoring

The network should enable better cooperation and communication between the national TCCs. For these purposes the European TMS can serve as an interconnecting interface. The European TMS is based on the TAF/TAP TSI regulation. European TMS is presenting train related information continuously. This information is stored for further reporting purposes. **[**SPT3TMS-9223 **]**

One core function of the European TMS enables real-time monitoring of the complete international train run from origin to destination even when the train run has only been separately recognised on national sections. Linking of related train runs creates a precondition for a network approach where TCC can follow the train run from its origin to its destination and exchange necessary information in advance before the train enters new national networks. The European TMS principles are predefined to establish the first level of national TMS interconnection via active TAF/TAP TSI message exchange. The dispatchers are recommended to use the European TMS Human Machine Interface (HMI)or use the data presented in their adapted national TMS or to exchange it bilaterally. **[**SPT3TMS-9234 **]**

For effective network performance, predictions covering the whole European network are essential. Network ETA has the goal to ensure at least one prediction for the most important locations labelled with accuracy indicators. As a precondition for effective network cooperation, the ETH information shall be available in any case. The forecast information from RIMs shall be sent to the European TMS where an accuracy calculation and further forwarding take place. This approach ensures a permanent train running prediction from different sources accompanied by accuracy indicators. The possibility to monitor the received train forecast information provides a basis for better decision-making. **[**SPT3TMS-9233 **]**

5.4.2 Incident Impact Management

5.4.2.1 Incident Impact Management

European TMS is designed to cope with international contingencies and incidents which significantly helps national TCCs to reduce the impact of such events.
The Incident Impact Management enables to identify and manage trains affected by incidents and inform all involved parties in an automated manner as a functionality in the TMS.
[SPT3TMS-9232 **]**

5.4.2.2 Further Updated Incident Impact Management

It shall be used for ongoing incidents and future expected obstructions. This means it will be used in a wider range of situations. In addition to this infrastructure managers may use other means of sharing information on such obstructions.
The updated Incident Impact Management is mandatory to be used in the European Traffic Management Network to inform about and manage all incidents' impacts with the following criteria:

- Incidents affects traffic cells on other RIM's networks,
- Expected that it will last at least 6 hours, or as agreed by neighbouring RIMs,
- At least 10 international trains are affected, or as agreed by neighbouring RIMs,
- As soon as you have to apply restrictions on received trains,
- Trains are rejected at the border,
- Several trains are parked at the border.

[SPT3TMS-9231 **]**

The updated Incident Impact Management is recommended to be used in the ETMN to inform about and manage expected obstructions with the following criteria:

- Obstruction expected to affect traffic cells on other RIM's networks,
- Potential duration of expected obstructions,
- International trains may be affected,

- Application of restrictions is expected.

[SPT3TMS-9242 **]**

This tool should gradually substitute all other internationally exchanged documents on incident related information, bringing benefits of structured digital data exchange. **[**SPT3TMS-9240 **]**

The national TCCs can benefit from automatic data exchange. For this purpose, in the future mutually agreed new sector messages should be used. These messages would cover information about ongoing incidents and future expected obstructions. All members should provide this information in the European TMS, and it can also be shared bilaterally. Afterwards, the European TMS can identify affected trains based on the received information, this exchange will automate the current manual Incident Impact Management usage. **[**SPT3TMS-9238 **]**

Incident Impact Management is done in TMS, where notification or publication of the incident shall be performed automatically (being developed), or manually based on user preference. The relevant affected trains should be managed using the European TMS Incident Impact Management application clearly defining their status on the network and presenting requested actions from RUs or neighbouring RIMs. In case of potential obstruction, the same procedure is recommended to be applied. **[**SPT3TMS-9250 **]**

5.4.3 Network Status

All the above listed modules/information (automated train running information, train running forecast and incident management information) comprised will provide an overview of the status of the European railway network to anyone it may concern at any given time to a chosen degree in a compact format. As it is based on the input of many sources, the module will evolve in the longer run. **[**SPT3TMS-9248 **]**

The addressees could be higher stakeholders as well as for national TCCs to coordinate. The latter may be especially interested in the possibility to zoom in a wider section beyond their own network to observe for instance not only the ETH but particular incoming trains and possible reasons for and duration for delay in neighbouring countries. **[**SPT3TMS-9246 **]**

European Network Status will enable better high-level decision making and planning of the next dispatcher shift. The information should be presented on a European map in a user-friendly way. The exact design will have to be developed, but the following is examples of what must or may be included: **[**SPT3TMS-9245 **]**

- Ongoing incidents reported in Incident Impact Management,
- Risks/future disruptions reported in Incident Impact Management (e.g., unplanned TCRs, bad weather, risk of strikes),
- TCRs with a substantial impact on international train traffic,
- Sections with severe train delays based on train running information.

[SPT3TMS-9254 **]**

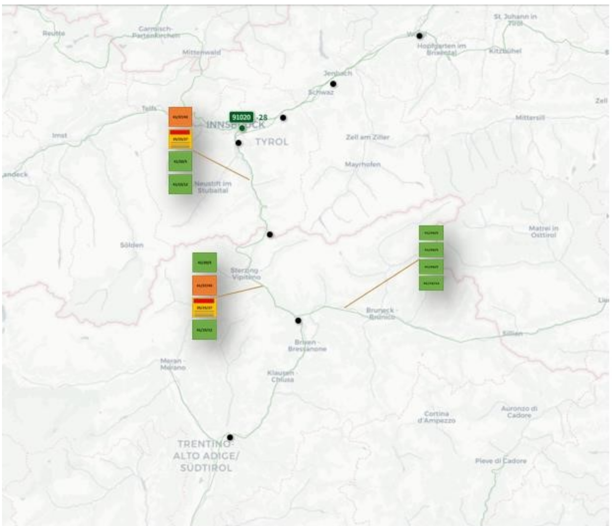
Complementary to a status representing the current situation, a solution, which can offer a general prediction for the whole national network or regions should be beneficial for the network. **[**SPT3TMS-9253 **]**

The “Network Status” will present the European network status and give the general picture how the international trains will be affected by the national network for the next twelve hours. **[**SPT3TMS-9252 **]**

Any forecasts on events which can affect train runs should be included in the report e.g., severe weather conditions, strikes or any situation which can cause deviation on the train run. The comprised presentation of each national network status jointly describes the European network situation. Such an information is just a base for dispatchers shift planning and creates a base for better cooperation to manage international train runs. **[**SPT3TMS-9272 **]**

5.4.4 Capacity Status

The idea of a capacity overview could be also beneficial for the efficiency of the network in the future. The proper capacity offer and its effective utilisation are the main preconditions for the success of the railway business and customer satisfaction. A constantly available accurate overview of the capacity that is available for traffic management combined with the current status of traffic and infrastructure allows dispatchers to optimise traffic. This constitutes the core responsibility of traffic management. **[**SPT3TMS-9270 **]**



Description

- Agregaded presentation of hourly capacity utilisation for the next time period (6/12/24 hours)

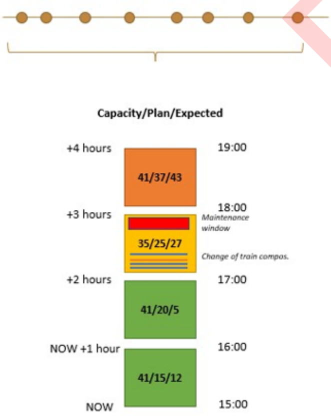
Benefits

- Overview of the situation on own and neighbouring section
- Information enables better assess the overall situation on the network
- Insight to work of possible communication party

[SPT3TMS-9269 **]**

Figure 10: Capacity Status for The Coming Hours of The Borderlines

The dispatchers shall be aware of the current and expected available capacity of the border lines under their responsibility and about the situation on the neighbouring cell up to a reasonable point as shown in Figure 10, and in Figure 11. This allows them to be more integrated with traffic management on the neighbouring cell and cooperate on the optimal train run. This approach can bring benefits for cooperating neighbours in better capacity utilisation with need of direct communication and negotiations for each case. This is especially the case during Incident Impact Management and the subsequent dispatching measures. **[**SPT3TMS-8518 **]**



Aim

- Provide dispatchers with overview of avalable capacity for the agreed time periods

Presented data

- Avalaible capacity for the line
- Planned capacity accordinfg to the timetable
- Occupied capacity according to the train run forecasts (Network ETA)

Source of the information

- National overview of the lines capacity
- Train run forecasting ETH & Network ETA

[SPT3TMS-9267 **]**

Figure 11: Capacity Status Details for The Coming Hours of The Borderlines

The output of the dispatching measures should contribute to the tool presenting capacity overviews for dispatchers in ETMN with all necessary information to assess the situation and better manage the traffic, reflecting the wider perspective of the line's capacity.

6 National CMS & TMS Core Scope

The core scope for Capacity and Traffic Management and any system that supports it is to reach a high, smart, and flexible automation level for its long-term planning and coordination processes (cross-company, cross country) in a manner that enables working with an integrated and rolling high-quality plan in near-real-time, based on automated information exchange between all involved planning partners. CMS & TMS will also include highly digitalised tactical planning functionality taking a relevant, cost-efficient approach. **[**SPT3TMS-9281 **]**

The quality of the plans is increased by including all factors (e.g., increase capacity utilisation, connection catching rate, trains punctuality, optimise energy consumption) that are influencing the planning process into an integrated information basis. Analytical processes, long-term planning, short-term planning and even dispatching can be executed using the same high quality of data and potentially similar algorithms. **[**SPT3TMS-9279 **]**

The plans are shared between all production partners and are open at European level, to allow dynamic automation and optimisation processes on all sides and to reduce coordination effort. **[**SPT3TMS-9277 **]**

The automated planning and re-planning interactions between ROC, RIM, shunting yards, stations, depots, terminals, clients, logistic value chain and border institutions, (etc.) enable swift reactions to production deviations and (re-)planning requests in a live and optimised way. **[**SPT3TMS-9275 **]**

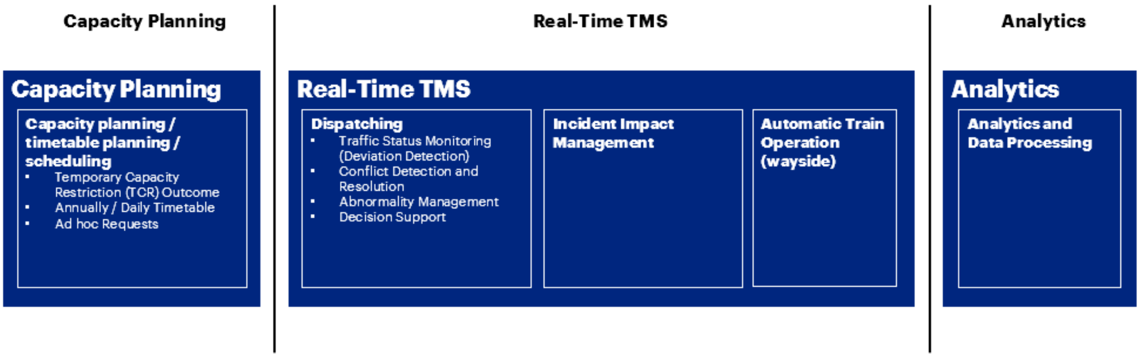
Short-term offers to ROC requests and rapid alerts for customers in the case of deviations or traffic congestions are made possible. A high degree of work-load reduction for planning resources, a reduction of some percent of the consumption of all production resources, and a significantly shorter duration of offers to customers and the solution for deviations can be achieved, leading to a lesser impact of deviations on the overall state of network traffic and, hence, increased punctuality. **[**SPT3TMS-9287 **]**

Implementing this core scope creates several additional benefits. Based on high-quality information several control processes can become more precise or assisted by smart self-learning digital assistants. Communication-based driver advisory systems, Automatic Train Operation (ATO), and on-board intelligent systems may be tuned to take the precise traffic flow forecast in the area into account. Synchronisation of traffic corridors are embedded into automated, national, cross-company planning processes. **[**SPT3TMS-9285 **]**

An operational plan integrating all production factors (infrastructure data, train data, etc.) and interfacing communication with all relevant partners (interfaces with ROCs, interfaces with CCS, interfaces with other CMSs & TMSs etc.), the details are in the SCI-OP document, also serves as the foundation for a quantum-leap in forecasting, conflict detection and conflict solution, and for any ex-post analysis used to optimise future planning processes. **[**SPT3TMS-8520 **]**

Ex-post analysis will allow for systematic problems to be detected earlier and better understood and hence more avoidable. An integrated real-time communication system enables deviation management and feedback loops that form the basis for precise production interventions and a continuous improvement process. **[**SPT3TMS-9290 **]**

Grouping the scope in boxes, as shown in Figure 12:



[SPT3TMS-9295 **]**

Figure 12: TMS System Function

The next chapters describe the main CMS & TMS functions.

6.1 Capacity Planning

6.1.1 Introduction

CMS consists of a planning ability to generate one rolling plan (immediate future to many years ahead, ad-hoc traffic or regular timetable), manage all types of track usages (stabling, train movements, construction, maintenance, occupation for other reasons, reduced/changed track usage conditions, etc.), manage all “planning partners” affecting the plan such as national/international RIMs and ROCs and dependent supporting services (e.g., energy, telecommunication, etc.), construction, maintenance, resource providers, planners for activities adjacent to the network, network access facilities, shunting yards, terminals, stations, connected transport systems, and any other actors on whom the plan depends (or vice versa). **[**SPT3TMS-9294 **]**

The static “offline capacity plan” is constructed based on customer demands (requests of a path/” slot” from RIM) and constraints in infrastructure capacity. The capacity plan comprises the arrival/departure times and the passing times of points/objects represented in the timetable e. g. junctions, terminals, stations. **[**SPT3TMS-9293 **]**

Capacity planning is based on the following fundamental concepts:

- Planning on track level (micro infrastructure)
- Single plan as a single source of truth for all stakeholders
- Unified topology model for capacity planning and capacity production
- Integrated planning for lines and stations (nodes)
- Construction rules

[SPT3TMS-9292 **]**

6.1.1.1 Key Concepts

6.1.1.1.1 Mixed Traffic

With a few exceptions, traffic on the network is mixed, i.e., passenger and freight traffic use the same tracks. The differences between the two types of traffic pose significant challenges for capacity-optimised planning of the infrastructure. **[**SPT3TMS-9303 **]**

The acceleration, braking and uphill driving behaviour (dynamic driving behaviour) of passenger and freight trains is very different. In addition, passenger trains usually have significantly more stops. In order to avoid mutual conflicts, overtaking at suitable points must be planned and longer reserve times between trains of different types must be provided. **[**SPT3TMS-9301 **]**

Most passenger train runs are regular and known well in advance. The definitive assignment of a freight slot with a specific train, on the other hand, often only occurs at short notice. Slot-determining train parameters such as length, weight, etc. are often only available late or must be adjusted. This circumstance means that the slots for freight traffic must be designed with greater flexibility, e.g., margins. **[**SPT3TMS-9299 **]**

Matching planned arrival and departure times at every stop to the minute is of great importance in passenger transport. This applies where connections with other trains must be secured. Freight trains, on the other hand, often only have time specifications for the start and finish. These key points are often flexible even within a time frame. Many trains in freight traffic are international. Due to the significantly longer running distances the actual behaviour of the trains depends more on the planning. The behaviour of a passenger train is quite predictable and varies little from day to day. The dynamic driving behaviour of a freight train, on the other hand, depends on the load and length. Even freight trains that run regularly therefore have significant travel time fluctuations. In addition, loading and length are usually not known at the time of planning. For this reason, the slots prepared for freight traffic must be contain a larger bandwidth, which can be adapted to the actual circumstances at short notice if necessary. The traffic peaks of passenger and freight traffic are in the off-peak times, in the morning and in the evening, so that the maximum network utilisation add up. Otherwise, passenger traffic is mostly carried out during the day and freight traffic at night. **[**SPT3TMS-9297 **]**

6.1.1.1.2 Timetable and Capacity Plan

In connection with planning activities, two perspectives can be distinguished:

1. From the point of view of the end customer (in passenger transport: passenger, in freight transport: e.g., freight forwarder) the timetable is of interest. The timetable contains the published arrival and departure times of trains as they can be found for passenger transport, e.g., in the online timetable and on notices.
2. Reservations of capacity, which are required, among other things, to implement the trains in the timetable, but also for service trains, operational activities, construction works and maintenance or orders that are still to be expected, can be found in the capacity plan. The times specified in the timetable and train path plan may deviate from one another, e.g., because the capacity plan uses a higher time temporal accuracy is worked. The capacity plan is accurate to the track.

[SPT3TMS-9308 **]**

Information on which operations are to be carried out on the infrastructure side to implement the planned train journeys can be found in the capacity plan as well. The capacity plan

- refines the slots in terms of time by providing speed profiles for path sections,
- adds supplements to capacity plan with information on the required work steps (e.g., provision of a train, change of locomotive) and resources (e.g., staff, water).

[SPT3TMS-9216 **]**

Beyond these primary levels of planning, the capacity plan must contain accompanying information. For example, services be provided by other ROCs. Such activities must be considered during planning, even if the infrastructure manager is not responsible for carrying them out. Further information required for the production is e.g., information about provision plans, change of traction (locomotive), change of train crew, etc. **[**SPT3TMS-9215 **]**

6.1.1.1.3 Planning at ROCs

Planning at ROCs entails distinctive processes for passenger and freight transport, characterized by differing slot requests and orders:

6.1.1.1.3.1 Passenger ROCs

For passenger transport, ROCs typically embark on concrete train planning and corresponding train path orders at least 14 months before the timetable change. For international traffic, planning begins in January for the December timetable change. International trains are typically designed over a period of several years before translating into detailed planning. **[**SPT3TMS-8528 **]**

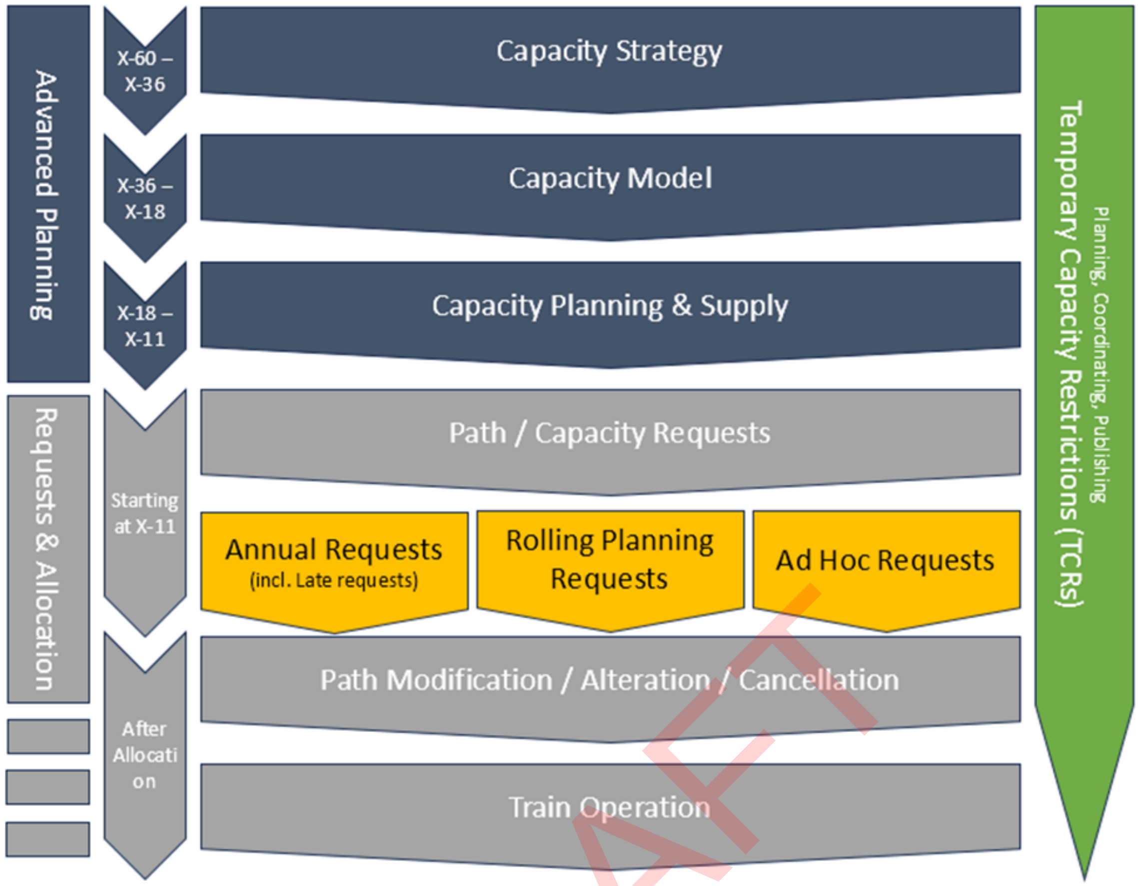
Once a slot has been ordered, ROCs work on the detailed planning of its production, including planning of rotations for wagons (rolling stock), locomotives (traction) and crew. This can result in requests for changes to already-requested slots, necessitating adjustments by the infrastructure. **[**SPT3TMS-8529 **]**

6.1.1.1.3.2 Freight ROCs

Freight traffic involves a more dynamic approach, where slots ordered in advance undergo adaptations within the timetable period. In this context, the term "rolling planning" is often used. ROCs develop a concept based on empirical data that they subsequently submit to RIMs as requests. At the time when the slot is requested by the ROC, precise information on the weight, length and traction of the train is usually unavailable. In addition to planning the rolling stock, traction, and crew, freight ROCs emphasise the planning of groups of wagons, their coupling up and separation is of great importance. These plans may have an impact on slots that have already been requested. **[**SPT3TMS-8531 **]**

6.1.1.1.4 Planning at RIMS

A future Capacity Management System, in terms of capacity planning, will support the following steps:



[SPT3TMS-8533 **]**

Figure 13: Capacity Planning Key Steps

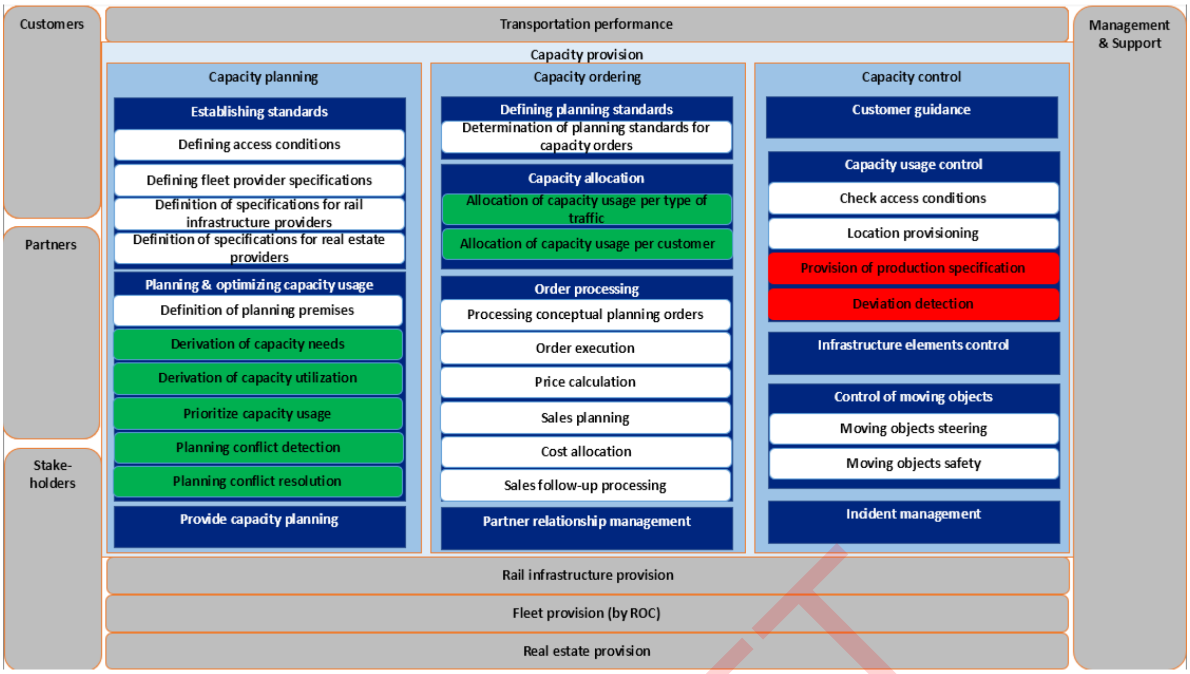
- Advanced planning:
  - Capacity Strategy (X-60 to X-36)
  - Capacity Model (X-36 to X-18)
  - Capacity Supply (X-18 to X-11)
- TCRs (X-60X + (X-60 to X+12))
- Timetabling:
  - Path/request (timetable planning, rolling planning, ad-hoc planning) - different timelines depending on the type of product (from X-11 to X+12)
  - Path/capacity allocation (timetable planning, rolling planning, ad-hoc planning)
  - Path modification/alteration/cancellation/optimisation – post-allocation

[SPT3TMS-8534 **]**

X=day of the timetable change **[**SPT3TMS-8535 **]**

6.1.2 CMS Functional Capabilities

CMS & TMS are both involved in processes for capacity planning and production along with a higher integration of CMS & TMS for planning with other systems. Capacity planning is divided into different domains e.g., conceptional and short-term planning and long-term strategical planning to produce train paths. [SPT3TMS-9222]



[SPT3TMS-8537]

Figure 14: Components of the Enterprise Architecture Of Railway System

For illustration purposes only, Figure 13 shows the business capabilities of RIM. Capabilities related to Capacity planning are shown in green and Real-Time TMS ones in red. As shown in Figure 14, capacity planning supports the design of an operational plan. [SPT3TMS-8538]

- Knowing the short-, medium- and long-term construction requirements and clustering the work for expansion, renewal, and maintenance works across the board in a way that may be implemented in a cost-efficient manner, taking into consideration construction works planning as defined in advance. This enables RIM to consider any capacity restriction in its planning and reflect it accordingly in the executed operational plan.
- CMS aims to increase schedule stability beyond the network boundaries and to increase robustness. The ability to differentiate punctuality targets on a route-specific basis depending on the influence on network stability and customer punctuality must be incorporated into planning. In addition, it will be possible in the future to schedule the planned travel time reserves on a situation-specific basis (in deviation from today's linearly scheduled travel time reserves). This more detailed depth of planning will increase planning accuracy. Data-based analyses and intelligent self-learning systems capable of measuring the quality of rail operations systematically and consistently and serve as a basis for improvement management in the overall process, should also be incorporated.
- Ability to plan path (slot), capacities to processing end-to-end automated/ highly automated, integrated planning across all time horizons and all objects (train and shunting movements, stabling, intervals). Optimised planning with capacity gain for demand-oriented requirements.

[SPT3TMS-9221]

Planning infrastructure usage is a crucial element in the planning phase, it is included in the annual capacity plan. The aim is to work out solutions for capacity needs and alternative scenarios, and to evaluate and adapt solution proposals from the system whenever a deviation is detected. Infrastructure usage should be free from conflicts as much as possible (should aim for 100%) to ensure smooth operations. The stakeholders performing planning must be responsible for evaluating the plan, being aware of any unavailability, developing an optimal plan, communicating the information in a timely manner, and informing the right departments of any conflicts that might occur or affect the infrastructure. **[**SPT3TMS-9220 **]**

Next to a capacity usage by trains, construction works are designed, ordered, planned, and communicated and must be requested as early as possible, so that CMS can plan capacity accordingly, and TMS can dispatch accordingly. Based on the analysis, alternative concepts are constructed, and logistic capacities are determined and ordered. The communication component serves to ensure the implementation of operational arrangement for construction such as temporary speed restrictions (TSR) or possessions. **[**SPT3TMS-9218 **]**

6.1.2.1 Long-Term Capacity Planning

The planning of infrastructure usage is the focus of the capacity planning system. This include finding slots, checking for conflicts, and solving conflicts. This procedure is in general the same for all time horizons, but the level of detail (e.g., topology) can be less exact at early stages. Additionally, the completeness raises from one planning period to the next. **[**SPT3TMS-9230 **]**

6.1.2.2 Short-Term and Very Short-Term (VSTP) Capacity Planning

The planning of daily infrastructure usage is the focus of the very short-term (24 hours) capacity planning. The capacity plan includes the plan for traffic and construction works for the next 24 hours and may include the design of alternative concepts. The capacity plan reveals open capacity or reserves previously kept available for secure traffic flow. It considers incidents which happens before production starts such as infrastructure possession changes, capacity changes, etc. Similar to a long-term infrastructure planning effort, a short-term one is conducted on daily basis to ensure smooth operations and an organised timetable. Also, alternative scenarios may be accompanied as part of the daily plan. The requirements must be checked every day for completeness, contradictions, and conflicts should be identified and assessed. The plan should be adjusted if necessary, according to the inputs and sent to stakeholders for approval and reflection in the timetable. **[**SPT3TMS-9228 **]**

6.1.2.2.1 VSTP Dimensions (Timelines)

The CMS must continuously incorporate planned train paths/slots from the annual capacity plan/ interim plan, 6 hours before departure or as per provision (earlier time point prevailing), with the following data:

- Reserves, travel time supplements
- Arrival and departure times
- Starting and ending states
- Relevant route(s) to be taken
- Stopping patterns
- Train dynamic data, load and length of the expected rolling stock
- Node behaviour, including required service facilities/services (e.g., shunting)

[SPT3TMS-9226 **]**

6.1.2.2.2 VSTP Slot-Specific Infrastructure for Orders

If the train path/slot is not provided with slot-specific information but as a sequence of locations, the CMS must calculate a complete track-specific route. The calculation must consider the up-to-date infrastructure (see master data). **[**SPT3TMS-9224 **]**

6.1.2.2.3 VSTP Receipt and processing of Ad-Hoc Orders

In addition to incorporating the annual timetable/interim network timetable, CMS must also incorporate and process ad-hoc orders from the order management system to create a timetable and provide it to the timetable manager. CMS allows the timetable manager to modify and supplement this data, if it does not concern train technical data. **[**SPT3TMS-9237 **]**

Orders are automatically transferred from the order management system to CMS. CMS has an order management function for this purpose. The order is automatically assigned to the respective timetable manager based on business rules defined and managed by the CMS administrator.
When orders are received, the contact details (ROC, requester, email, telephone number) of the ordering entity must be provided. CMS enables verification processes to ensure the correctness of the data according to the defined business rules. Communication with the order management system is workflow-driven and traceable. **[**SPT3TMS-9236 **]**

6.1.2.3 Slot and Path Construction

The attributes of a slot include various points in time and periods. When it comes to arrival and departure times, operational and published (commercial) times can be distinguished. Operational may vary per day. The published ones are usually fixed within a timetable period. The operational times are calculated by the sectional run time calculator, considering any margins. The published times are calculated manually or automatically according to a formula, as times. Published and operational time can be coupled or independent of each other. If necessary, further time specifications in the capacity plan, such as provision time are required. **[**SPT3TMS-9235 **]**

Similar differences apply to run times. A distinction must be made here at least between a technical run time, i.e. the minimum period of time that a specific train composition requires on a defined topology, and a planned travel time. The planned travel time is based on the technical, calculated run time, which has been modified by margins. In addition to general margins, to depict fluctuations of traction, engine driver, weather, etc., margins can be allocated e.g., for construction sites or other special features. Additional margins are required for the departure process, among other things. Margins are defined as percentage or absolute surcharges in minutes. Margins can be set at any operational point within a path or in between two operational points. **[**SPT3TMS-9244 **]**

CMS enables:

- Detailed and realistic construction of slots (station and track) with allowed conflicts according to corresponding business rules.
- Detection of transitional conflicts between areas managed by route managers.
- Conflict detection for infrastructure limitations (e.g., line closures, service rest times, maintenance windows, construction works, track occupancy, train parameters).

- Optimisation of train routes based on energy principles. CMS provides the capability to implement energy-optimised travel time calculation, where reserves are distributed in an energy-optimised manner and the vmax (maximum speed) is reduced, while arrival and departure times remain unchanged (optional).

[SPT3TMS-9243 **]**

6.1.2.3.1 Interactive Editing

CMS allows for interactive editing of routes in graphical or tabular form.

- Can display train routes in time-distance line diagrams. Users can adjust train routes in a time-distance line diagram using drag and drop. Users can initiate the editing of a train route from the time-distance line diagram.
- Allows the setting of fixed points for train route editing.
- Can complete a non-conflict-free train route and subsequently treating it as a conflict-free train route.
- Using a graphical user interface (GUI), all orders for ad-hoc changes/deviations can be interactively edited. Therefore, CMS must provide compact and clear representations.
- For enhanced visual overview and usability, CMS offers various interactive chart types/ graphics. The charts provide the following capabilities:

[SPT3TMS-9241 **]**

  - General editing options for the charts.
  - Scaling of graphics (zooming).
  - Activating and deactivating trains.
  - Editing trains.
  - Creating trains.
  - Exporting trains.
  - Importing trains.
  - Marking trains.
  - Following a preceding train.
  - Checking compatibility of trains.
  - Moving train sections.
  - Comparing trains.
  - Managing train stops (reasons for stopping).
  - Managing train classes and train class groups.
  - Moving or copying train numbers in the graphic.
  - Managing reserves according to business rules.
  - Editability of stops and arrival/departure times.
  - Displaying technical travel time and train-specific data provided by the TOC in the train schedule table.

[SPT3TMS-9239 **]**

6.1.2.3.1.1 Train Graph (Time-Distance Line Diagram)

CMS can display train routes in a train graph (time-distance line diagram). Users can adjust train routes using drag and drop and can initiate the editing of a train route from this HMI component.
[SPT3TMS-9251 **]**

6.1.2.3.1.2 Station Representations

CMS offers the following representations of a station:

- Schematic track representation
- Track occupancy plan
- Arrival and departure table

[SPT3TMS-9249 **]**

In these representations, the user can see the train number and the direction of departure, among other details. The user can modify the track occupancy of train routes in the graphical representation. Filters can be applied by the user to simplify the display (including operating days, calendar days, tracks, availabilities, operational restrictions, operating times). These graphical representations can be printed without any loss of information (e.g., for meetings). These visual representations provide the operations manager with all the necessary information and capabilities to assess feasibility. Routes using drag and drop and can initiate the editing of a train route from this HMI component. **[**SPT3TMS-9247 **]**

6.1.2.3.2 Automatic, System-Driven Path Construction

Based on the train parameters provided through order management system requests, CMS constructs a train path and assigns it to the requester.CMS has predefined and customisable business rules for conflict-free train path/slotting construction and customer compatibility, such as: **[**SPT3TMS-9266 **]**

- Minimum average speed
- Predefined paths for capacity reasons
- Allowed conflicts and types of conflicts

[SPT3TMS-9265 **]**

CMS also allows for the definition of business rules that restrict automatic system-driven timetable construction. **[**SPT3TMS-9264 **]**

CMS supports automatic train route search while considering business rules (e.g., "freight trains with ETCS over a new route"). **[**SPT3TMS-9263 **]**

6.1.2.4 Construction & Maintenance Planning

Railway capacity planning consists of the important areas of works- & construction planning and maintenance planning. Both planning tasks are leading to a certain unavailability of infrastructure. The difference between construction & maintenance planning is not very precise and handled in various ways at European infrastructure managers.

- Works- & construction planning covers a longer time horizon, dealing with the renewal of substantial parts of the infrastructure, like bridges or tunnels or building new infrastructure. Construction planning is done months to years in advance and the resulting infrastructure restrictions are lasting over a long period, from some months to a few years.
- Maintenance planning is a short-term approach, driven mainly by status of the fixed assets like switches or tracks. Furthermore, maintenance task beside the track, e.g. cutting bushes and trees, are part of works- & maintenance planning. The resulting infrastructure restrictions are lasting typically over a shorter period, from some hours to a few days.

As a result of these plannings, infrastructure becomes unavailable or restricted. Sections of temporarily unavailable tracks are called *possessions,* in the future usage restrictions areas (URA). This covers also e.g. temporarily speed restrictions. URA are consuming capacity, and they are stored in the capacity plan.

If works takes place on the infrastructure, typically performed by people, rail traffic is still operated beside the construction side. To avoid incidents or hazards to the workers, warning areas are established as a part of the construction & maintenance planning process. Warning areas are consuming capacity, and they are stored in the capacity plan.
[SPT3TMS-15704 **]**

6.1.2.5 Technical (minimal) Run Times and Run Time Calculation

Based on the precise path and dynamic characteristics of the train, CMS must perform a travel time calculation for each train and repeat it when parameters change. The technical run time is the minimum run time between two points, considering the rolling stock, traction and topological parameters without adding any margins. **[**SPT3TMS-9273 **]**

6.1.2.6 Margins

This includes all types of surcharges in the form of percentages or absolute values. Several margins are defined with a typification for each operating point. Several different margins can be defined and added to a location. An operating point can be any topology element. Typical margins are:

- Margins to cover the normal volatility caused by different actors. (Different train drivers, fluctuating passenger numbers)
- Additions and deductions due to special circumstances or experience, e.g., for crossing, overtaking, merging periods or similar.
- General surcharges to consider, for example, different weather conditions that affect driving behaviour or visibility.

Process-related margins, such as the train departure preparation time, which always comes into play when a train has a stopover in a station and its onward journey picks up. The train departure preparation time is the period between the last possible boarding time (closing of the doors) and the time when the train starts moving. **[**SPT3TMS-9271 **]**

6.1.2.7 Checks for Conflicts

CMS continuously checks each train route for conflicts
When constructing a capacity plan, numerous requirements must be observed e.g., from the physical and geographical conditions, but also from the request of the ROCs and the processes in the operating locations. In addition to optimisation goals (e.g., minimum driving times and minimum energy consumption, maximum capacity, and stability), is a multitude of differently prioritised conditions to comply with.
As a rule, not all conditions can be met - especially not the first one work step. The creation of a route plan is rather gradual, whereby existing conflicts are eliminated step by step or - if not otherwise possible – consciously be accepted. A planning conflict always exists when the capacity plan in production (from a physical, security, operational or commercial reason) cannot, may or should not be implemented. This definition already becomes evident that there are very different types of conflicts.
Efficiently assist the planner in discovering, prioritising, and eliminating conflicts is one of the most important tasks of the capacity planning system. **[**SPT3TMS-9368 **]**

6.1.2.7.1 Run time conflicts

If there is a run time conflict, the plan cannot be implemented due to the dynamic properties of the train or existing speed limits leading to longer run times than planned. **[**SPT3TMS-9367 **]**

6.1.2.7.2 Path Conflicts

In the event of a path conflict, the signalling system or the safety level does not allow a planned constellation at all or not in the planned time frame. Path conflicts usually result from the simultaneous or consecutive occupancy of the same or adjacent track elements by several trains. **[**SPT3TMS-9370 **]**

This includes the following cases:

6.1.2.7.2.1 Crossing conflict

Two trains running in opposite directions meet at a point where they cannot pass each other (= "cross") because it is not possible to switch to a suitable siding. A special case is when there is a siding that is too short for both trains. **[**SPT3TMS-9369 **]**

6.1.2.7.2.2 Overtaking conflict

A planned overtaking is not possible because it is not possible to switch to a suitable overtaking or siding track at the point in question. A special case is when such a track is available but is too short for the overtaking manoeuvre. **[**SPT3TMS-9364 **]**

6.1.2.7.2.3 Headway conflict

A train cannot meet the planned travel times because track elements are occupied by a slower train ahead. **[**SPT3TMS-9363 **]**

6.1.2.7.2.4 Junction conflict

In a junction, turning onto a path cannot be realised as planned, since a track to be crossed is occupied by another train (usually: oncoming traffic). **[**SPT3TMS-9366 **]**

6.1.2.7.2.5 Joining conflict

In a junction, it is not possible to turn onto a path as planned because the track is already being occupied by a train coming from another direction. **[**SPT3TMS-9365 **]**

6.1.2.7.2.6 Station entry and exit conflicts

In a station, an entry or exit cannot be implemented as planned because it crosses or overlaps with the entry or exit path of another train. **[**SPT3TMS-9378 **]**

6.1.2.7.2.7 Other path exclusions

For reasons other than those already mentioned, the safety level prevents two paths from being set up simultaneously as planned. This includes e.g., flank protection or slip routes that are too short. **[**SPT3TMS-9387 **]**

6.1.2.7.2.8 Train capability conflicts

A train capability conflict occurs when a train is not allowed to run on a planned track element due to its specific properties (weight, height, or width profile). The following cases are possible:

- Simple profile or weight conflict: The single train only exceeds a permissible weight (e.g., on a bridge) or profile (e.g., in a tunnel).
- Profile or weight conflict at encounter: Driving on the track section is permitted for the given weight or profile, but it must not encroach other trains.
- Meeting of two trains that are too wide or too heavy: Driving on the track section is permitted for the given weight or profile, but there must be no encounters with other trains that are too wide or too heavy.

[SPT3TMS-9384 **]**

6.1.2.7.3 Operational Conflicts

An operational conflict exists when a slot cannot or may not be implemented due to specific operational requirements. Causes can be, for example: **[**SPT3TMS-9381 **]**

6.1.2.7.3.1 Violation of track occupancy requirements

For a specific operation (e.g., filling up water, changing locomotives, attaching wagons, moving the train at its destination), restrictions regarding the permitted track occupancy are not observed. **[**SPT3TMS-9379 **]**

6.1.2.7.3.2 Insufficient length of stay

A minimum duration for a specific operation (these often depend on local conditions) is not considered in the capacity plan. **[**SPT3TMS-9399 **]**

6.1.2.7.3.3 Insufficient platform length

Boarding of passengers is scheduled on a track without a platform or with a platform that is too short. **[**SPT3TMS-9396 **]**

6.1.2.7.3.4 Level access

At stations with level access to the platform, entry or transit of a train takes place on a track that can be crossed by passengers at this time. **[**SPT3TMS-9393 **]**

6.1.2.7.3.5 Unsuitable stopping place

Trains are stopped in a not fitting place. In the case of heavy freight trains, for example, stopping during a climb must be avoided. **[**SPT3TMS-9390 **]**

6.1.2.7.3.6 Violation of order requirements

Requirements for the sequence order in which trains arrive at a station (e.g., when trains are joined or if they are to stop one after the other on the same platform) are violated. **[**SPT3TMS-9403 **]**

6.1.2.7.4 Commercial Conflicts

A commercial conflict exists when the requirements of the ROC for the slot are not met. This includes the following cases: **[**SPT3TMS-9402 **]**

6.1.2.7.4.1 Timing Deviations

Time specifications with regard to e.g., arrival or departure time (these are made either to the minute or in the form of a time window when ordering) are not met. It is also possible that specified minimum lengths of stopover or the maximum permissible run time are violated. **[**SPT3TMS-9409 **]**

6.1.2.7.4.2 Connection conflicts

Specifications regarding connections to be maintained and the minimum transfer times to be considered are violated. Connection conditions can either be specified explicitly or they are determined as "implicit connections" from the arrival times of the other trains. **[**SPT3TMS-9419 **]**

6.1.2.7.4.3 Circulation conflicts

Specifications of the ordering ROCs regarding the further use of the rolling stock at the destination are not complied with. **[**SPT3TMS-9416 **]**

6.1.2.7.4.4 Violation of other specifications

In addition to the specifications already mentioned, other agreements can be made with the ordering ROC (e.g., track specifications in stations or specific operations at specific operating points). Also, the mismatch of such agreements constitute a conflict. **[**SPT3TMS-9413 **]**

6.1.2.7.5 Check on Non-Standard Shipments

CMS considers the associated infrastructure constraints when constructing routes for trains carrying non-standard shipments, such as the compatibility of the infrastructure with non-standard train parameters like axle load or loading gauge.
The following distinctions apply to routes serving the transportation of extraordinary shipments:

- A route with an assigned profile (identified by the profile number) is valid for the entire timetable period. The different profiles are published in a profile catalogue. Profiles are already considered during the route construction for the network timetable (including change supplements).
- A single transport authorisation for shipments is valid for routes within a specific period and for a specific ROC. A non-standard shipment number is assigned when a non-standard shipment cannot be classified into a profile by the ROC. Requirements from single transport authorisations must be considered in change supplements and for ad-hoc traffic routes.
- A route with a single transport authorisation for an extraordinary shipment is required when:
  - There is an exceedance of the loading gauge or axle and meter load, or vehicles with restricted vehicle approval are to be transported.
  - The loading gauge is the clearance around the train that must remain free. The loading gauge is a specification - tunnel walls or signals, for example, must not encroach on the loading gauge. If a vehicle or cargo extends into the loading gauge, it is considered an non-standard shipment. An extraordinary shipment may require additional measures, such as reducing speed or prohibiting certain tracks.
    - Permissible axle and meter loads are the basis for load exceedances and are defined in the UIC track classes. If the actual load exceeds the permissible load according to the track class, additional measures (transport conditions) may be required, such as reducing speed or prohibiting certain tracks.

[SPT3TMS-9410 **]**

The ordering of a route for a train with a non-standard shipment is done by the requester in the order management system. CMS retrieves the profile data from the order.
When constructing routes for route orders that involve the transportation of a train with profile requirements or a non-standard shipment, the transport conditions for the timetable must be strictly

considered. A train can be assigned multiple profiles - for example, because each wagon/load/vehicle causes different transport conditions. In that case, the route construction must consider all the transport conditions of the individual profiles.
For example, the following transport conditions may be relevant for route construction:

- Track prohibitions
- Speed restrictions
- Meeting restrictions

Required stops (e.g., load transpositions) **[**SPT3TMS-9431 **]**

6.1.2.7.6 Feasibility Check

CMS determines a physical part of the infrastructure (track segment) to be used in each operating location (according to predefined business rules and considering conflicts, cf. below).
For each stop, CMS performs a conflict check and, if necessary, requests a feasibility check (according to and considering business rules). The result of a feasibility check can be:

- Approval of CMS's suggestion
- Alternative possession: Time deviations can be accommodated within standard scheduling reserves, but actual travel times must not change (if there is a timing deviation that exceeds the reserve, confirmation is required)
- Rejection - in this case, planner must re-construct the plan

For each operating location, the following is defined:

- A responsible person for confirming track occupancy (feasibility check)
- Business rules for which CMS requests a feasibility check from the responsible person.

[SPT3TMS-9428 **]**

6.1.2.8 Temporal Validity of Slots

Each train path / slot has a validity period (from, to).
Within the validity period, each train route may have an optional timetable validity (from, to) - during this period, the train route is a regular train and is included in a timetable update. Outside the timetable validity period, the train route is considered a special train. **[**SPT3TMS-9425 **]**

6.1.2.9 Variants

CMS allows for the creation and management of different slot variants. **[**SPT3TMS-9422 **]**

6.1.3 CMS System Interfaces

CMS has interfaces to Systems for production in passenger and freight transport, customer information, construction work and maintenance. The exchange of information and data flows in both ways. One of the goals for CMS is enhanced support for short-term planning of train paths in coordination with known possessions, temporary speed restrictions, and scenario management for variants evaluation.
[SPT3TMS-9434 **]**

On a European level, the ordering of capacity usage is an interaction between different actors and systems. A capacity request is formally processed by RailNetEurope (RNE) or local RIM, capacity planning adds the request to the current planning timetable and works out the capacity implications and needs. Having received the result from capacity planning, CRM can create an offer and RNE or local RIM is able to formally approve. RNE or local RIM issues capacity offer, which the applicant may accept, reject, or for which they may request alternative offers. In case of acceptance, RNE or local RIM allocates the capacity to the applicant. Order conflicts are solved by either RNE or local RIM. **[**SPT3TMS-9314 **]**

6.1.3.1 Inbound System Interfaces

6.1.3.1.1 Import from Slot Construction System

CMS imports planned slots from the slot construction system in regular intervals. **[**SPT3TMS-9313 **]**

6.1.3.1.2 Import of New Slot Orders / Ad-Hoc Slot Requests

CMS regularly imports short-term orders (ad-hoc traffic) and new slot orders from the slot ordering system. **[**SPT3TMS-9324 **]**

6.1.3.1.3 Master Data Import

CMS regularly imports master data required to complete its planning process, including:

- Track sections
- Stations
- Customers
- ROCs
- Other relevant RIMs
- Train classes
- Non-operating times (periods when stations are not staffed)
- Planning master data
- Etc.

[SPT3TMS-9321 **]**

6.1.3.2 Outbound System Interfaces

6.1.3.2.1 Capacity Plan Export to TMS

After the calculation of the current/daily capacity plan, the current capacity plan per train is sent to the TMS. CMS only transmits a new capacity plan if it has been changed through merging. **[**SPT3TMS-9318 **]**

6.1.3.2.2 Capacity Plan Export to ROC

After the calculation of the current capacity plan, the plan per train is sent to the ROC (and/or the Driver Advisory System of the locomotive). CMS only transmits a new capacity plan if it has been changed through merging. **[**SPT3TMS-9315 **]**

6.1.3.2.3 Export Billing Data

Billing-related changes (e.g., slot modifications) are transferred to the billing system. No further CMSs are required by CMS to perform invoicing for capacity usage. **[**SPT3TMS-9336 **]**

6.2 Capacity Production (Real-Time TMS (Dispatching))

The capacity production system is called TMS and is designed to create an operational plan that includes all infrastructure usage for all trains, including cross-border trains, that:

- Fulfils customer needs in an optimised way
- Is executable / feasible,
- Adjustable during production by means of dispatching to solve production problems.

[SPT3TMS-9333 **]**

The operational plan describes in detail all types of track usage (train movements, stabling, construction sites, usage restriction areas, alternative corridor slots, etc.). It does not include other resources or process management areas (train start-up processes, driver staff management, construction processes, etc.). Capacity usage may be based on external requests from infrastructure users or from conflict solution. The operational plan may include all types of track usage (trains, train units, shunting, construction, maintenance, obstacles within the track perimeter, etc.). It is a rolling plan starting at the time of production and is updated frequently during the train run. **[**SPT3TMS-9327 **]**

Planned capacity usages are modelled with the level of detail available and necessary at the time of planning. The dispatching function should be automated whenever it is feasible and desirable and shall ensure that dispatching actions adhere to defined solution assessment criteria. At a minimum, it must be capable of creating conflict solutions that may be selected and optimised by a (human) dispatcher. **[**SPT3TMS-9345 **]**

- Key features of this business service include:
  - Visualisation of the planned and actual traffic status,
  - Forecasting of the expected traffic situation,
  - Detection and solution of conflicts.

[SPT3TMS-9344 **]**

Based on the design of an integrated communication network linking all services and the integration of “new” information e. g. weather, asset status, etc., a significant increase in the robustness of the operational plan might be achieved. **[**SPT3TMS-9343 **]**

TMS allows centralised supervision and management of the entire rail network and traffic. **[**SPT3TMS-9352 **]**

The main functionalities needed for traffic management (dispatching) are the following: **[**SPT3TMS-10207 **]**

- Train tracking (mapping train positions to operational plan),
- Visualisation tools for:
  - Train positions, e.g., by describer messages,
  - Train Time Graph (TG),
  - Other Infrastructure-, train- and asset-status,
- Dispatching, with these:
  - Decisions:
    - Change of route,
    - Change of track,
    - Change of platform,
    - Change of arrival time,
    - Change of departure time,
    - Change of driving strategy,
  - Changes of products:
    - Cancellation of a train, or part of it
    - Extra train,

    - Redirection / bypass,
    - Change of connections,
    - Skip a stop
    - Train deactivation (removing a train temporarily from the forecast calculations until it is reactivated and hence included again in the forecast calculations)
    - Change of train sequence
    - Change of resource allocation (rolling stock),

- Conflict detection and solution for the future traffic,
- Traffic forecasting including sectional run time calculation to update the operational plan based on current positions of trains, availability of assets and mutual influence of trains.

[SPT3TMS-9350 **]**

6.3 Functional Capabilities

6.3.1 Deviation Detection

A deviation is a difference between the plan and the current operational state of traffic (as shown by real-time data). The difference between a forecast and the plan is called a RT- conflict, see below for details. The deviation detection compares the current operational state (precise train and infrastructure status data) with the operational plan. If a predicted (or unpredicted) conflict becomes real, it is a deviation and may not be avoided by applying a conflict solution anymore. For each deviation, a root cause should be (automatically) recorded by TMS. **[**SPT3TMS-9331 **]**

6.3.2 Conflict Detection

A necessary precondition for conflict detection and solution is forecasting train runs by calculating the future traffic flow based on the current operational state (precise train and infrastructure status data), dispatching decisions made, and the latest version of the operational plan. The conflict detection function detects planned moves that are not possible to make (within tolerance thresholds). A conflict occurs e.g., when two trains try to use the same resource, or two incompatible resources, at the same time, or when a difference between forecast and plan is detected for a single train. **[**SPT3TMS-9328 **]**

Typical conflicts are:

- Headway conflict,
- Track usage and platform conflict,
- Circulation conflict,
- Connection conflict,
- Shunting conflict,
- Exceptional consignment transport conflict

[SPT3TMS-9325 **]**

Predicted traffic conflicts (difference between plan and forecast) are identified automatically, registered, and shown to the dispatcher via TMS's graphical User Interface (GUI). in real-time. **[**SPT3TMS-9322 **]**

6.3.3 Conflict Solution

Conflict detection triggers a solution process (manual or automatic). "Solving" a conflict is to define a single measure (dispatching action) or a set of measures applying to single train or various trains. Evaluation algorithms are computing real time KPI impacts (e. g. delay at destination), to support the dispatcher´s decision.
Conflicts may be solved manually from the operator or with the help of automatic tools providing different solutions to solve the detected conflict.
The selected solution will result in a new operational plan based on the measures taken. The new operational plan immediately leads to a new forecast and will be broadcast to the different information consumers. **[**SPT3TMS-9319 **]**

6.3.4 User Interfaces

There are various user interfaces associated with TMS, e.g., the Train Graph, in which dispatchers can see the current situation of the entire rail infrastructure, including real-time train information and a forecast for further train runs, allowing short-term changes in case of abnormal situations and infrastructure unavailability to be made easily.
The time slot displayed may be configured to consist of trains that run in the last few hours, those in circulation and those scheduled to circulate in the coming hours.
The Train Graph is updated dynamically as time progresses, recording events received by Traffic Control and representing future states as calculated by forecasting algorithms. This can include planned and unplanned abnormal situations, possessions, TSRs and any other useful information, coming from CTC capable of causing a change of the operational plan.((Europe´s, Annex 2 CCS_TMS Systems Architecture: Annex 2 CCS/TMS/CMS Systems Architecture, 2022, p. 20)) **[**SPT3TMS-9316 **]**

6.3.5 Conflict Solution and Incident Impact Management

Conflict solution and incident impact management shall provide information and tools to manage abnormal or emergency situations that impact the traffic such as: nature of the abnormality, location, duration, reasons and involved trains. The information related abnormal/emergency situations may be displayed on the Train Graph (TG).
Operational incident impact management (e.g., for emergency cases, accidents, system failures, etc.) must handle a high complexity of often unstructured information flowing between several different organisations (police, maintenance organisations, …). Information retrieval, and collaboration concerning the planning of interventions is often overstraining operation centres.
The target for incident impact management envisages a high grade of digitally automated communication that allows electronic workflow support with high performance and precision.
The key feature of incident impact management is dispatching support for the use of available capacity.
The targets are:

- To be able to receive and process all production-relevant events (if sources are available) in a very flexible, efficient and effective way,
- To automatically inform all planning partners about the incident impacts,
- An incident is described as infrastructure not being available due to a single root cause. In case of a double track section the definition applies if one track or both are not available for the traffic and the line capacity is reduced,
- Typically, incident impact management is part of the Traffic Management procedures but requires intensive communication and data exchange with railway internal and external partners.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 16))

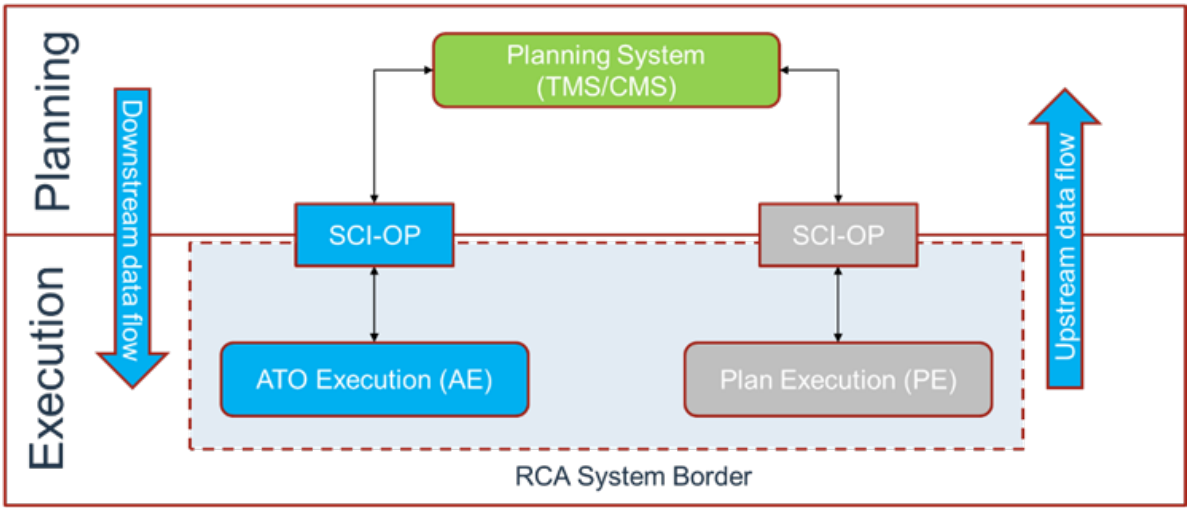
[SPT3TMS-9340 **]**

6.3.6 Delay Justification

A delay justification is issued by the RIM to the contracted ROC as soon as reasonably possible to provide the cause of any delay in a train's journey. Causes provided may include factors driven by the RIM (e.g., various types of infrastructure technical defects, construction works), ROC (e.g., technical defects pertaining to rolling stock, personnel) and external third party (e.g., persons on tracks, inclement weather).
A delay must correspond to exactly one delay justification, though TMS may update the information originally provided as additional insights are being gained. TMS must be capable of interfacing with ROC systems and provide both the original delay justification as well as any later changes. **[**SPT3TMS-9339 **]**

6.3.7 Automatic Train Operation Execution (Wayside)

The following Figure 15 shows the connections from ATO Execution (AE) to TMS/CMS, also the ways of data flow.



[SPT3TMS-9310 **]**

Figure 15: ATO Execution map

ATO Execution (AE) contributes to the Automatic Train Operation as a part of the capacity layer. ATO Execution receives data as specified in SCI-OP (Standard Communication Interface Operational Plan) regarding the operational plan execution and operating state messages / commands. Conflicts and mutual influences between trains are solved by TMS. **[**SPT3TMS-9432 **]**

The functionality of ATO includes:

- Generation of Journey profiles,
- Provision of Segment Profiles,

[SPT3TMS-9429 **]**

The ATO Execution system interacts with TMS in real-time, receives operational plan information, monitors changes, and creates Journey Profiles (JP) for the train services to be executed in ATO mode. TMS creates a Train Path Envelope (TPE) containing the timing points in which trains should path through, and update it whenever there is a change. TMS shares the TPE via SCI-OP. **[**SPT3TMS-9426 **]**

6.3.8 Incident Impact Management

TMS is capable of recording operational incidents with a temporary impact on network capacity, both in the case of complete infrastructure unavailability and in that of temporary limitations (e.g., speed restrictions). To be able to effectively support its users in managing the impact of any incident upon traffic, TMS will need to record information relevant to its ability to correctly predict and mitigate the incident’s impact upon the production plan such as: **[**SPT3TMS-9423 **]**

- Location of the incident (including the wider impacted area, if applicable)
- Affected assets or train, if applicable
- Nature of any limitations and/or (un-)availability of network infrastructure
- Any constraints that may apply in the case of partial availability (e.g., speed, weight, …)
- Start time and duration (if known) of any capacity limitations.
- Etc.

[SPT3TMS-9420 **]**

On the basis of this information, TMS must be capable of recording any limitations in infrastructure availability that result out of the incident and must be capable of adding these to its model in real time. Furthermore, TMS must be capable of displaying any limitations and affected areas to its users in an intuitive, instantly recognisable fashion and must further allow them to access more detailed information on the nature of the situation on demand.
Based on incident data, TMS is capable of automatically determining the impact incident triggered restrictions have on both current and planned traffic over the affected parts of the infrastructure network

and supporting its user in recognising and managing it. To achieve this, TMS must support the following functionality:

- Detection of conflicts between current or (short-term-) planned traffic and any restrictions triggered by the incident (cf. above)
- Identification of all trains the production plan for whom is affected by incident-related restrictions.

TMS must, once again, be capable of displaying this information to the user in an intuitive manner and must support the user in recognising the exceptional nature of the situation via suitable user interaction design.
TMS supports its users in mitigating the effect of any incident and optimising the usage of the remaining network capacity. It is capable of doing so both ad-hoc and based on pre-defined, scenario-based responses. In order to achieve this, TMS requires the following minimum capabilities:

- The ability to suggest suitable ad-hoc dispatching measures for individual trains, based on TMS' regular conflict resolution and deviation management capabilities (e.g., re-routing, cancellation, partial cancellation, …).
- The ability to automatically implement mitigation measures in bulk via the application of scenario-based response plans (see below)

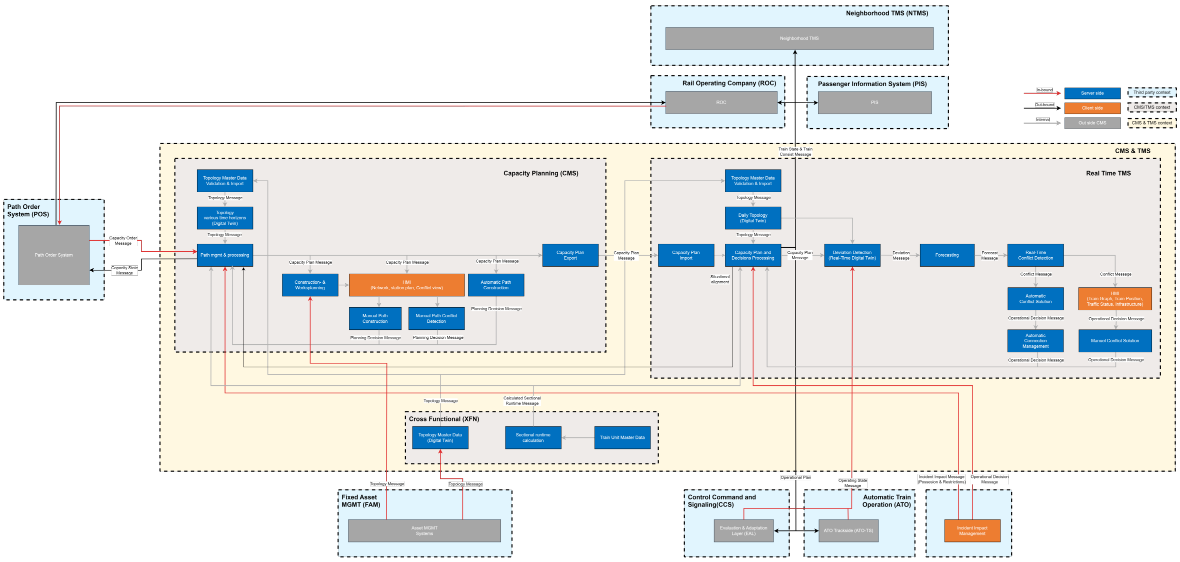
TMS must include the possibility to apply pre-defined bulk measures (e.g., "cancel all trains", or "cancel all local traffic, re-route any long-distance trains") to manage a large amount of train traffic in the affected area effectively. To support this, TMS must support at the very least the following functionality:

- Ability to store user-defined "if-then" style response scenarios of both …
    1. A specific nature (e.g., "if X type of incident occurs in Y location, re-route trains A, B, and C between point 1 and point 2")
    2. Of a more generic nature (e.g., "cancel or stop all trains within a perimeter of 2 km from a user defined location during the next 30 minutes") to especially support in initial emergency response situations.
- Ability to make ad-hoc, user defined changes to pre-defined scenarios (e.g., "play 'Scenario X' – but except train A from its effect so as to leave it for manual management", or "do 'Scenario Y' but extend the pre-defined perimeter as follows …")
- Ability to put pre-defined scenarios into effect with minimal effort for the user. For this purpose, TMS should be capable of deriving, mass-creating, and implementing dispatching measured automatically based on minimum user input.

TMS should ideally include additional functionality that allows not only for the user to select and apply a pre-defined scenario but for TMS itself to suggest suitable response scenarios to its user based on matching criteria such as e.g., the nature and expected duration of the incident and the resulting restrictions, the affected perimeter, etc., and should support users with e.g., response checklists so as to minimise employee workload.
TMS may utilise any available impact duration forecast from the incident management system which contains an estimate of a return to "business as usual". Such an estimate of the expected duration of restrictions may then be used to assist both TMS itself and/or the user in selecting and implementing a suitable response (e.g., to decide the duration, for which a pre-defined scenario should be applied, etc.)
[SPT3TMS-9417 **]**

6.4 Real-Time TMS Architectural Scope

Figure 16 shows the technical components to carry out a conflict free operational plan. Every single second a new operational plan is produced.



[SPT3TMS-10452 **]**

Figure 16: RT-TMS System Architecture

6.4.1 Process Description and Dependencies

Real-Time TMS receives data and information from various sources and systems. With every change of topology, TMS imports a new topology master data. TMS validates the master data against safety rules to generate one single source of truth of correct topology data (TMS Daily Topology). This source provides the virtual description of the infrastructure for the following process steps and is one basis for operational plan and HMI. TMS receives the capacity plan from CMS, performs a compatibility check between the daily topology and capacity plan, taking into account the train calculations from the sectional runtime calculator to evaluate the feasibility of the capacity plan along with any taken decisions affecting the plan and train properties. TMS then converts the capacity plan into operational plan during plan execution (Real-time). The operational plan is sent to stakeholders from network layer to generate information for passengers and ROC companies outside of RT-TMS scope. Sending the operational plan to plan execution (PE) and ATO Execution (both routing layer), carry out automated route settings and train advice for operations. ATO and PE respond back to RT-TMS with the state of operations (possessions, route state, train positions, etc.). Deviation detection compares the operational plan with the current state and record deviations (e.g., delays, wrong platform, etc.). TMS feeds the "Forecasting and RT Conflict Detection" with the deviation report to calculate/ predict the future state of the train run and detect any future conflicts. Based on the forecast and conflicts data, the impact analysis creates proposals containing all possible measures to solve this conflict. Solving the conflicts through dispatching measures is done either automatically where TMS selects a dispatching measure automatically, or using an HMI where a dispatcher gets involved in the solution process depending on the degree of automation. HMI supports the conflict solution by visualising the possible solutions and allowing the dispatcher to select the most appropriate one according to the defined KPIs for each RIM. The selected dispatching measure contributes to the operational plan update and execution. TMS can manage/ mitigate the impact of incidents through the different dispatching measures (single and in bulk) derived from incident impact management. **[**SPT3TMS-9411 **]**

6.4.1.1 Topology Master Data Validation & Import

Checks Master Data/Topology according to safety rules. To ensure high quality Master Data the validation process checks the data against inconsistent and prove it on rightness. **[**SPT3TMS-9435 **]**

6.4.1.2 TMS Daily Topology

Exact physical and topological description of the current state of railway infrastructure on a daily basis. **[**SPT3TMS-9406 **]**

6.4.1.3 Capacity Plan and Decision Processing

TMS receives the Capacity Plan from CMS, the plan should include the track possession and train position along the defined path, available train information and the TCRs which are executed in the form of restriction areas (URAS) and warning areas for the trains for driving style considerations. Restriction areas are generated as part of the TCR planning, they are considered as reference points to any planned restriction on the infrastructure as well as any warning related to speed limitation (a train is passing through a platform in a station where passengers are waiting, and hence reduce the speed), updated whenever there is a change in the restriction (whether is it removed earlier or extended beyond the set date communicated through warning area state message). According to these URAS and/or warning areas, URAS and/ or warning areas are created in order to communicate with TMS and inform the system about the URAS and/ or warning for each section in the Operational Plan. TMS later receives the real-time state of URAS and/ or warning from PE and ATO as part of the communication between TMS and the mentioned systems. These URAS/ warning areas could come from automated systems or manually through HMI. Processing the capacity plan along with the current decisions to generate an updated operational plan. Capacity plan is mapped to daily topology. Sectional runtime is re-calculated for the new operational plan. Every single second a new operational plan will be processed. **[**SPT3TMS-9404 **]**

6.4.1.4 Sectional Runtime Calculation

Every train has a sectional minimal runtime depending on path, vehicle capabilities, rolling stock and driving strategy. Considering these inputs, a minimal runtime calculation for every single can carry out. **[**SPT3TMS-9400 **]**

6.4.1.5 Deviation Detection

- Deviation Detection
Comparing the operational plan with the real-time status to detected operational deviations. Deviations have already happened and may only be mitigated but not solved. **[**SPT3TMS-9397 **]**

6.4.1.6 Real-Time Conflict Detection

- Real-Time Conflict Detection
Determine the difference between the operational plan and the forecast. Conflicts predicted to occur in the future but may be solved before they happen. Conflicts arise from the impact of deviations. **[**SPT3TMS-9394 **]**

6.4.1.7 Human Machine Interface (HMI)

- Human Machine Interface
Graphical component to interact with a user e.g., by train graph. **[**SPT3TMS-9391 **]**

6.4.1.8 Automatic Conflict Solution

- Automatic Conflict Solution
Solves conflicts based on algorithms. May use optimisation functions. **[**SPT3TMS-9388 **]**

6.4.1.9 Incident Impact Management

- Incident Impact Management
Managing the recovery from incidents to normal state of operations. **[**SPT3TMS-9385 **]**

6.5 Analytics and Decision Support

For railway assets, much information needs to be captured and analysed to assess the divergence of the received results from the target state, e. g. data on planned departure and arrival times per train and per station, actual departure and arrival times for these stations and root causes for reported delays. ((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 8)) Analytics and decision support functions provide tools for calculation of sophisticated KPIs. **[**SPT3TMS-9382 **]**

7 Incident Impact Management Scope

7.1 Introduction & Approach

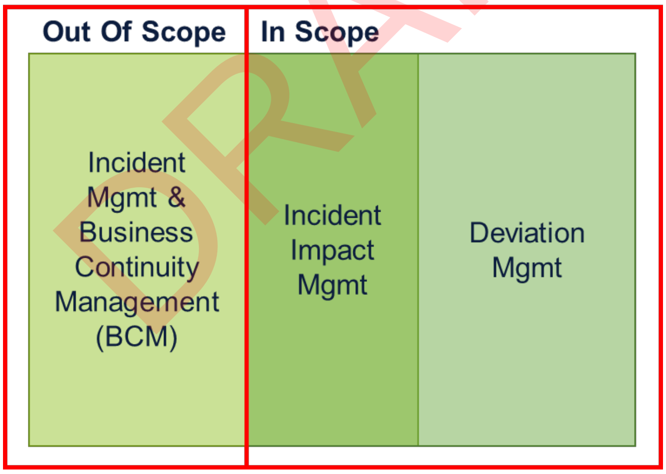
This document outlines and delimits the functional scope for incident impact management in TMS and the general approach taken towards it and serves as an initial basis for discussion. **[**SPT3TMS-9380 **]**

An incident, from a TMS point of view, is any event that temporarily affects the availability of network infrastructure and hence its total capacity and, as a result, requires adjustments to the production plan. While incident and, especially, emergency management is a far-reaching discipline, TMS is, crucially, not an Incident Management System (IMS) but concerns itself strictly with the necessary capacity and operational plan adaptations for the mitigation of and response to any deviations from plan that result directly or indirectly out of the events. **[**SPT3TMS-9375 **]**

As such, the TMS supports “incident impact management” rather than “incident management”. Its primary goals are to provide optimal decision-making support and minimise employee workload during non-standard traffic statewith, typically, a time-critical need to respond. This includes efficient and targeted communication between all parties involved in incident impact management to minimise the coordination effort. **[**SPT3TMS-9373 **]**

Deviation management handles situations in which trains deviate from the operational plan / are delayed. Mitigating actions such as priority assignments, platform or route allocations, cancelling of stops, short turning, aim at maximising the overall robustness of the plan. **[**SPT3TMS-9371 **]**

Incident Impact Management, sometimes also referred to as “disruption management”, manages situations, in which infrastructure capacity is subject to unplanned changes in availability. For example, due to defects in infrastructure assets (e.g. points, catenary) or in trains that block a track. Mitigating actions taken, such as re-routing, cancelling, short turning trains, etc. often lead to changes in the service to passengers and also require changes in ROCs' planning and dispatching systems, such as rolling stock and personnel deployment. **[**SPT3TMS-8611 **]**



[SPT3TMS-9498 **]**

Figure 17: TMS Scope Regarding Incident Handling

7.2 In Scope Functionality

7.2.1 Incident Recording

TMS is capable of recording operational incidents with a temporary impact on network capacity, both in the case of complete infrastructure unavailability and in that of temporary limitations (e.g. speed restrictions). To be able to effectively support its users in managing the impact of any incident upon traffic, TMS will need to record information relevant to its ability to correctly predict and mitigate the incident's impact upon the production plan such as:

- Location of the incident (including the wider impacted area, if applicable)
- Affected assets or train, if applicable
- Nature of any limitations and/or (un-)availability of network infrastructure
- Any constraints that may apply in the case of partial availability (e.g. speed, weight, …)
- Start time and duration (if known) of any capacity limitations
- Reporting user or party
- Etc.

[SPT3TMS-9496 **]**

If known and available, additional information may be recorded, such as:

- Cause / classification of the non-standard state of traffic
- Any possible pre-defined mitigation actions associated with it
- Estimated duration
- Etc.

On the basis of this information, TMS must be capable of recording any limitations in infrastructure availability that result out of the incident and must be capable of adding these to its model in real time. Furthermore, TMS must be capable of displaying incident-related information to its users in an intuitive, instantly recognisable fashion and must further allow them to access more detailed information on the nature of the situation on demand. **[**SPT3TMS-9494 **]**

7.2.2 Impact Recognition

Based on incident data, TMS is capable of automatically determining the impact incident triggered restrictions have on both current and planned traffic over the affected parts of the infrastructure network and supporting its user in recognising and managing it. To achieve this, TMS must support the following functionality:

- Detection of conflicts between current or (short-term-) planned traffic and any restrictions triggered by the incident (cf. above)
- Identification of all trains the production plan for whom is affected by incident-related restrictions

[SPT3TMS-9492 **]**

TMS must, once again, be capable of displaying this information to the user in an intuitive manner and must support the user in recognising the exceptional nature of the situation via suitable user interaction design.
TMS should be capable of recognising potential duplicate incident reports as well as, ideally, be capable of recognising related events (e.g. several reports of flooding related restrictions in several locations in close proximity to one another) so as to be able to take a more comprehensive view. In such cases, TMS should be capable of merging information contained in separate reports so as to model a comprehensive view of current capacity restrictions.
[SPT3TMS-9489 **]**

7.2.3 Impact Mitigation / Management

TMS supports its users in mitigating the effect of any incident and optimising the usage of the remaining network capacity. It is capable of doing so both ad-hoc and based on pre-defined, scenario-based responses. In order to achieve this, TMS requires the following minimum capabilities:

- The ability to suggest suitable ad-hoc dispatching measures for individual trains, based on TMS' regular conflict resolution and deviation management (decision support) capabilities (e.g., re-routing, cancellation, partial cancellation, possibly also shift to alternative modes of transportation…).
- The ability to implement mitigation measures (i.e., dispatching actions) in bulk via the application of scenario-based response plans (see below)

[SPT3TMS-9486 **]**

7.2.4 Scenario-based Incident Impact Mitigation Support

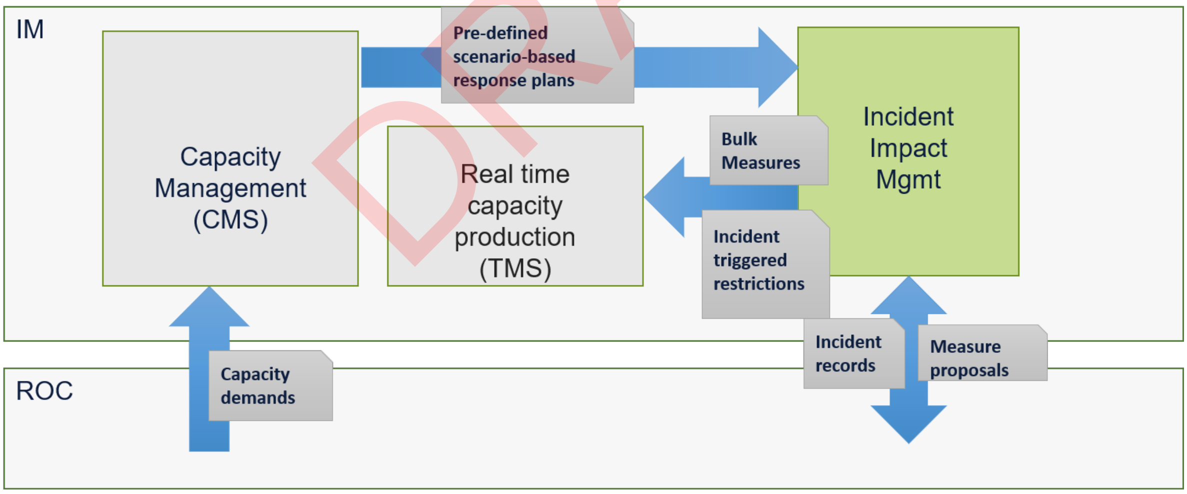
TMS must include the possibility to apply pre-defined bulk measures (e.g., “cancel all trains”, or “cancel all local traffic, re-route any long-distance trains”) to manage a large amount of train traffic in the affected area effectively. To support this, TMS must support at the very least the following functionality:

- Ability to store user-defined “if-then” style response scenarios of both …
    1. A specific nature (e.g., “if X type of restriction occurs in Y location short-term, re-route trains A, B, and C between point 1 and point 2”)
    2. Of a more generic nature (e.g., “cancel or stop all trains within a perimeter of 2 km from a user defined location during the next 30 minutes”) to especially support in initial emergency response situations
- Ability to make ad-hoc, user defined changes to pre-defined scenarios (e.g., “play ‘Scenario X’ – but except train A from its effect so as to leave it for manual management”, or “do ‘Scenario Y’ but extend the pre-defined perimeter as follows …”)
- Ability to put pre-defined scenarios into effect with minimal effort for the user. For this purpose, TMS should be capable of deriving, mass-creating, and implementing dispatching measured automatically based on minimum user input

[SPT3TMS-9484 **]**

TMS should ideally include additional functionality that allows not only for the user to select and apply a pre-defined scenario but for TMS itself to suggest suitable response scenarios to its user based on matching criteria such as e.g., the nature and expected duration of the incident and the resulting restrictions, the affected perimeter, assumed duration (cf. duration forecasting; this may be automatically extended unless confirmed resolved at the end of the period), etc., and should support users with e.g. response checklists so as to minimise employee workload. **[**SPT3TMS-9477 **]**

7.2.5 Centralised sharing of incident status information



[SPT3TMS-9474 **]**

Figure 18 : Scenario-based Incident Impact Mitigation

TMS enables the efficient and rapid exchange of information (chat and alarming) in the event of disruptions to rail operations. TMS channels incident-specific information and distributes it in the shortest possible time. TMS uses sophisticated filtering and distribution functions to ensure that the large volume of messages be addressed in a targeted manner. TMS ensures that all parties involved in rail production (incl. ROCs, potentially neighbouring TMSs, international bodies) receive information about current deviations in rail operations in the fastest possible electronic way. When it comes to alerting the emergency services, TMS supports the staff involved in the process in their task, thus shortening the alarm chain. **[**SPT3TMS-9471 **]**

7.3 Out of Scope

As TMS concerns itself only with managing the impacts incidents may have on current and planned rail traffic, the following items are considered out of scope and will not be part of any future TMS (although they may be supported by separate, supplementary systems): **[**SPT3TMS-9468 **]**

7.3.1 Response Co-Ordination

TMS is not, nor is it intended to function as, a general incident management tool. As such, any incident co-ordination activities such as e.g., organising, and co-ordinating repair works and/or alternative modes of transportation, co-ordination and communication with emergency services or internal or external situation management bodies, or the dissemination of incident status information beyond TMS' standard communication interfaces is out of scope. When it comes to alerting the emergency services (e.g., Police), TMS can support the staff involved in the process in their task, thus shortening the alarm chain (optional). **[**SPT3TMS-9466 **]**

7.3.2 Incident and Trigger Detection

While TMS is capable of detecting deviations from the production plan, the identification of any such deviation as, specifically, an incident is out of scope. Furthermore, it is not required for TMS to interface with any other systems or to apply other means so as to automatically recognise as potential or actual incident triggers information such as e.g., asset status. **[**SPT3TMS-9464 **]**

7.3.3 Incident Analysis

TMS functionality does not include any tool support for the ad-hoc or systematic analysis of specific incidents or incident patterns. Neither are documentation of or support for incident investigations, classifications, and/or the analysis of root causes part of TMS' functional scope. As such, TMS is also not capable of applying any wider ranging analytics based on its own data or other systems to support such goals as e.g., incident prediction or avoidance, or any other "enhanced" features geared at achieving incident avoidance. **[**SPT3TMS-9462 **]**

7.3.4 Incident Reporting

TMS does not include any features for either internal or external incident reporting and does not directly support any regulatory reporting requirements, even though its data may potentially be drawn upon to fulfil these. **[**SPT3TMS-9460 **]**

7.3.5 Business Continuity & Risk Management and Planning

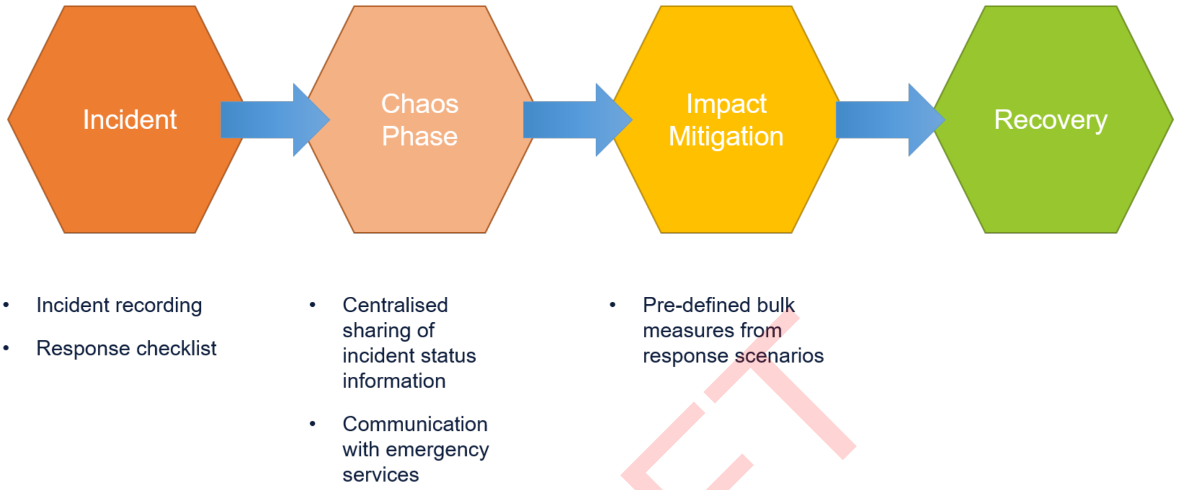
TMS includes strictly real-time, executing functionality to support the implementation of mitigating measures during non-standard traffic states. As such, TMS does not directly support and upstream or downstream processes such as Business Continuity and Risk Management or Planning activities such as e.g., the systematic analysis of risk factors and exposure, the planning of business continuity plans or response scenarios or the measurement of the effectiveness of any such measures. This does not preclude TMS' capabilities from being leveraged in the implementation of any real-time response resulting out of of the aforementioned neighbouring processes. **[**SPT3TMS-9457 **]**

7.3.6 Other Non-Traffic-Management Functionality

Furthermore, any other activities involved in detecting, recording, documenting, managing, investigating, and reporting operational incidents are considered out of scope for TMS unless they concern themselves directly with the management of traffic and network capacity. **[**SPT3TMS-9455 **]**

7.3.7 Incident Duration Forecast

The responsibility of forecasting the likely duration of any impacts an incident may have and the likely timing of a return to “business as usual” is the incident management system's responsibility. Such an estimate of the expected duration of restrictions may then be used to assist both TMS itself and/or the user in selecting and implementing a suitable response (e.g., to decide the duration, for which a pre-defined scenario should be applied, etc.). TMS’ ability to do this presumes and depends on wider Incident Management (IM) support systems including an incident impact duration forecasting component. **[**SPT3TMS-9446 **]**



[SPT3TMS-9444 **]**

Figure 19 : Stages of an Incident

8 ATO Feedback Loop Scope

8.1 System Context ATO

An effective interface with ATO Trackside/C-DAS is a key factor to enhance train and trackside efficiency, availability, reliability, increasing overall system performances. The possibility to take advantage of ATO Trackside/C-DAS features shall permit to improve the timetable structure, maximizing the capacity of the rail network. **[**SPT3TMS-9442 **]**

To achieve these goals, the information exchange between TMS and Traffic Control and Supervision system shall be bidirectional, and shall consist of:

- from TMS to Traffic Control and Supervision system: a dynamically updated Operational Plan describing a single train run from an origin to a destination. Here, with Operational Plan we mean the outcome of the planning process performed by TMS/CMS. According to RCA , which is not definitively approved, but is in an advanced state of design and for this reason from now on is taken as a reference, an Operational Movement, hence a specific type of an Operational Plan, describes a planned train run through a spatiotemporal sequence of Operational Movement Events to be implemented by the Traffic Control and Supervision and the other RCA subsystems.
- from Traffic Control and Supervision system to TMS: for every train, and according to ETCS standards, the train position and speed, data about train composition, and information about the state of the execution of the Operational Plan

[SPT3TMS-9439 **]**

As anticipated, as RCA architecture is not approved yet, it is possible that further contributions and improvements to the design occur later. In case these improvements are deemed to be relevant and useful by the domain team, they shall be considered, and a further release of the document shall be released. **[**SPT3TMS-9436 **]**

In addition to the document referred to in [(RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))], other available documentations have been considered, delivered in the frame of Shift2Rail 4 project [(X2R4-WP03-D-ALS-009-10_-_Deliverable_D3.2_-_GoA34_Specification.docx)]. In addition to that, two subsets referred into [(RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))] have been taken into account to better qualify some parameters described when dealing with actions to be taken when receiving data from ATO Execution subsystem [(ATO over ETCS - System Requirements Specification – Subset 125, issue 0.1.0), (ATO over ETCS - ATO-OB / ATO-TS FFFIS Application Layer – Subset 126, issue 0.0.16)]. This led to propose an integration according to the principles described in the following paragraph. **[**SPT3TMS-9540 **]**

Finally, this document is tightly coupled with the analysis which is on-going inside the TMS CMS domain itself, regarding the review of the SCI-OP (Standard Communication Interface Operational Plan). This document shall be updated later, if needed, to be consistent with the achieved results. **[**SPT3TMS-9539 **]**

In the next paragraphs, a proposal of which information should be provided by ATO trackside / C-DAS subsystem through the interface with the Traffic Control and Supervision subsystem will be deepened, along with the triggering events and related consequent actions which TMS shall need to take, considering [(RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))] as a basis and complementing it with other contributions.

The analysis of the feedback loop from C-DAS shall be dealt with into a separate document/annex as part of the TMS/CMS domain documentation package. [SPT3TMS-9538]

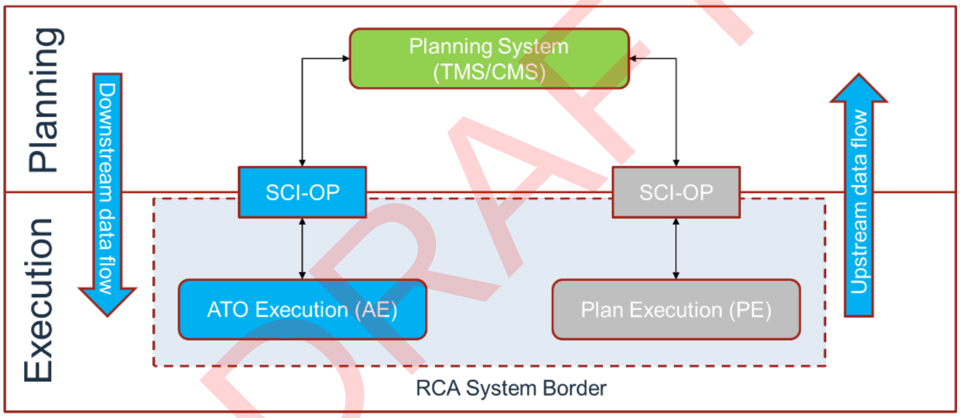
8.1.1 Scope and Exclusions

As this is a concept document, it shall focus on principles and macro-data which are proposed to be exchanged, with the purpose to establish the high-level boundary of the interface between Traffic Control and Supervision system and TMS, in the direction from the former to the latter. This interface is not safety related. [SPT3TMS-9537]

For the detailed analysis of the data structures and data types exchanged between Traffic Control and Supervision system and TMS, please refer to ((RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))). [SPT3TMS-9535]

The structure and details of the interface which TMS shall connect to the Traffic Control and Supervision system is instead dealt with in other deliverables. [SPT3TMS-9526]

The design of the interface between TMS and ATO trackside / C-DAS is based on the results of the RCA. According to it, two main actors are interfacing TMS: subsystem ATO Execution (AE) and Plan subsystem Execution (PE), as shown in the following picture which recalls the general structure of the Planning and Execution roles: [SPT3TMS-9528]



[SPT3TMS-9525]

Figure 20: Scope of interface SCI-OP

It is for now assumed that there's not a direct interface between TMS/CMS and ATO Trackside/C-DAS. Instead, whichever is the subsystem to be connected, according to the high-level architecture described inside the CCS and TMS/CMS System Architecture document is for now assumed that the data exchange shall be mediated by the Traffic Control and Supervision system, and the peer subsystem shall be identified by the ATO Execution Subsystem. [SPT3TMS-9524]

According to RCA, the Plan Execution subsystems is in charge of train protection and management of trackside equipment for plan execution, while ATO Execution subsystem is in charge of train control. Therefore, as this document focuses on the interface between TMS and ATO Execution Subsystem, the interface with the Planning Execution Subsystem has been greyed out, because it is not in scope of this document. [SPT3TMS-9523]

8.1.2 Priority, Difficulty and Maturity

The priority of this interface is high, as the ATO feature is one of the most innovative and less "explored" up to now, and for this reason this feature is not yet stable and mature as many other interfaces that are proven in use for many years and tested by various systems already in commercial operation. [SPT3TMS-9521]

The difficulty of implementation will depend on the architectural choices which shall be taken and therefore a proper assessment shall be possible at a later stage. However, the effort which shall be pursued is to design an architecture which defines a common framework to implement all interfaces, to maximise the reuse of the common parts and differentiate only the specific characteristics of each of them. **[**SPT3TMS-9519 **]**

8.1.3 As-Is Situation

Nowadays, very few instances of TMS-ATO Execution Subsystem interfaces are active and in Commercial Operation. This is because even if ERTMS-based systems are already in Commercial Operation in Europe, they are still few when compared with the traditional control systems deployed or whose deployment is in progress and nearly no ATO trackside systems in mainline lines are yet deployed. However, ATO Trackside Subsystems are quickly growing in importance, and studies and prototype developments are already on-going. **[**SPT3TMS-9517 **]**

C-DAS implementations already exist as a precursor to ATO. Here, the currently missing interface between TMS/CMS and the vehicle is replaced by an HMI to the train driver. Exemplarily, the following C-DAS applications describe the current situation: **[**SPT3TMS-9516 **]**

In Fjernbane Infrastructure East project (Denmark) it is now active and in Commercial Operation an interface between the TMS which supervises the East side of Denmark and a C-DAS system provided by Banedanmark, which displays train's arrival and departure data onto a tablet provided to the train driver. No additional data are shown even if more data would be available. This is a small improvement with respect the previous legacy system and doesn't suggest the optimal speed but permits the driver to have an estimation of when the train is envisaged to reach the next locations of its trip. **[**SPT3TMS-9515 **]**

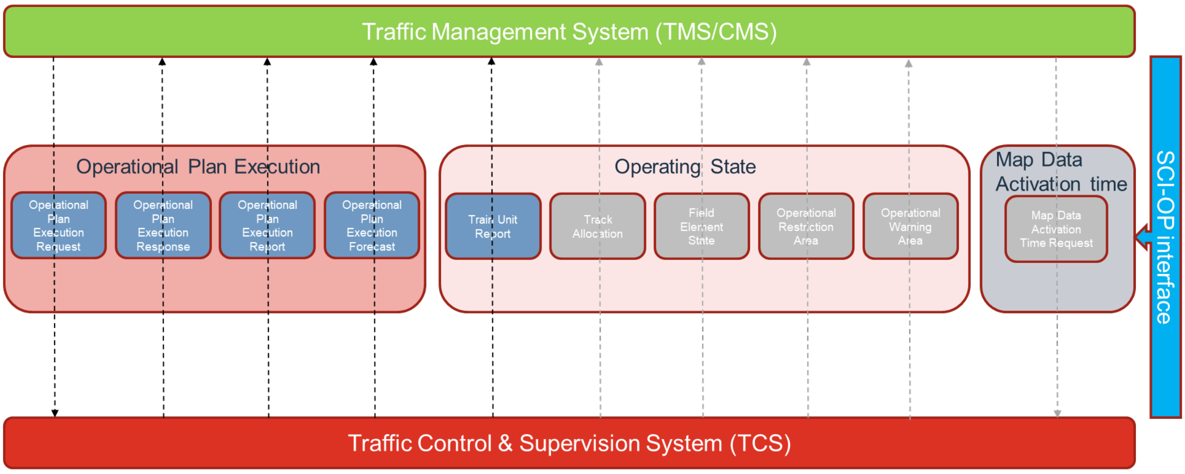
The SBB in Switzerland has been operating the c-DAS Adaptive Guidance (ADL) system on the entire Swiss rail network since 2015. All trains on the network are measured under real-time conditions. The central TMS of the SBB and the associated ADL c-DAS components provide all trains in real time with messages on the optimal speed (vOpt). These driving recommendations are displayed to the train driver on a separate mobile device (iPAD). The communication takes place via a permanent GSM public connection and the protocol is SFERA compliant. **[**SPT3TMS-9508 **]**

The driving recommendations are supplemented by additional information, such as reasons for guidance (e.g., slow train ahead, red signal at a conflict point) and slow speed section information. The C-DAS ADL system works for the calculation of the optimal driving profile either with profiles to avoid signal stops due to conflicts (conflict elimination) or with ECO Drive profiles for trains without delay and without conflicts. The system calculates the energy-optimal driving profiles for all trains on the network permanently (< 1 Sec) and transmits them to the train driver. In 2020, a fully automatic ATO GOA-2 test was successfully carried out on ETCS-L2 lines in Switzerland with real time TMS production data via a UNISIG conform interface. **[**SPT3TMS-9506 **]**

8.1.4 Communication Interface

According to RCA documents package, specifically RCA.Doc.73, System Concept ATO execution, the Standard Communication Interface – Operational Plan (SCI-OP) shall be adopted. **[**SPT3TMS-9504 **]**

The following picture recalls the general structure of the defined SCI-OP interface, as described inside the document RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan), which specifies which are the foreseen messages and their content. The upstream data flows generated by the PE Subsystem from the Traffic Control and Supervision system (TCS) to TMS, as not of interest in this document, are greyed out: **[**SPT3TMS-9503 **]**



[SPT3TMS-9502 **]**

Figure 21: General structure of SCI-OP

The next sections shall deal with the high-level description of the data flows between TMS and ATO Execution Subsystem.

8.1.5 Messages and Data expected to be sent from TMS/CMS to ATO Execution Subsystem

This paragraph aims to recall which messages are assumed to be sent to ATO Execution (AE) Subsystem by TMS, which is relevant to understand the rationale behind the expected feedback. **[**SPT3TMS-9501 **]**

The paragraph shall be updated (if the case) once the specification of these messages has been accomplished by the dedicated team and according to the discussion which shall occur with the Task 2 Traffic Control and Supervision system, which will lead to the final specification of the interface between the two subsystems. **[**SPT3TMS-9500 **]**

According to the RCA architecture design, TMS shall send Traffic Control and Supervision system (which will provide to AE subsystem after a possible manipulation/integration) the following message during a communication session:

- Operational Plan Execution Request

[SPT3TMS-9563 **]**

The next paragraphs will give some more high-level information about what the content of the messages is expected to be, with the only goal to understand the context and without any assumption about how they are structured and their content is made available. **[**SPT3TMS-9562 **]**

8.1.5.1 Operational Plan Execution Request

TMS shall send the Operational Plan Execution Request every time an Operational Plan is ready or modified and shall identify every Operational Plan with a unique Identifier, which shall be used by the Traffic Control and Supervision system for its feedback messages. ATO Execution Subsystem shall use the received information to generate the necessary driving instructions for the Physical Train Unit associated to the Operational Plan. **[**SPT3TMS-9561 **]**

An Operational Plan can have different characteristics according to its content: it can be configured to deal with either:

- an Operational Movement, which describes a Train Run. The Operational Movement shall contain information about the train trip, expressed as a list of relevant trackside resources (stopping points, marker boards, platforms, etc) and associated forecasted arrival, passing and departure time, and the different compositions of the physical train unit.
- an Operational Restriction, which precisely describes a set of Operational Restrictions inside an Operational Area. The type of Operational Restriction is not limited to Possession but can also indicate a Temporary speed Restriction (TSR), a Low Adhesion Area (LAA) or other kind of limitations associated to that area.
- an Operational Warning Measure, which contains a set of information related to a Warning Area

[SPT3TMS-9560 **]**

Of these three types of Operational Plan requests, TMS/CMS shall send AE subsystem only the first type, i.e. Operational Plan Operational Movement, as this is the only one which is interesting for the AE subsystem. **[**SPT3TMS-9559 **]**

A detailed description of these messages can be found in ((RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))). They shall be also dealt with in another document, which shall focus on the full interface between Traffic Management and Traffic Control and Supervision System. **[**SPT3TMS-9558 **]**

8.1.6 Data expected from ATO Execution Subsystem

TMS needs continuous feedback from AE Subsystem (in addition to the PE Subsystem) to keep continuously and properly updated the Operational Plan. By means of the Traffic Control and Supervision System, it is assumed to receive from AE the following kind of information:

- Feedback on Operational Plan Execution
- Feedback on the position, speed and other properties of every Train Unit running inside the controlled area

[SPT3TMS-9557 **]**

According to the RCA architecture design, TMS shall receive from the Traffic Control and Supervision system (after a possible elaboration of data received by AE subsystem) the following messages during a communication session:

- Operational Plan Execution Response
- Operational Plan Execution Report
- Operational Plan Execution Forecast
- Train Unit Report

[SPT3TMS-9556 **]**

8.1.6.1 Operational Plan Execution Response

This message informs TMS whether the AE subsystem has accepted the Request for Operational Plan Execution or not and, in case of rejection, gives a reason. Actually, the current protocol specification doesn't give any further detail about possible reasons for rejecting the plan; they shall be refined later. Consequently, another version of this document shall be issued to take them into account.
It is anyway assumed that every rejection reason shall not impact safety, or it is due to keep safety conditions detected by the Traffic Control and Supervision system. **[**SPT3TMS-9555 **]**

8.1.6.1.1 Triggering Event

This message is generated as result of the processing of an Operational Plan Execution Request received by AE subsystem. **[**SPT3TMS-9554 **]**

8.1.6.1.2 Actions

This information shall be used by TMS to elaborate possible alternative strategies in case AE subsystem rejects the received Operational Plan (which nowadays are not yet specified; the related Use Cases should be designed); an alarm shall be anyway raised to the dispatcher. In case of success, the Operational Plan is confirmed and this state shall be registered into the system. **[**SPT3TMS-9553 **]**

8.1.6.2 Operational Plan Execution Report

This message keeps TMS updated about the execution state of any previously accepted Operational Plan, from AE viewpoint. The execution state refers to every single Operational Movement Event completed by AE subsystem, in terms of passing or stopping on a given ATO timing point. **[**SPT3TMS-9552 **]**

In case a failure is detected, a reason is given.
When the Train Unit comes to a standstill at a planned stop, and if available, AE also provides an indication of the accuracy of the stop itself. **[**SPT3TMS-9551 **]**

8.1.6.2.1 Triggering Event

This information is generated every time AE determines that a Train Unit fully performed an Operational Movement Event, i.e., one of the possible actions on a ATO timing point (arrival, departure, passed). If AE determines that this action cannot be completed in time, this information is triggered as well.
[SPT3TMS-9542 **]**

8.1.6.2.2 Actions

The TMS shall use this information with other detailed ones coming from the Train Unit Report message (and those generated by the PE subsystem) to keep updated the future trip of the Train Unit the message refers to.
This shall keep up to date the state of execution of all Operational Plans and provide a reliable basis for the execution of the regulation and optimisation functions apportioned to TMS. **[**SPT3TMS-9550 **]**

8.1.7 Train Unit Report

The Train Unit Report is assumed to be a message set which is made by the following elementary upstream messages:

- Train Unit Data Report
- Train Unit State Report
- Train Unit Position Report

[SPT3TMS-9544 **]**

These messages provide TMS information about position, state and other properties of any train running inside the controlled area, together with header data, such as references to the Operational Plan, the Operational and the Physical Train Unit. **[**SPT3TMS-9543 **]**

Actually, a proposal is ongoing to manage a larger set of information which should be provided by an extension of the ATO over ETCS (AoE), namely Train Capability Report (TCR). This additional information is considered and referred separately in the next sections. **[**SPT3TMS-9574 **]**

8.1.7.1 Train Unit Data Report

The Train Unit Data Report message shall provide TMS the length of the physical train unit. This data can be complemented by the TCR, whose purpose is to deliver further data regarding train mass, position and state of the train doors, information about passenger load, additional brake information and the list of the physical consists. **[**SPT3TMS-9581 **]**

8.1.7.1.1 Triggering Event

The message containing the train length is assumed to be generated when the driver terminates the data entry phase by using the Driver Machine interface and triggers the Start Of Mission or when ATO trackside system starts-up in case this data is already preconfigured and therefore available. **[**SPT3TMS-9580 **]**

Nowadays, no assumptions can be done about other data which are supposed to be managed by the ATO TCR extension. This part shall be further elaborated when the integration of ATO TCR is further elaborated. **[**SPT3TMS-9579 **]**

8.1.7.1.2 Actions

The TMS shall use the physical train length and other received data inside its regulation and optimisation functions, when determining the position of the train on a platform in a station, or to decide whether the train can be allowed to stop on a platform or not, for example when solving a conflict. **[**SPT3TMS-9578 **]**

Additional information provided by ATO TCR can be used to improve the train forecast algorithm, for example considering these further train technical characteristics, and/or taking into account dynamically the time needed by passengers to get on/off. **[**SPT3TMS-9577 **]**

Afterwards some considerations are done, which have to be considered as a first suggestion and not as mandatory requirements, which instead shall be defined at a later stage of the process, according to the steps defined by SEMP: **[**SPT3TMS-9576 **]**

- trainLength: it is assumed that TMS should already own this data, as part of the train unit consist received by CMS, which must be available in advance with respect the train run. However, it might happen that train length changes due to some unforeseen event, occurring just before the beginning of the train mission, or even during its run. It might be that the train driver updates this parameter using his Driver Machine Interface as part of train set-up just before the Start of Mission. Even if deprecated, this possibility must be considered.

[SPT3TMS-9575 **]**

In this case, the Traffic Control and Supervision system will forward TMS this information, which TMS shall compare with his available data and, in case of discrepancy, TMS will give priority to what received by the Traffic Control and Supervision system, who is supposed to have last-minute data. **[**SPT3TMS-9584 **]**

It is assumed that, among other features, this information shall be used by TMS for its Conflict Detection and Resolution function, e.g., to check the consistency between train and platform length, and to change the platform, update the Operational Plan, raise an alarm to the user or trigger other TMS functions to perform different actions. **[**SPT3TMS-9583 **]**

If and when the Train Capability Report packet is agreed to be implemented as an extension of the existing AoE Subsets, a suggestion for using the following parameters is given:

- etcsOperationalTrainCategory: no quantitative indications can be derived by this parameter so it can be used to add e.g., a 2nd-order corrective factor to evaluate train forecast
- doorData: this parameter might be used to re-estimate embarking/disembarking time according to how many doors are blocked, and then re-evaluate train forecast
- passengerData: the percentage of passengers load might be used as a corrective factor to estimate the minimum dwell time, while the last door opening time (also given as part of the parameter structure) might be used to evaluate a trend for the time needed to close doors.
- additionalBrakeData: several characteristics of the brakes of an identified Physical Train Unit are given with this parameter structure, which might be evaluated to refine the estimation of train braking. These data, as in other cases, if deemed useful, should be already available by TMS as part of the configuration process and it is considered that usually should be received just in case of a change in train unit.
- physicalConsist: similar considerations done for additionalBrakeData parameter apply

[SPT3TMS-9582 **]**

Other parameters are assumed to be already available by TMS, either because already received in other messages (e.g., trainLength) or as part of train configuration (maximumSpeed, mass) and are not considered here. **[**SPT3TMS-9359 **]**

8.1.7.2 Train Unit State Report

The Train Unit State Report message shall forward TMS the state of a physical train unit based on ATO Status Report (AoE, SS-126), including the connection state, the ATO state, whether the operational conditions are satisfied or not and the driver identifier. No additional messages from ATO TCR are foreseen for now, due to the lack of readiness of the SS-126. As soon as available, more data can be transmitted in the Train Unit State Report. This will be made possible with a further revision of the document. **[**SPT3TMS-9357 **]**

8.1.7.2.1 Triggering Event

A message is sent with every ATO status change. **[**SPT3TMS-9355 **]**

8.1.7.2.2 Actions

The TMS shall display the Train status onto the Time Distance Graph and other HMI representations where it is deemed useful for the dispatcher. When a failure is detected, an alarm is raised. **[**SPT3TMS-9354 **]**

Several scenarios can be drawn according to the train state; at the time being, the connection state of a Physical Train Unit defined in ((RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))) can be either “CONNECTION_ESTABLISHED” or “CONNECTION_TERMINATED”, even if it is assumed that further details could be added in next releases of the document. **[**SPT3TMS-9353 **]**

It is understood that when connectionState is “CONNECTION_TERMINATED“, ATO doesn’t play an active role for the train mission and then for trains in this state ATO related information are not applicable; in this case it is just reasonable to display a suitable information onto TMS HMI which shows the current trains status. **[**SPT3TMS-9351 **]**

In case the connectionState is “CONNECTION_ESTABLISHED”, some considerations are done afterwards, which have to be considered as a first suggestion and not as mandatory requirements, which instead shall be defined at a later stage of the process, according to the steps defined by SEMP: **[**SPT3TMS-9348 **]**

- atoState: this parameter reports the current state of ATO according to what specified in [Ref 4]: this status might be collected for every train to be displayed into a tabular view but also graphically for immediate viewing by the user onto a suitable graphical mimic, such as Train Graph. At least a different representation should be foreseen for each of the following groups of states:
    - When ATO is not ready: ATO No Power (NP, ATO Configuration (CO), ATO Not Available (NA); in terms of business logic, this state brings the same consequences as the “CONNECTION_TERMINATED“ connectionState
    - When ATO is ready but not operating: ATO available (AV), ATO Ready (RE)
    - When ATO is operating: ATO Engaged (EG)
    - When ATO is in failure: ATO Failure (FA)
- operationalConditionsFullfilled: this parameter seems not to provide additional information with respect the previous one, just an overall status of readiness (Y/N) of ATO; so its real usefulness should be further analysed.

driverID: the Driver identifier number has no direct impact on TMS activities and can be used to give the TMS user information about the driver. **[**SPT3TMS-9346 **]**

8.1.7.3 Train Unit Position Report

The Train Unit Position Report message shall provide TMS some accurate data related with the train run and the conditions of the track: the position of the estimated front end of the train, the train speed and whether low adhesion area and slipping conditions are present when detected. Additional information is foreseen to be provided by ATO TRC, regarding the wheel-rail adhesion. **[**SPT3TMS-9362 **]**

8.1.7.3.1 Triggering Event

It is assumed that the message is sent every N seconds, N configurable, for performances reasons, as all contained data are dynamically changing over time. Nowadays, no assumptions can be done about other data which are supposed to be managed by the ATO TCR extension. This part shall be further elaborated when the integration of ATO TCR is further elaborated. **[**SPT3TMS-9361 **]**

8.1.7.3.2 Actions

The TMS shall use this data to improve the train forecast algorithm, using the reported position and speed and, if relevant, the adhesion conditions. Afterwards some considerations are done, which must be considered as a first suggestion and not as mandatory requirements, which instead shall be defined at a later stage of the process, according to the steps defined by SEMP:

- frontPosition: this parameter can be used to precisely identify the train position inside a topological element, so as to better evaluate the remaining time before passing to the new one
- velocity: it is reasonable to use this parameter jointly with the previous one, for the same purpose to evaluate the time needed to reach the next remarkable point inside the defined topology or (along with other parameters, as frontPosition or isMoving) if the train is on a stopping point/station or not)
- lowAdhesion: no quantitative indications can be derived by this parameter so it can be used to add e.g., a corrective value to the forecast in case the train is running on a low adhesion area. A better estimation of the train forecast when in a low Adhesion area can be achieved when the Train Capability Report proposal for the extension of the existing AoE Subsets is accepted.
- isMoving: no quantitative indications can be derived by this parameter so it can be used to identify (along with other parameters, as frontPosition or velocity) if the train is arrived at a stopping point/station or not)
- isSlipping: no quantitative indications can be derived by this parameter so it can be used to add e.g., a corrective value to the train forecast

[SPT3TMS-9342 **]**

8.1.7.4 Reinitialisation and fail-over management

The Use Case for (re)initialisation has to be considered, as it is not dealt with into ((RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan))). The work done in the frame of S2Rail program provides a solution, which is based on the Integration Layer; this infrastructure handles the event of a crash at any time of any system, which will be supplied with the valid data after re-connection by default, so the (re)initialisation logic (protocol) is extracted from the system into a separate component. **[**SPT3TMS-9337 **]**

8.1.7.4.1 Triggering Event

The (re)initialisation comes from the need to envisage an alignment phase between AE subsystem and TMS when one of the following scenarios occurs:

- The TMS subsystem starts or restarts, due to a possible fault or a planned event.
- The TMS works properly, but a network fault happens, despite all foreseen redundancies, and a down-up transition is detected by the AE subsystem.
- The Traffic Control and Supervision system (Or AE) starts or restarts, and a re-establish connection event is detected.

As part of the planned events, the reconfiguration process which follows an infrastructure update, with its associated new release, must be considered. **[**SPT3TMS-9334 **]**

8.1.7.4.2 Actions

When any of the above-mentioned events occurs, the business logic developed by TMS and AE systems shall use the services provided by the Integration Layer to resynchronise and get updated. This architecture shall enable both systems TMS & ATO TS to restart independently and be supplied with the current state of the objects, flowing through the interfaces between them. NOTE: This topic is a “cross-task” one and shall need to be shared and discussed with the the Core-Architecture team, to reach common agreements and requirements. **[**SPT3TMS-9332 **]**

9 Treatment of Connected Driver Advisory System (C-DAS)

9.1 Intension of a c-DAS

If capacity and energy efficiency on the rail network is to be further increased without construction measures, it must be possible to plan and (in particular) control and produce more precisely than is already the case in many areas today. In today's production systems for capacity production, the communication channel to one of the most important participants in the production of rail traffic is missing: the train driver. **[**SPT3TMS-9329 **]**

Except in specific situations (with voice communication), there is usually no (data driven) communication between the rail traffic control (dispatcher) and the locomotive crew. This means that driving situations and conflicts that lead to an unscheduled stop or the possibilities to drive energy-optimally in punctual traffic cannot be exploited and communicated. Even if the experience and good route knowledge of the train driver have a positive influence on the stability of the railway network in many driving situations, it is impossible for the train driver to know the exact traffic situation around his own train in case of conflict with other trains. **[**SPT3TMS-9326 **]**

It is also very difficult for the train driver to decide in punctual traffic whether his driving time reserve should be used for an energy-optimised driving style or whether other unpunctual trains running behind might be hindered (e.g., in the case of cargo trains). **[**SPT3TMS-9323 **]**

A communication system such as c-DAS closes this missing information bridge between the train driver and the dispatcher. **[**SPT3TMS-9317 **]**

The primary purpose of a c-DAS is to provide the train driver with driving recommendations (speed profiles / segment profiles (e.g., smaller bits of speed profiles)), which enable him to

- avoid conflicts without a red signal stop and thereby save energy, and
- to run in punctual traffic in an energy-optimised manner and still on time
- perform a comfortable driving for the passenger.

[SPT3TMS-9320 **]**

For this purpose, an energy-optimised driving profile for each individual train is calculated in the control systems TMS. This driving profile is enriched with further information relevant to the driving service and displayed to the train driver on their mobile device. A display of the information that would also be made available to a system for automated operation should enable the train crew to drive similarly precisely according to plan, as is forecast for ATO (GOA-2 and higher). Challenges for the TMS exist in the compilation of all necessary information from a wide variety of source systems. The calculation of the energy-optimised driving profile is also complex. In particular, the detailed consideration of the driving dynamic characteristics of the different train types (and wagon rows in freight traffic) is somehow complex. A distinction is made between dynamic guiding in the case of conflict, static guiding to optimise the energy demand in passenger traffic and updated driving position and route in freight traffic.
In the event of a conflict, one or more driving recommendations can be transmitted to the train crew on a mobile on-board device, which, if the suggested speed is adhered to, prevent the train from coming to a standstill in front of a signal indicating a stop. If the train is running on time and without conflict, the operationally calculated speed profiles provide the train driver with a recommendation of the average speed, which enables energy-efficient driving in compliance with the operational timetable. In freight traffic, in the event of delays with updated transit times, the train driver is provided with the necessary information for selecting the driving strategy. **[**SPT3TMS-9341 **]**

With increasing traffic on the railways, the potential for conflicts increases and the demand for precise driving according to operational planning becomes greater. It is important to be able to react quickly to changes in ongoing operations. **[**SPT3TMS-9312 **]**

9.1.1 Styles of Driver Advisory Systems

A distinction is usually made between three forms of a "Driver Advisory System":

- Standalone DAS (s-DAS)
- Connected DAS with on board calculation (c-DAS-O)
- Connected DAS with central calculation (c-DAS-C)

[SPT3TMS-9311 **]**

9.1.1.1 s-DAS

In a DAS (or s-DAS standalone), static timetable data as well as track data (topography) are loaded into an on-board device before the train starts its journey. During the journey, a comparison with the actual train position can be determined, possibly by GPS-based position reception, in order to calculate and suggest possible adjustments to the energy-optimal driving strategy of the individual train. **[**SPT3TMS-9433 **]**

A pure, standalone DAS is not connected live to TMS, and the local on-board unit cannot have any knowledge of the driving situation (conflicts etc.) around the individual train. Although the train itself is guided in an energy-optimised way, it behaves as if it were virtually travelling alone on the network. This leads to potentially counterproductive driving situations in almost all dense rail networks in Europe. For example, a train guided by a DAS at a slow, because energy-optimal, speed in a dense mixed traffic network can lead to rear-end collisions, which can have a negative impact on punctual traffic. Because of this singular perspective without connection to a real time TMS, pure DAS systems can only be used in night-time freight traffic or on very sparsely frequented routes. **[**SPT3TMS-9430 **]**

9.1.1.2 c-DAS-O

O = On Board Calculation Mode
The on-board unit is sent a continuous sequence of the train's journey, with precisely positioned control points - typically 'passing points' at signals and 'stopping points' at stops. **[**SPT3TMS-9427 **]**

This sequence consists of timing information for these points, speed limits and other topology and regulatory information. This data is transmitted as a segment profile and a journey profile. The on-board unit on the locomotive accordingly calculates the ideal journey profile between these reference points itself on an on-board unit. **[**SPT3TMS-9424 **]**

The central TMS can take control of the train by specifying closely positioned timing points. A graph with distances and a set of timing points with its position and due time (arrival, stopping, passing) is sent to the on-board unit. **[**SPT3TMS-9421 **]**

The main disadvantage of the "on board calculation mode" is the fact that a comprehensive, network-wide c-DAS can only achieve a positive effect with a significant number of rolled-out on-board units, which are permanently fixed installed in the train driver CAB, as in the case of the ATO-OBU. The necessary set-up and conversion times as well as the required approval projects result in a long-time horizon for achieving network-wide availability of a c-DAS-O. The great advantages of a c-DAS can essentially only be used if the installation base in the traction units is very high. **[**SPT3TMS-9418 **]**

9.1.1.3 c-DAS-C

C= Central Calculation Mode
If the advantages of a c-DAS are to be realised as simply, quickly, and comprehensively as possible, independently of an OBU hardware upgrade (e.g., ATO), the c-DAS-C model is to be favoured. **[**SPT3TMS-9415 **]**

Here, all driving profiles are calculated on a very precise working TMS and constantly recalculated and adapted to the driving situation and transmitted to the on-board unit. The on-board device (commodity mobile device) has no further logic, no interfaces to the traction unit and displays the received information graphically. If traction units with corresponding ATO OBUs are available in the future, which will successively enter the ROC fleets, the c-DAS-C can migrate to a c-DAS-O and operate the interfaces of the ATO OBU or be replaced by an ATO OBU. **[**SPT3TMS-9412 **]**

Thus, the c-DAS-C model is currently the only model that can be rolled out and used immediately within a reasonable period of time, as it does not require fixed installations in the driver CAB. **[**SPT3TMS-9408 **]**

The disadvantage of a c-DAS-C system is the high precision required of a real time TMS (capacity production), which, in addition to excellent conflict detection, also requires a significant amount of vehicle-specific data in order to calculate an energy-optimised driving profile. **[**SPT3TMS-9407 **]**

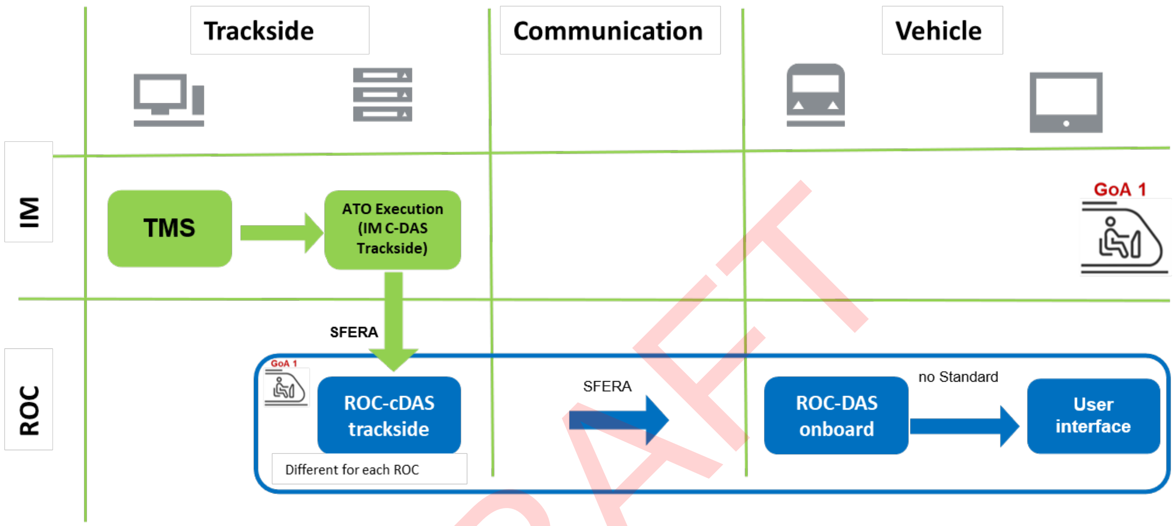
In the medium to long term, a Connected DAS in operation mode O is recommended, if the IM cannot provide a detailed, precise enough TMS, as it provides the optimal combination of an energetically optimally calculated driving profile with all physical parameters of the traction unit plus a continuously recalculated driving profile (timing points) from the TMS working under real time conditions and controlled according to the traffic situation. **[**SPT3TMS-9405 **]**

9.2 System Context

The basic system architecture of a c-DAS can be divided into two categories:

- c-DAS with different trackside and vehicle software ROC.
- ATO Execution with trackside uniformly from the IM

[SPT3TMS-9401 **]**



[SPT3TMS-10871 **]**

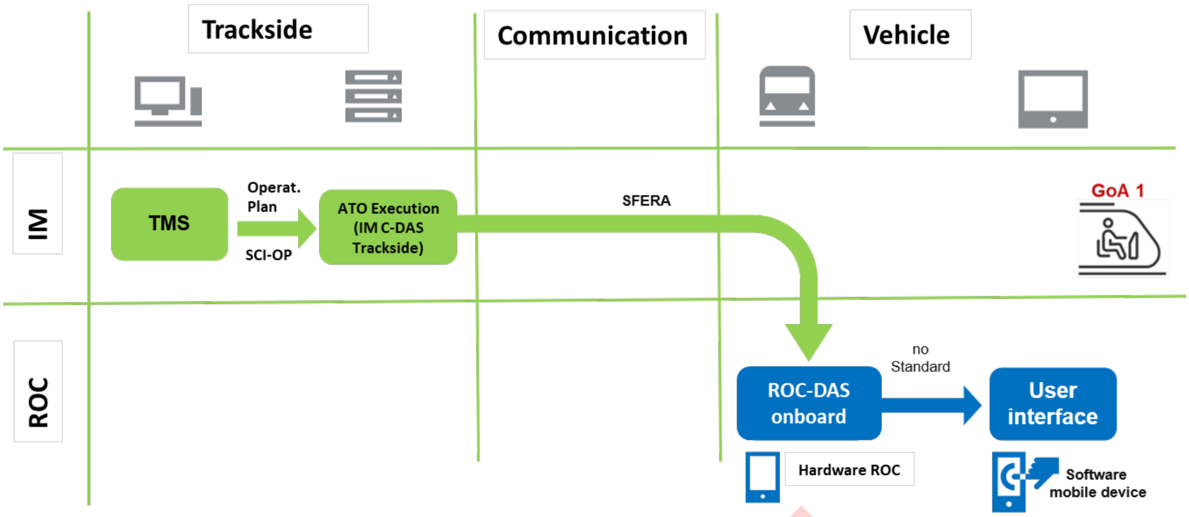
Figure 22: c-DAS with Trackside and Vehicle Software from IM/RU

In this variant, the speed profiles are calculated on the TMS side of the IM and already transferred to the ROC on the trackside infrastructure as SFERA-compatible data. The ROC is then responsible for further processing and transport through communication networks to the traction unit. ROC hardware (mobile devices) and ROC user interfaces are located on the traction unit.

+ Clear separation between IM and ROC already on the trackside side
- Complex solution to guarantee that the driving profiles actually arrive in the correct latency (complex system structure)
- IM has a separate interface to each ROC
  International traffic (cross border) barely possible. The train driver changes at the border and the IM sends the data to the other international ROC.
- "Closed status loop" for the display in the TMS GUI about the transmitted speeds hardly possible.
- ROC has to manage the telecom transmission path (GSM-P / FRMCS(GSM-R is not suitable for transmission because of the low bandwidth. This is not only true for ETCS-L2 lines, where the RBC operates with the highest priority, but also on other lines. In order to supply the mobile on-board unit with data and updates with low latency, an always connected connection is necessary.)) itself, which is mostly easier for IM because of the connection to its own telecom.

[SPT3TMS-9395 **]**

The second form of system architecture is one where the IM and ROC work together and the ROC provides the hardware (mobile device) on the traction unit and either uses a default HMI from the IM or develops its own user interface. **[**SPT3TMS-9392 **]**



[SPT3TMS-9389 **]**

Figure 23: c-DAS with Trackside and Vehicle Software uniform from IM

+ "Closed status loop" for displaying the transmitted driving recommendations on the GUI of the TMS

- No systemic clear separation between ROC and IM (only on the traction unit).

+ IM only has a technical interface up to the traction unit.

- Joint, complex project between IM and ROC necessary for success.
  IM must provide a default user interface on the mobile device.

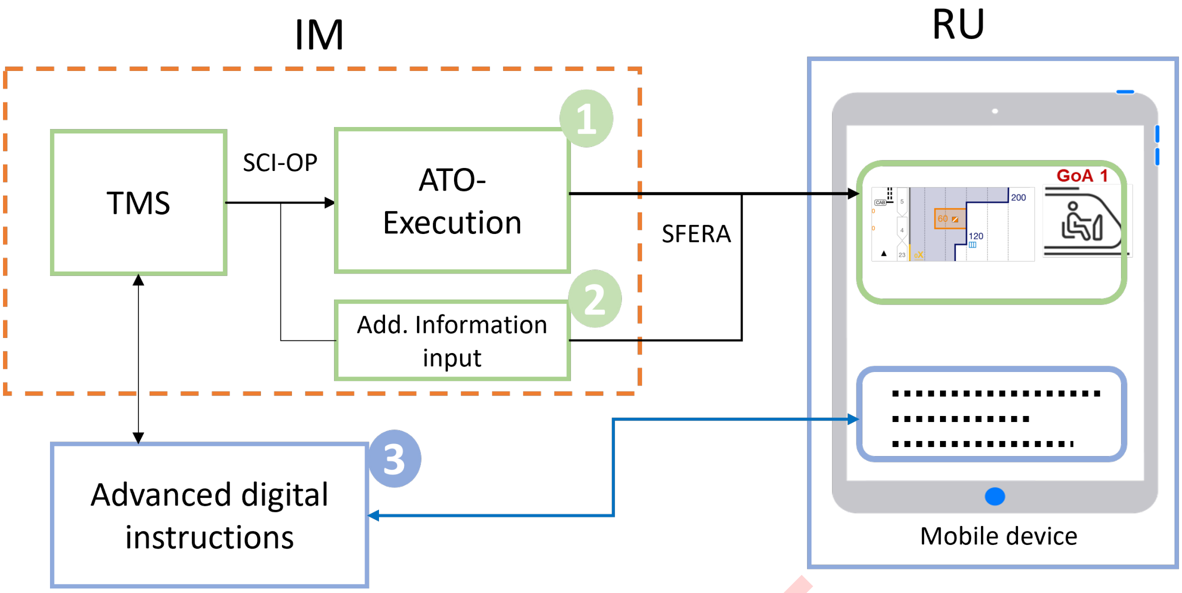
+ Fewer interfaces and media interruptions make the system faster to roll out and more consistent in use and monitoring.

+ IM can implement extensions more easily and migrate the communication channels of the future easily.

[SPT3TMS-9386 **]**

9.3 Scope and Exclusions

There are essentially three information structures to be distinguished:



[SPT3TMS-10870]

Figure 24: Information channels in/excluded c-DAS

9.3.1 ATO Execution Core functions (1)

In addition to the static route data, a "dynamically integrated and conflict-free" driving profile and the information on operational times are provided dynamically. [SPT3TMS-9377]

The driving profile is supplemented with a tolerance information, which enables the locomotive staff to drive within the conflict-free area.
The information is updated automatically when the production specification is updated. [SPT3TMS-9376]

The static route data according to speed restrictions of the topology are displayed. This data is supplemented with the existing speed restrictions. [SPT3TMS-9374]

In addition to the basic data, steering information (why do they receive a driving recommendation) is displayed to the locomotive crew. The basis for this is the information from the TMS. [SPT3TMS-9372]

The information is updated automatically by the TMS when the production specification is updated. If the update contains a route change, this is displayed to the locomotive staff. Notification in the event of an acknowledgement obligation still takes place via the conventional communication channels. [SPT3TMS-9499]

9.3.2 Additional unidirectional Information (2)

There is an integrated communication option between the locomotive crew and the dispatcher or train dispatcher for the transmission of standardised messages. [SPT3TMS-9497]

This can be all information that is relevant for the train driver in addition to an energy-optimised driving profile.
The timetable with commercial traffic times and stops is also displayed. [SPT3TMS-9495]

9.3.3 Advanced bidirectional Communication (3)

This category of information includes all data and processes between the train driver and other persons involved that are not related to a driving strategy.
Digital written orders and any other digital information, that are today manually (by paper) covered. [SPT3TMS-9493]

Messages requiring acknowledgement can be transmitted manually by the dispatcher and digitally acknowledged by the locomotive staff. [SPT3TMS-9490]

Messages requiring acknowledgement can be transmitted by the dispatcher. Acknowledgement by the train driver takes place via the existing communication channels (telephone). [SPT3TMS-9487]

Manual transmission of a message by the train driver for all other processes, such as departure readiness messages, digital load slips (cargo), digital work order information etc., is possible. [SPT3TMS-9479]

9.3.4 Scope Conclusion

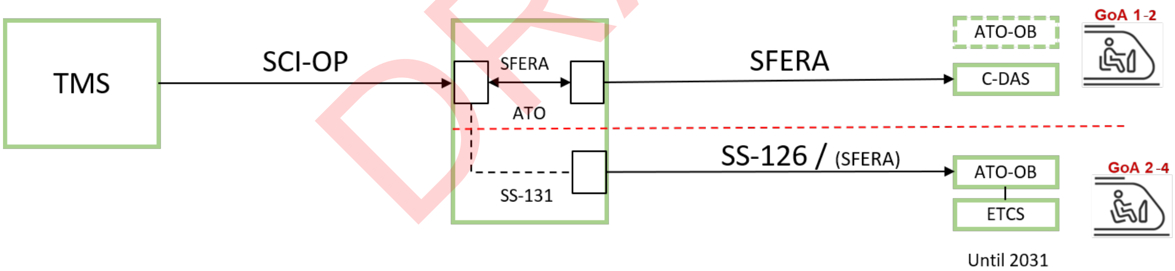
An ATO Execution system should be a pure system for calculating and transmitting an optimal (energy-optimal and conflict-avoiding) driving profile (1). [SPT3TMS-9478]

Important additional information, such as route data, speed restrictions and the context-sensitive explanation of a driving recommendation should also be part of a ATO Execution system (2). [SPT3TMS-9475]

Other processes that deal with the digitalisation of work steps and communication with the train driver should be handled outside of an ATO Execution (3). This includes processes such as "digital written orders" and all data requiring logging and confirmation processes. In particular, data exchange with the train driver that requires logging and confirmation can place considerable demands on the safety of the system. These potentially safety-relevant processes should not be mixed with a driver advisory system, which is not safety-relevant per se (no SIL). [SPT3TMS-9472]

Should it make sense in the future to digitalise the entire communication with the train driver, then synergies can be generated through the joint use of telecom communication of the ATO Execution or also extensions of certain protocols. In order to realise a uniform presentation of all information important for the train driver (not only c-DAS), but different applications can also be developed on the mobile device (1+2 / 3). When introducing ATO on board units (OBU), the c-DAS specific presentations can then very easily switch to the ATO OBU, while other applications for other processes remain on the mobile device. This also keeps future ATO installations and developments lean and manageable. [SPT3TMS-9335]

9.4 ATO Coexistence and Migration



[SPT3TMS-9338]

Figure 25: Technical migration scenario c-DAS to ATO

An existing c-DAS can facilitate the migration to ATO through the GOA 1 stage and can very easily make essential added values of ATO-GOA-2-4 available and usable at a very early stage. [SPT3TMS-9572]

The migration of a complete rolling stock fleet with new ATO OBUs, all of which require approval, can take a long time to migrate. During this migration phase towards ATO GOA 2-4, valuable knowledge can be gained for the TMS and CCS surrounding systems for the application of an ATO operation. Likewise, a coexistence of both system worlds during the migration period to a full expansion of ATO (GOA >= 2) is technically easy to realise. [SPT3TMS-9573]

For the entire duration of the development and upgrade to ATO systems with GOA 2-4, an actively operated, network-wide c-DAS/ATO Execution can not only gain important experience with the communication to the traction unit, but also realise major business cases at an early stage, such as the saving of traction energy (2-5%) as well as the development of a powerful TMS, which is thus already prepared for the fine-granular control of rail traffic when the first ATO components are introduced. [SPT3TMS-9568]

10 CMS & TMS out of Scope

This chapter lists a selection of functionality linked to CMS & TMS which are currently considered “out of scope”.

10.1 Automatic Route Setting

Automatic route-setting (ARS) functionality triggers interlockings to set and lock routes for a specific train. Based on the applied procedure for ARS, the application may be split into a vital component allocated to the Central Traffic Control (CTC) and a non-vital component embedded into the execution functionalities of the timetable. The Traffic Management system sends information about current plan including routes for the trains to the ARS function allocated to the CTC to trigger the setting and locking of a route for a specific train. **[**SPT3TMS-9569 **]**

10.2 Train Describer System

The Train Describer System (TDS) visualises the track and signalling infrastructure and status and indicates trains' positions based on information from track occupation detection devices. The Train Describer System is also often considered a part of the Central Traffic Control (CTC).((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 7 f.)) **[**SPT3TMS-9570 **]**

10.3 Alarm Management

Alarm management affects rail service and safety. The modern railway consists of many complex and highly automated systems that enable a relatively small number of people to monitor, control, and maintain trains, signalling, and infrastructure, remotely. Each of these systems may produce many hundreds of alarms, alerts, warnings, and notifications to maintain operator situation awareness and require an efficient Alarm Management System.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 8 f.)) **[**SPT3TMS-9571 **]**

10.4 Asset Management and Maintenance

Asset management comprises all systems, methods, procedures, and tools to optimise costs, performance, and risks for the complete life cycle. The aim is to realise the best 'value for money'. Maintenance is required to achieve the goals for reliability and quality of service. When Assets deteriorate service performance will decrease which will result in a loss of passengers or freight transportation volume. Different strategies allow various concepts for preventive, predictive or condition-based Maintenance. Furthermore, real-time data, big data and digitalisation are improving the way maintenance can be predicted and optimised.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 9)) **[**SPT3TMS-9564 **]**

10.5 Traffic Control

Central Traffic Control (CTC) communicates critical real-time data between different interfaces traditionally structured as a Point2Point Messaging allows for specific procedural safety protocols to mitigate defined Hazard rates. The CTC receives information on the operational and updated capacity plan communicated to the field signalling systems.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 9 f.)) **[**SPT3TMS-9565 **]**

10.6 Communication Module

WATO and ATO-TS communicate the messaging processes between trackside and onboard. In case of WATO, the Communication Module provides the API to the Integration Layer and translates the data from and to the train. In case of ATO-TS approach, the internal architecture is flexible how the communication managing function and a possible API are embedded in the system implementation.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 14)) [SPT3TMS-9566]

10.7 Integration Layer

The Integration Layer carries and persists the different data following an interoperable Data Model and provides this information and services to all subscribed clients and services (CTC, Timetable Management system, ATO Control, Asset Management, and other internal and external systems) through an API. ((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 15)) [SPT3TMS-9567]

10.8 Passenger Information System (PIS)

Passenger Information Systems provide passengers with various information e. g. status of the trip, route, connections and even travel disruption. This information can be displayed via monitors onboard the train or at any location at the trackside/terminals or via mobile devices. The data related to traffic status are broadcasted via IL.((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 15 f.)) [SPT3TMS-9485]

10.9 Rail Passenger and Employee Security

New technologies such as CCTV surveillance, facial recognition, metal detectors are introduced into rail services both for security for new infrastructure such as train stations and for rolling stock and will have a strong impact of the architecture and processes of the different rail business services to fulfil the increasing passengers' demands for security and convenience of mobility from booking to travelling. ((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 16)) [SPT3TMS-9488]

10.10 Traffic Control and Supervision (Traffic CS)

Traffic Control and Supervision executes the operational plan controlling and reporting infrastructure usages (traffic, stabling, possessions, etc.). The execution of a plan controls infrastructure users and infrastructure states in a compatible and safe way to fulfil the commands inside of plan at the right time. The used safety logic to reach this shall integrate all types of track usage (like shunting or trackworker) into a highly automated control and supervision process. This system shall be identical in all CCS/TMS installations in terms of interface.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 12)) [SPT3TMS-9491]

10.11 Train Control and Supervision (Train CS) and Interfaces to Traffic CS

Train Control and Supervision contains all CCS/TMS onboard functions, especially for ATO, ATP, radio, localisation, map services, ensuring train integrity and known train length, and advisory information systems used by the driver for operational reasons. The future vehicle CCS/TMS architecture shall offer a greater adaptability, upgradeability, and maintainability. This will be achieved by a standardised modular approach based, also using standard interfaces to the rest of the vehicle systems (TCMS, Train Control

Management Systems). Train CS is expected also to provide innovations in regards the fully automatic driverless train movement.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 12 f.)) **[**SPT3TMS-9480 **]**

10.12 Field Force Applications Control and Supervision and the Interface to Traffic CS

All moving objects (persons, obstacle detection, construction sites, trackworkers, etc.) that can occupy or influence the track or trains – even without having wheels – shall be managed in the CCS/TMS production control loops. This means that requesting possessions, or just placing an object (like a heavy tool or a single wagon), a construction site or a person on the track shall be handled by the same production control processes (but respecting the different characteristics). Out of this the interfaces from Traffic CS to Field Force Applications CS shall implement commands like *Grant/revoke track usage authority*, *warn track user*, *show production situation to track user*, or *get track user's track occupation/position*.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 13)) **[**SPT3TMS-9481 **]**

10.13 Trackside Assets CS and the Interface to Traffic CS

Trackside assets are point-machines, level crossings, trackside train detection, adjacent IO systems with discrete input/output and conventional signals (where CCS/TMS borders legacy). The subsystems of the Trackside Asset CS (aka Object Controller) control and supervise the trackside assets. These Assets produce most of the trackside CCS cost. High scalability of cost/quality, open and flexible standard interfaces to integrate future technologies or different communication methods, long backwards compatibility, and separation of life cycles of Traffic CS Systems and Trackside Assets CS Systems are the targets.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 13)) **[**SPT3TMS-9482 **]**

10.14 Cross Cutting Systems

Cross-cutting systems are the Tool Chain for managing and maintain all other CCS/TMS systems. This includes services that provide map and asset information, that are used for diagnosis for maintenance, that allow to simplify configuration and deployment on network level, that authenticate and authorise CCS/TMS actors (persons, systems) or monitor security, or that provide generic technical platforms for the CCS/TMS systems. In general products for systems like Traffic Management or Traffic CS contain those functions (like diagnosis) as local features. Such component-local functions are needed also in future for example for migration, specialisation, or availability reasons.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 14)) **[**SPT3TMS-9483 **]**

10.15 Possession Management

There are many cases where the infrastructure assets are unavailable. The three scenarios describe the unavailability of the infrastructure for trains are: the asset is possessed from another train - for the asset maintenance activities are executed - the asset is technically not available (default). The unavailability of assets may be represented on the Train Graph (TG) and is one key input used by the "Conflict detection and resolution Module".((Shift2Rail, X2Rail-4, Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers, 2021, p. 7 f.)) **[**SPT3TMS-9469 **]**

11 System Interfaces

The goal is for data flows from and to TMS to be open and expandable. An open capacity management platform should allow the implementation of future features. TMS has a large set of external interfaces to a variety of enterprise systems for coordinating planning, deviation management, and providing information about production status. They are defined as a set of standard interfaces. TMS shall offer standard APIs (e.g., for displaying a picture of the track layout) that may be used by other applications and shall, especially, be capable of providing interfaces to other transport modes. **[**SPT3TMS-9473 **]**

11.1 Interface for Traffic Control and Supervision: SCI-OP

The interfaces between TMS and CCS is named SCI-OP.
Traffic Control and Supervision executes the operational plan received by the Traffic Management System. The execution of the plan is performed with control of infrastructure users and infrastructure states in a compatible and safe way to fulfil the commands inside of plan at the right time. Infrastructure usages (traffic, stabling, possessions, etc.) is controlled and reported to TMS. Traffic CS splits incoming plans into single commands for the control level, checks the compatibility of the commands from a safety point of view, and sends them to the actors of the physical field level (trains, trackworkers, trackside assets, etc.). It supervises and aggregates the status of all "physical field level" actors as logical object information and events and reports them to Traffic Management System to give the status of traffic and Infrastructure usages. **[**SPT3TMS-9476 **]**

11.2 Interface to Automatic Train Operation Execution (AE)

The interface is named SCI-OP. **[**SPT3TMS-9453 **]**

11.3 Infrastructure Management Systems (asset state, track access)

These systems are responsible for the control, maintenance, and supervision of the trackside assets to ensure safe track usage as required by the system Traffic Control and Supervision. The system architecture defines trackside assets (like points or signals) as subsystems with standardised interfaces to command and control physical objects. **[**SPT3TMS-9454 **]**

11.4 Track/Network Condition Systems (sensors, alarm management, etc)

These systems/ interfaces are required to detect or monitor the train conditions to reactions upon certain events to ensure a high quality and safe service. **[**SPT3TMS-9456 **]**

11.5 Yards/Terminals Systems

Intelligent freight trains relying on the digital automatic coupling (DAC) where automation is applied to its full capacity, e.g., automated yards, train preparation, operation and maintenance, and intermodal terminals.((Europe´s Rail, 20211216-Master-Plan_agreed-in-princ_clean, 2022, p. 41)) Other high TRL activities comprises demonstration around improved terminal operations, for example with the use of intelligent video gate captured information.((Europe´s Rail, 20211216-Master-Plan_agreed-in-princ_clean, 2022, p. 39)) **[**SPT3TMS-9458 **]**

11.6 Interface to Engineering and Topology Data

This is expected to be broken down further for example to broadcast the availability of new data, to provide an index of data, and to provide an endpoint for interfacing systems to download data. Systems that download data from the Data Management System must manage their data configuration to make certain that they have the appropriate version (utilising the appropriate Data Management System function(s) that enable this).((Europe´s, Annex 2 CCS_TMS Systems Architecture: Annex 2 CCS/TMS/CMS Systems Architecture, 2022, p. 55)) **[**SPT3TMS-9447 **]**

11.7 CCS Configuration Management

The aim is to define methods/protocol/data to be shared by the system components and define the configuration management set of functions to be provided as a basis for a standardised management process on network level for CCS+ systems. **[**SPT3TMS-9449 **]**

11.8 Identity and Access Management for Systems and Persons

The identity and access management decide which role has access to which functionalities and buildings. Roles can be defined in the operational and support area. A quick and easy access tool should give one access to systems and personalised set ups, can be realised. It must identify persons and systems which exchange e.g., information's, devices, and link unique identities in addition to the exchange objects. **[**SPT3TMS-9451 **]**

11.9 Integrated User Interface

An integrated user interface based on graphics where the railway's signalling system is represented as well as the operational status of the TMS components, through a set of graphical resources such as layouts and views. This supports an intuitive use of TMS and will reduce training time. The integrated User Interfaces should be able to integrate real-time status and forecast data from sub-systems and applications like the Railway Infrastructure, trains, CCS were specified collaboratively by the partners. **[**SPT3TMS-9452 **]**

11.10 Interfaces to Rail Operation Companies (ROC)

Fully digitalised operations, planning and management functions as well as delivering specific solutions for integrated rail cargo systems, including connected digital services (e.g., capacity and yield management, multimodality with predictive Planned Time of Arrival, load and empty flows equilibrium) and terminal improvements that drive innovation in customer interactions: the objective is to ensure rail is integrated in the logistics value chain, feeding into logistic information exchange systems. This should considerably increase productivity (including shortening the average transportation time and increasing capacity utilisation), reliability and flexibility of rail freight.((Europe´s Rail, 20211216-Master-Plan_agreed-in-princ_clean, 2022, p. 25)). Also the interface to the fleet management system exchanges information with the ROCs' production systems including some relevant functionalities for Train CS such as: determine mission data, request train wake-up, forbid start, ensure communication with passengers, provide video stream, process remote driving commands, register autonomous train unit, and manage remote driver requests **[**SPT3TMS-8697 **]**

11.11 Other Transport Management Systems (multi-modal)

Multi-modal open capacity management platform is the extended vision for traffic planning is to implement large demand-and-satisfy intelligent interaction networks like this known or modern transport sharing applications, to achieve a high grade of Business2Business automation, real-time response to customer needs, maintainability, availability, performance, and cost reduction. Other transport management systems can be found in the topics of Railway Operations, Traffic Planning and Management, Asset Management & Maintenance, Traffic Control, or other business services. **[**SPT3TMS-9437 **]**

12 Business Objectives

The Business Objectives are derived from the identified impacts of the EU-Rail Master Plan and are based on the importance of delivering an overall system view. Business objectives in this document were copied from the original document, sorted in alphabetical order and coded with CBO(xxx) to ease referring to them in other chapters and documents and link them to the achieved Common Business Objectives (CBOs). The original CBOs are here: T1_Common_Business_Objectives . **[**SPT3TMS-8700 **]**

The relevant CBOs are:

- analytical information for passenger flow/incidents(1) -> CBO001
- analytical information for passenger flow/incidents(2) -> CBO002
- ATO(1) -> CBO003
- ATO(2), automated shunting -> CBO004
- attractive labour -> CBO005
- availability, robustness, reliability -> CBO006
- automate operators knowledge management -> CBO007
- changeability -> CBO008
- changeability and upgradeability(1) -> CBO009
- changeability and upgradeability(2) -> CBO010
- changeability and upgradeability(3), simplified integration -> CBO011
- completeness of planning and live update -> CBO012
- comprehensive incident management -> CBO013
- continuous supervision -> CBO014
- deep/optimized plan -> CBO015
- efficient energy use(1) -> CBO016
- efficient energy use(2) -> CBO017
- efficient migration based on adaptable systems -> CBO018
- flexible use of infrastructure capacity -> CBO019
- implement a full system optimisation approach for better capacity -> CBO020
- increase capacity -> CBO021
- multi-modal mobility(1) -> CBO022
- multi-modal connections(2) -> CBO023
- new technologies, harmonized processes -> CBO024
- non invasive/noticeable cyber security -> CBO025
- optimize timetables -> CBO026
- rapid deviation information/solution -> CBO027
- rapid response to capacity request -> CBO028
- rapid return of experience -> CBO029
- reduce human elements and factors -> CBO030
- reduce noise, reduce vibration, reduce carbon emissions -> CBO031
- smart/assisted incidence handling -> CBO032
- standard know how -> CBO033
- standardized architecture(1) -> CBO034
- standardized architecture(2) -> CBO035
- suitable cyber-security levels -> CBO036
- system robustness and robustness against weather -> CBO037
- systems: extensible capacity, scalability(1) -> CBO038
- systems: extensible capacity, scalability(2) -> CBO039
- tools support new services -> CBO040
- validated system performance, robust PRAMSS framework -> CBO041
- viable forward/backward compatibility -> CBO042
- viable migration path -> CBO043

[SPT3TMS-8701 **]**

13 Non-Functional Considerations

13.1 Reliability

TMS is a reactive system that interacts continuously with other components throughout the overall systems landscape. Its behaviour is driven by data fed into it via its interfaces. TMS will re-distribute data back to its systems environment immediately after receiving and processing it. **[**SPT3TMS-9440 **]**

Data processing must occur within defined timespans. Any lack of reliability in TMS carries the risk of dependent systems also failing to work reliably. **[**SPT3TMS-9541 **]**

Important aspects to be considered by TMS:

- Correctness, i.e., calculations are performed without any errors, and any output produced must be correct and capable of being processed by the environment.
- Concurrency (parallel processing), i.e., the ability to process multiple calculations simultaneously. The capability to process concurrently applies to both requests of an entirely independent nature (e.g., geographically, or logically – example: train number) and to the joint processing of requests (bundles of train paths).
- Resistance to Resilience against
    - Errors resulting from inconsistent or incomplete input data (via interfaces or manual input),
    - Defects,
    - Systems overload.

[SPT3TMS-9534 **]**

- Defined timing (performance) to:
    - Transmit results in a timely manner and free of avoidable repetitions (repeated reading or writing of the same data in the same service or context),
    - Perform any calculations with minimal latency and with one second,
    - Provide immediate user feedback (e.g., upon data entry, mouse click),
    - Provide minimum latency calculation via interface requests (e.g., path request),
    - Provide simultaneous (synchronised) display of information to all users,
    - Enable synchronisation between all server instances minimum latency,
    - Near-real-time capabilities able to support future requirements from digitisation projects.

[SPT3TMS-9533 **]**

- Elasticity, i.e., the ability to adapt to changing loads and thus to process varying data volumes and frequencies (scalability), and to remain responsive at all times without any negative impact on timing / latency.
- Timing behaviour is intended as follows:
    - TMS uses coordinated universal time UTC. For display purposes, time values are converted to the local time zone, the maximum permitted deviation between TMS and UTC is 10 milliseconds.
    - The granularity (minimum resolution) for calculations, logs, interfaces, and timestamps is 1 millisecond.

The granularity (minimum resolution) for commercial / operational data is 1 second. **[**SPT3TMS-9532 **]**

13.2 Availability

In case of TMS downtime, the dispatching system is no longer supplied with timetable data. There is no automatic generation of timetable data. As a consequence, railway operations realistically cease after some time due to the timetables not being transmitted by TMS. This is hence neither acceptable for TMS operating in normal mode nor in maintenance mode. **[**SPT3TMS-9536 **]**

The maximum permitted annual downtime of a national TMS is 10 minutes, which translates into a mandatory minimum annual availability of 99.998%: **[**SPT3TMS-8705 **]**

Availability is significantly improved via timely detection and proactive elimination of errors. To make this possible, TMS is equipped with extensive real-time diagnostic and monitoring functionality. For this purpose, potential error cases and effective error handling strategies addressing each of these must be identified in advance and implemented. Other parts of TMS not affected by the error must continue to function without restriction. **[**SPT3TMS-9527 **]**

TMS's availability must not be compromised by maintenance windows with service interruption, and no maintenance windows leading to system downtime are envisaged. The architecture and the operating concept shall support updates, including replacements of hardware, and updates of operating systems, middleware, database, and application versions, without any interruption to system availability. Furthermore, operations-driven changes to master data without any changes to data structures or data semantics shall be carried out during operation and outside maintenance windows. **[**SPT3TMS-9529 **]**

13.3 Maintainability

TMS is predicted to remain in active service for 20 years or longer. High maintainability is hence a crucial pre-requisite for its ability to support successful changes with reasonable effort – especially given the limited availability of experts on this topic. **[**SPT3TMS-9530 **]**

To ensure TMS's maintainability:

- **Development** adheres to the EU Rail process.
- **Documentation**, detailed specifications for interfaces and algorithms in particular, adhere to EU Rail stipulations.
- Designs are:
    - Modular, with a decomposition into atomic, individually testable units.
    - Utilise:
        - Generally known and accepted design patterns.
        - Tested components (COTS).
        - Industry interface standards.
    - Capable of supporting fully automated testing.
- The Implementation:
    - Uses a widely used programming language.
    - Uses open source whenever possible.

[SPT3TMS-9531 **]**

A lack of portability, e.g., to newer versions of standard software products used or to different hardware, significantly reduces maintainability. Therefore, whenever possible, standards must be used in design and adhered to during implementation. The use of and adherence to standards must be ensured throughout the development process, and any use of vendor-specific extensions must be kept to a minimum, encapsulated within the software, and must be documented. An impact analysis must be performed and approved as part of the development process before any deviations from standards, especially pertaining to avoidance of standard products, may occur. A list of approved exceptions shall be kept. **[**SPT3TMS-9522 **]**

Likewise, the chosen architecture influences maintainability: maintainability is improved by clear definition and documentation of services and their interfaces and by describing:

- The services' task and/or purpose.
- Input / output structures.
- Error and exception handling.
- Conditions (pre- / post conditions).
- Versioning concepts used.

[SPT3TMS-9518 **]**

Safety-relevant application rules according to EN 50128 (SAR) Functionality may only be used via the interface published by the subsystem. Implementation details of the subsystems must remain hidden by their interfaces and thus remain changeable or replaceable. Minimal dependency between subsystems must be aimed for. **[**SPT3TMS-9520 **]**

Maintainability further requires that organisational changes, or changes to the operating concept may be performed without changing the software (configurability, decoupling of use and operating concept). In terms of availability, diagnostics and monitoring, the software design must ensure decoupling between operational use and operating concepts (locations, workstation design). Maintainability must be ensured over a long period of time (> 20 years). Lifecycles of any products selected must be analysed, and their longevity proven. **[**SPT3TMS-9511 **]**

Good maintainability of TMS requires, among other things:

- Support for flexible deployment with an identical architecture with the infrastructure options of:
    - On-premises.
    - Private cloud.
    - Public cloud.
- The use of a web client without the need for any local software installations.
- Consideration of virtualised and standardised server hardware for the technical architecture.

[SPT3TMS-9512 **]**

13.4 Safety

The development of TM components typically has minimal safety requirements i.e., only assure the operational plan is fit for purpose to the operate the railway.((Europe´s , CCS_TMS System of Systems Architecture: CCS and TMS System Architecture, 2022, p. 11))TMS is intended as a non-safety-relevant system and is not intended to assume any responsibility for safety as per to EN 50126-1 or EN 50128. No safety targets are expected for TMS, and hence no risk minimizing measures are envisaged for it. **[**SPT3TMS-9513 **]**

This assumption is based on:

- Comparable functionality in currently used systems being implemented without safety responsibility.
- No safety responsibility being assigned to TMS within the overall architecture (system of systems).
- No safety requirements existing for any of the interfaces propagating data from TMS.

[SPT3TMS-9514 **]**

As soon as SAR (safety-relevant application rules according to EN 50128) of the systems with which TMS interfaces are available, the assumptions will need to be checked. TMS must not assume any safety responsibility without the SAR for its interfaces explicitly requiring and permitting the transmission of safety-relevant data. **[**SPT3TMS-9505 **]**

13.5 Security

The CIA protection goals are **C**onfidentiality, **I**ntegrity, **A**vailability, Authenticity, Privacy, Reliability and (non) repudiation.

- Confidentiality: there are no specific confidentiality-related requirements, hence no special measures addressing either the "protection of information behaviour" or the "protection of information content" are required.

- Integrity: unauthorised data manipulation shall be precluded. Unauthorised data manipulation may impair the availability and reliability of TMS. Dedicated integrity requirements must therefore address:
  - The correctness of data (data integrity).
  - Functional correctness of the system (system integrity).
- Availability: availability-related requirements for availability are described in general terms. Additional considerations from a security perspective are that the system's availability must not be compromised by attacks upon it.
- Authenticity: Special requirements exist regarding:
  - Proof of identity of all interface partners (partner authenticity).
  - Proof that the data received originates from the authenticated instance (data authenticity).
- Privacy: There are no special requirements regarding privacy, and communication processes are not subject to any secrecy requirements. TMS is not intended to support anonymous use.
- Accountability: There are no special requirements regarding immutability. Technical traceability of use (e.g., via data logging) must be ensured.
- Non-repudiation: There are no special requirements for non-repudiation. Technical traceability of use (e.g., via data logging) must be ensured.

[SPT3TMS-9507 **]**

TMS must provide medium levels of protection against intentional violations of security requirements. It shall, however, be accepted that this level of protection will be surmountable to persons with average knowledge of the system applying a medium amount of effort. **[**SPT3TMS-9509 **]**

14 Safety Legislation

14.1 Safety Regulations

The development of TMS takes place in compliance with the recognised rules of technology according to European and National rail legislation. Recognised rules of technology manifest themselves in standards. EN 50128 is therefore applied to the development independently of the determination of the SIL; in the absence of a safety responsibility, further development takes place in SIL 0. EN 50128:2012 applies to 'Railway applications - telecommunications, signalling and data processing systems Software for railway control and supervision systems. TMS is a railway control and supervision system, non-application is generally not permitted. According to the law railway installations and vehicles must be constructed, operated, maintained, and renewed in accordance with the requirements of traffic, environmental protection, and the state of the art. The EN 50126, the EN 50128, the EN 50129, and the EN 50159 are considered as recognised rules of technology in Europe. **[**SPT3TMS-9510 **]**

14.2 Identified Legislation and its Impact

The following table Identified Regulations lists the identified Regulation with characteristic of relevant safety legislation for the system incl. the impact on the system:

Legislation	Impact on System
Commission Implementing Regulation (EU) 2019/773 of 16 May 2019 on the technical specification for interoperability relating to the operation and traffic management subsystem of the rail system within the European Union and repealing Decision 2012/757/EU	Taking interoperability into account EU directive on interoperability, also Traffic Management System
Directive (EU) 2016/798 of the European Parliament and of the Council of 11 May 2016 on railway safety	Consideration of the Common safety methods (‘CSMs’) In particular, the consideration of Article 6- Common safety methods (‘CSMs’)
Railway applications - Communication, signalling and processing systems Software for railway control and protection systems	Development according to EN 50128 Implement specifications and processes according to EN 50128
Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 1: Generic RAMS Process	Consideration of RAMSS EN 50126-1 Observance of the processes according to EN 50126 - 1

Legislation	Impact on System
Railway Applications - The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) - Part 2: Systems Approach to Safety	Consideration of RAMSS EN 50126-2 Observance of the processes according to EN 50126 - 2

[SPT3TMS-9356 **]**

15 Assumptions

Although it is assumed that a much higher level than today’s can and shall be achieved, above a certain threshold automation can become counterproductive depending on technological evolution. It is important to analyse all automated CCS and TMS systems to determine the right level of automation and integration of human and system interactions as well as to identify any legal and commercial constraints that may make human decisions necessary. The architecture shall offer (system/user) interfaces to allow a high grade of automation in the future evolution - but the implementation steps need to follow a European optimal balance, building upon national input that needs to be analysed in the System Pillar.
[SPT3TMS-9358 **]**

16 Bibliography

Europe´s , R. (2022). *master CCS_TMS System Of Systems Architecture_220715%20(3).docx* **[**SPT3TMS-16211 **]**

Europe´s Rail. (2022). *20211216-Master-Plan_agreed-in-princ_clean.* **[**SPT3TMS-16176 **]**

Europe´s, R. (2022). *_master CCS_TMS System Of Systems Architecture_220715%20(3).docx* **[**SPT3TMS-16210 **]**

Europe´s, R. (2022). *CBO: WP2 - Common Business Objectives* **[**SPT3TMS-16177 **]**

Europe's Rail Joint Undertaking (2022) **[**SPT3TMS-16212 **]**

Shift2Rail, X2Rail-4. (2021). *Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers.* **[**SPT3TMS-16173 **]**

Shift2Rail, X2Rail-4. (2021). *Abstract D9.1 - Deliverable D9.1 Amendment to the SRS of the Integration Layer: Advanced signaling and automation system – Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers.* **[**SPT3TMS-16172 **]**

3113-5-ScopeDefinition_Deliverable_V0.1 **[**SPT3TMS-16174 **]**

RCA doc 73 System Concept ATO execution **[**SPT3TMS-16175 **]**

RCA.Doc.31, SCI-OP (Standard Communication Interface Operational Plan) **[**SPT3TMS-16178 **]**

X2R4-WP03-D-ALS-009-10_-_Deliverable_D3.2_-_GoA34_Specification.docx **[**SPT3TMS-16182 **]**

X2R4-WP03-D-ALS-009-10_-_Deliverable_D3.2_-_GoA34_Specification.docx **[**SPT3TMS-16181 **]**

ATO over ETCS - System Requirements Specification – Subset 125, issue 0.1.0 **[**SPT3TMS-9467 **]**

ATO over ETCS - ATO-OB / ATO-TS FFFIS Application Layer – Subset 126, issue 0.0.16 **[**SPT3TMS-9470 **]**

Commercial Conditions – RNE-FTE Common Understanding 13/06/2022 **[**SPT3TMS-16179 **]**

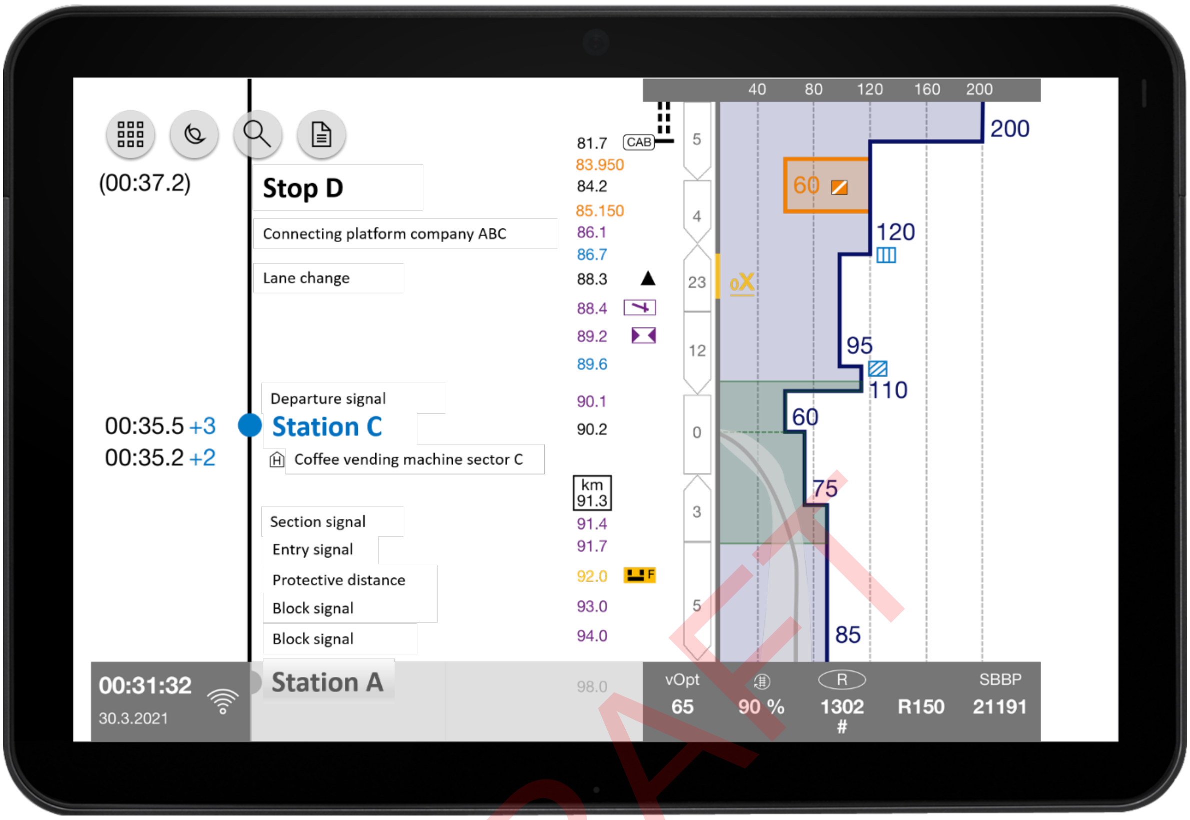
17 Appendix A

17.1 TMS Interface With Voice Communication

Interface To Voice Communication

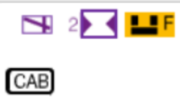
18 Appendix B

18.1 Example of HMI for C-DAS



[SPT3TMS-9360]

Figure 1: Example prototype c-DAS HMI with kind permission from (c) SBB AG

00:35.5	Operationally relevant arrival / departure time
+11	Deviation from commercial arrival / departure time
(00:32.4)	Operationally relevant transit time
	Next stop
	Relevant infrastructure objects such as barriers, balise, protective sections, CAB boards.
	Track classes (e.g., extended speed range)
	Effective slope information (slope, gradient)

	Decisive slope information
	Non-stopping area
	Tolerance driving bandwidth information (until the next stop)
	Slow speed point
	RADN maximum speed
	End of curve (R / N)
	Route
	Station
	Centre BP or center platform
	Speed spectrum (depending on the selected train / brake series)

Table 1: Legend c-DAS HMI

Figure 1 and Table 1 are representation on the HMI of a c-DAS should provide the following qualitative information:

- The relevant information for the journey from topology, speed restrictions and local regulations are displayed.
- The route preview is displayed in the same way as the ETCS display.
- By means of a prominently highlighted display of the next commercial stop and the display of driving recommendations (as soon as available) only up to the next commercial stop, erroneous passage is counteracted.
- In addition to the optimal speed line, permissible bands are displayed, which show the train driver the available tolerance range, according to the known blocking times available in the TMS.
- Information on deviating stopping places is initially loaded and displayed.
- Display of a guidance preview already before departure with driving profile and, if necessary, a message text that draws attention to operational deviations/specialties.
- In addition to the signals on the line (if available), the signals within the station (section signals) are also displayed.
- Driving recommendations are visualised as an optimum line, free of conflicts with permissible speeds and speed restrictions.
- The preview horizon of the journey recommendation ("journey profile") is limited by (at most) the next commercial stop.
- In addition to the operationally planned times, currently scheduled production times from the TMS are displayed dynamically (forecast arrival, departure, or transit times per operating point).

[SPT3TMS-9347 **]**

19 Appendix C

19.1 Abbreviations

AI Artificial Intelligence **[**SPT3TMS-12977 **]**

API Application Programming Interface **[**SPT3TMS-12976 **]**

ARS Automatic route-setting **[**SPT3TMS-12979 **]**

ATO E Automatic Train Operation Execution **[**SPT3TMS-12978 **]**

ATO Automatic Train Operation **[**SPT3TMS-12973 **]**

AT-TS ATO-Trackside **[**SPT3TMS-12972 **]**

CCTV Closed Circuit Television Systems **[**SPT3TMS-12974 **]**

CDAS Connected Driver Advisory System **[**SPT3TMS-12980 **]**

CIA Confidentiality, Integrity, Availability **[**SPT3TMS-12986 **]**

CM Communication Module **[**SPT3TMS-12985 **]**

CMS Capacity Management system **[**SPT3TMS-12984 **]**

COTS Commercial Off The Shelf **[**SPT3TMS-12983 **]**

CRD Central Reference Data **[**SPT3TMS-12990 **]**

DCM Digital Capacity Management **[**SPT3TMS-13005 **]**

E2E End to End **[**SPT3TMS-12988 **]**

ETMN European Traffic Management Network **[**SPT3TMS-12997 **]**

ETx Estimated Time of Arrival/Departure/ Handover/ Run-through **[**SPT3TMS-12996 **]**

EU European Union **[**SPT3TMS-12995 **]**

HMI Human Machine Interface **[**SPT3TMS-12994 **]**

IL Integration Layer **[**SPT3TMS-13001 **]**

IM Infrastructure Manager **[**SPT3TMS-13000 **]**

IO Input/Output **[**SPT3TMS-12999 **]**

IOT Internet of Things **[**SPT3TMS-12998 **]**

IT Information Technology **[**SPT3TMS-13002 **]**

KPI Key Performance Indicator **[**SPT3TMS-12953 **]**

PCS Path Coordination System **[**SPT3TMS-13008 **]**

RAMSS Reliability, availability, maintainability, safety, and security **[**SPT3TMS-12952 **]**

RIM Rail Infrastructure Manager **[**SPT3TMS-12957 **]**

RIS Railway Infrastructure System **[**SPT3TMS-13006 **]**

ROC Rail Operating Company **[**SPT3TMS-12956 **]**

SAR Safety-relevant Application Rules **[**SPT3TMS-12955 **]**

SCI Standard Communications Interfaces **[**SPT3TMS-12954 **]**

SW Software **[**SPT3TMS-12961 **]**

T2T Track to Train **[**SPT3TMS-12960 **]**

T2T CM Track to Train Communication Module **[**SPT3TMS-12959 **]**

TAF/TAP Telematics Applications for Freight/Passenger Services **[**SPT3TMS-13004 **]**

TCC Traffic Control Centre **[**SPT3TMS-12958 **]**

TCMS Train Control Management Systems **[**SPT3TMS-12964 **]**

TCR Temporary Capacity Restriction **[**SPT3TMS-12963 **]**

TCS Train Control & Supervision **[**SPT3TMS-12962 **]**

TG Train Graph **[**SPT3TMS-12968 **]**

TMS Traffic Management System **[**SPT3TMS-12967 **]**

TOC Train Operating Company **[**SPT3TMS-12966 **]**

TPE Train Path Envelope **[**SPT3TMS-12965 **]**

TPM Train Performance Management **[**SPT3TMS-12971 **]**

TRL Technology Readiness Level **[**SPT3TMS-12970 **]**

TSI Technical Specifications for Interoperability **[**SPT3TMS-13010 **]**

TSR Temporary Speed Restriction **[**SPT3TMS-12969 **]**

UTC Universal Time Co-ordinated **[**SPT3TMS-12982 **]**

WATO Wayside ATO **[**SPT3TMS-12981 **]**

20 Appendix D

20.1 Glossary

- Operating state
The operating state describes the current state of production:
* how trains move
* where trains are
* which route is set in control system
* status of assets
This information is based on inputs from control systems. **[**SPT3TMS-15942 **]**

- Capability
The ability of a system in performing a specific functionality **[**SPT3TMS-15941 **]**

- Capacity
The total overall capability of the infrastructure that can be utilised by traffic or by maintenance. Capacity may apply to specific geographic sectors like stations or lines. Capacity usage must be requested, which results in capacity demand. **[**SPLI-1283 **]**

- Capacity Restriction
Capacity restriction is a temporary full or partial unavailability of network infrastructure due to construction works, maintenance, inspection works or due to environmental influences and disruptions. **[**SPLI-1284 **]**

- Capacity Planning
Capacity Planning is an instrument to determining the total theoretically available capacity supply (max. number of journeys per direction) and compare it to demand. Capacity can be requested from long term to short term (ad hoc slot ordering). Capacity planning supports the planning along all-time horizons (strategic to short term). **[**SPLI-1285 **]**

- Capacity Plan
The capacity plan comprises any planned capacity usage (traffic and construction works) at any point in time during the planning period. The aim is a consistent and conflict free capacity plan. **[**SPLI-1286 **]**

- Capacity Production
Capacity production is the implementation of the operational plan. Capacity production begins when the train starts its scheduled mission and ends with when it ends. **[**SPLI-1287 **]**

- Conflict
A conflict is any difference between the operational plan and the forecast, regardless of any actual need for intervention to resolve it. **[**SPLI-1288 **]**

- Dispatching
Dispatching is the sum of actions intended to make modifications the operational plan. **[**SPLI-1289 **]**

- Deviation
A deviation is any difference between the operational plan and the actual state of traffic; unlike a conflict, deviations may only be mitigated but not solved. **[**SPLI-1290 **]**

- Decision
A decision is a single action intended to make a modification the operational plan. **[**SPLI-1291 **]**

- Forecast
The forecast displays the future state of traffic. It based on the current operational state. The forecast projects the current operational plan into the future. A forecast for each train run under consideration of mutual train influence is processed (train run time, section run time, minimal section run time, detailed topology, headways and train sequence, circulation, connection, etc.). **[**SPLI-1292 **]**

- Operational Plan
Analogous to the capacity plan, the operational plan supplies the train and traffic control and all other components with the operational train data. The operational plan is fed from the active timetable buffer and contains all trains (from the timetable buffer) that are currently in their operational time window. The operational plan is the result of various influences (decisions from dispatching, map data, etc.). It is updated every single minute. **[**SPLI-1293 **]**

- Master Data
Master data represents "data about the business entities that provide context for business transactions".
[SPLI-1294 **]**