ERJU SYSTEM PILLAR

T3-System Concept_CMS-TMS_HarmScope

Analysis for CMS-TMS interface harmonization

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Abstract	The document recommends a functional allocation for TMS an d CMS systems and proposes an harmonization scope for the interface between them.
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Review Description

Comments	**#1 Approval comment** by **Rolf Gooßmann** on 2025-06-17 11:41 Local CMS (Station/Depots or Yards) not considered explicitly but could be interpreted as Regional CMS; In this context, track reservations as part of the local capacity plan need to be managed and transferred to TMS; Note: the track reservations can not be interpreted as TCRs since they need different business data, e.g., linked trains once the train ID is known. Links between trains only considered as “circulation status”. It is not clear whether the full details of train links are meant by that (links Next working, Splitting, Coupling etc); In this context, the train links available in the capacity plan need to be transferred to TMS to consider them for control decisions used for correct train running forecast calculation and decision making in/with TMS; It is not clear, how cancellations of planned trains in CMS are communicated to the TMS. They should not be transferred as ‘deleted’ but as modified (with changed cancellation status information which could be relevant for the whole train, a part of the train’s journey leg or single stops).
Approvals	Knoedl Herbert (INFRA.Netzzugang) : Waiting , NANNI Marco : Waiting , Patrick Konix : Waiting , PETTINATI, Valter : Waiting , Simone Brezzi : Waiting , Ghersi Mirko : Waiting , BO MARCO : Waiting , CANEPA RENZO : Waiting , Bence Jenőfi : Waiting , SCHWAN Nico : Waiting , Rolf Gooßmann : Waiting
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1 Preamble

1.1 Scope and intended audience

The scope of this document deals with the context of application of TMS and CMS, their functions apportionment and the analysis of possible options for those functions which might be implemented by one of the two systems. **[**SPT3TMS-16874 **]**

This analysis shall be performed on top of a review of the main features apportioned to CMS and TMS, which determine which classes of data have to be exchanged. This apportionment shall be preliminarily applied to some Use Cases which define which are the relevant environments where CMS and TMS are interfaced, with a specific focus on cross-borders; then, information to be exchanged shall be grouped in macro classes, each for a different topic but without entering the details of every specific data. **[**SPT3TMS-16873 **]**

Finally, this analysis shall be demonstrated to be consistent with ARC D2.3 Granularity Concepts and Principles and for this purpose the principles and concepts of this document are applied to the CMS TMS System Architecture Description and the allocation of functions to CMS and TMS previously elaborated, to cross-check the compliance of the design to the recommended guidelines. **[**SPT3TMS-16876 **]**

This document is intended for all stakeholders involved in the specification, development, implementation, and operation of TMS and neighbouring systems which connect with CMS or TMS "horizontally", as Passenger Information systems, neighbouring TMS, Timetable publishing systems, etc. (e.g. Business stakeholders, End users, Development and engineering teams, Assessors, etc.) **[**SPT3TMS-16875 **]**

1.2 Purpose

This document is a deliverable of the Remit Plan for Task 3 CMS-TMS and, on top of the existing design documents as System Concept, System Definition, System Architecture Description and others, its goal is to elaborate a proposal for a harmonization of the interface between CMS and TMS, which leads to the standardization of a kernel of data which shall be exchanged in all contexts of application of an interface between these two systems. **[**SPT3TMS-16872 **]**

Overall, the goal of the analysis is to identify and recommend how the CMS and TMS functional distribution and interface specification should be harmonized; specific applications may envisage to add further data to be exchanged to this harmonized kernel, which shall be valid only for their customized instance of application.

1.3 Glossary

1.3.1 Terms and definitions

No references

The following terms and descriptions apply to this document: **[**SPT3TMS-16796 **]**

Term	Description
CMS	A Capacity Management System (CMS) is a technology platform used in the rail industry to plan and manage infrastructure capacity as a resource. It serves as a centralized system that provides for all relevant time horizons the planned consumption of infrastructure capacity for all capacity objects like train paths, TCR, and track reservations.
TMS	A TMS (Traffic Management System) system is a technology platform used in the rail industry to manage and control train operations. It serves as a centralized system that provides real-time monitoring, control, and coordination of trains, tracks, and related infrastructure.
Traffic Controller	A user of the TMS supervising the traffic on a defined railway network and taking control decisions to address forecasted train conflicts or the impact of incidents on trains in the predefined time horizon. With reference to the detailed Operator Roles as defined in [Ref 2] (see below the reference list), the figure identified as involved in the UseCases described here is the Signaller. In any case, to simplify reading, in the remainder of this document the operator will be called Traffic Controller (abbreviated TC) without further specifications, as that is the name commonly used.
Timetable/Traffic Planner	A CMS user who decides traffic on a defined rail network, taking planning decisions to meet train or network capacity requests ahead of the predefined time horizon, but also checking and accepting plan changes if it is necessary to add, delete or modify scheduled trains or restrictions within the predefined time horizon. With reference to the detailed Operator Roles as defined in [Ref 2] (see below the reference list), the figure identified as involved in the UseCases described here is the Short-Term Planner. In any case, to simplify reading, in the remainder of this document the operator will be called Traffic Planner (abbreviated TP) without further specifications, as that is the name commonly used.

1.3.2 Abbreviations

Term	Definition
AI	Artificial Intelligence
ATO-TS	Automatic Train Operation - TrackSide
CBO	Common Business Objective
CMS	Capacity Management System
COTS	Commercial Off-the-Shelf
HMI	Human Machine Interface
HW	HardWare
IM	Infrastructure Manager
IT	Information Technology
LCC	LifeCycle Cost
OS	Operating System
PES	Planning Execution System
RIM	Rail Infrastructure Manager
RU	Railway Undertaking
SERA	Single European Railway Area
SW	Software
SP	System Pillars
TCS	Traffic Control and Supervision System
TMS	Traffic Management System
TTR	TimeTable Redesigned
UC	Use Case
VSTP	Very-Short Term Planning
WP	Work Package

2 History of Changes

Nr.	Changes	Leader/Authors
1.00	First draft for internal revision.	Valter Pettinati - Marco Nanni
1.1	Document reorganization, more UCs added, Options presented and application of ARC Guideline principles completed	Valter Pettinati - Marco Nanni

3 Reference

1. System Concept R2 Europe Rail CMS & TMS
2. SPT3-CMS_TMS T3- OperationalEntitiesActorsRoles
3. SPT2-Architecture_and_release_coordination_30_Deliverables_ARC-D2-3_Granularity_Concepts_and_Principles
4. SPT2-Architecture_and_release_coordination_30_Deliverables_ARC-D2_3_Granularity_Concepts_and_Principles_-_Case_Study_EAL
5. D6.3_PIS_TMS_Interface_M20_v1.0 Requirements and interface design for TMS-PIS
6. T3-System Architecture Description
7. T3-OperationalEntitiesActorsRoles
8. CMS TMS Variants Analysis Version 2
9. Operational Processes Capacity Management & Capacity Production CMS & TMS – V1.0
10. Draft for DCM Messages
11. EUR-Lex - 52023PC0443

[SPT3TMS-16788 **]**

4 Introduction

This document draws an analysis and a following assessment for a harmonization of the interface between CMS and TMS systems, which represents a key step towards the realization of a Single European Railway Area (SERA). **[**SPT3TMS-16357 **]**

In order to achieve this goal, the first step is to recall shortly what CMS and TMS are assumed to do at macroscopic level, highlighting which functions are definitely in charge of each of them and which features instead could be in line of principle apportioned to one or the other. Anyway, also for the latter, a proposal is done to avoid any ambiguity, and this choice shall be challenged according to the criteria and guidelines defined in [Ref. 3]. **[**SPT3TMS-16356 **]**

Afterwards, relevant operational Use Cases shall be characterized, identifying strengths and drawbacks with respect the proposed architecture and gathering which classes of data should be exchanged according to the functional apportionment. Where deemed relevant, further considerations on specific parameters belonging to these classes shall be performed, highlighting whether they should be considered mandatory (and then forcing them to be part of the harmonization scope) or optional (in this case they might be either part of the standardization package or formatted with a maybe richer set of information in a proprietary customized data packet).
[SPT3TMS-16256 **]**

The principles and criteria defined in [Ref. 3] shall be applied to the previous analysis to validate the consistency of the proposal against the Common Business Objectives (CBO) established by System Pillars initiative, which considers the modularity approach a key factor for improving the development, the deployment and the operation of all railways subsystems.

This analysis should be tightly coupled with the analysis performed in [Ref. 8], and assumes that the federated approach there depicted is the reference framework for CMS and TMS application.
[SPT3TMS-16257 **]**

Apart from the introduction, the document is structured into the following sections: **[**SPT3TMS-16451 **]**

- **Current CMS/TMS Architecture** (chap. 5): this section provides a brief introduction to the CMS and TMS needs for data exchange, showing the principles of the communication and which are the main timeline boundaries.
- **Operational Use Cases** (chap. 6): this section provides the relevant operational Use Cases for the identification of the harmonization scope; for each UC the context of application is given, along with preconditions, CMS and TMS assumed interactions and associated functionalities. Afterwards, the CMS TMS architecture shall be reviewed and the alternatives which are identified to be in the scope of this case study, that comply with the purpose of these use cases, shall be indicated.
- **Functions apportionment: assumptions ad options** (chap.7): According to the relevant Use Cases, this section gives a view of which features are clearly in charge of each system and should not be discussed, and which options should be instead considered for function distribution between CMS and TMS. This leads to identify different classes of data to be exchanged for the different options. Where it is considered not necessary to harmonize all these data, but just a subset, then it is stated along which the related justification.
- **Validation against granularity principles** (chap. 8): in this section the objectives and the rules defined in [Ref. 3] are applied to the alternatives identified in this case study, which shall be indicated in the previously identified Use Cases. The goal is to carry out the cost/benefit analysis of the interface harmonization considering the rationale for the harmonization.
- **Conclusions** (Chap. 9): this section summarizes the result of the analysis and draws achievements and findings.

[SPT3TMS-16450 **]**

4.1 Definitions

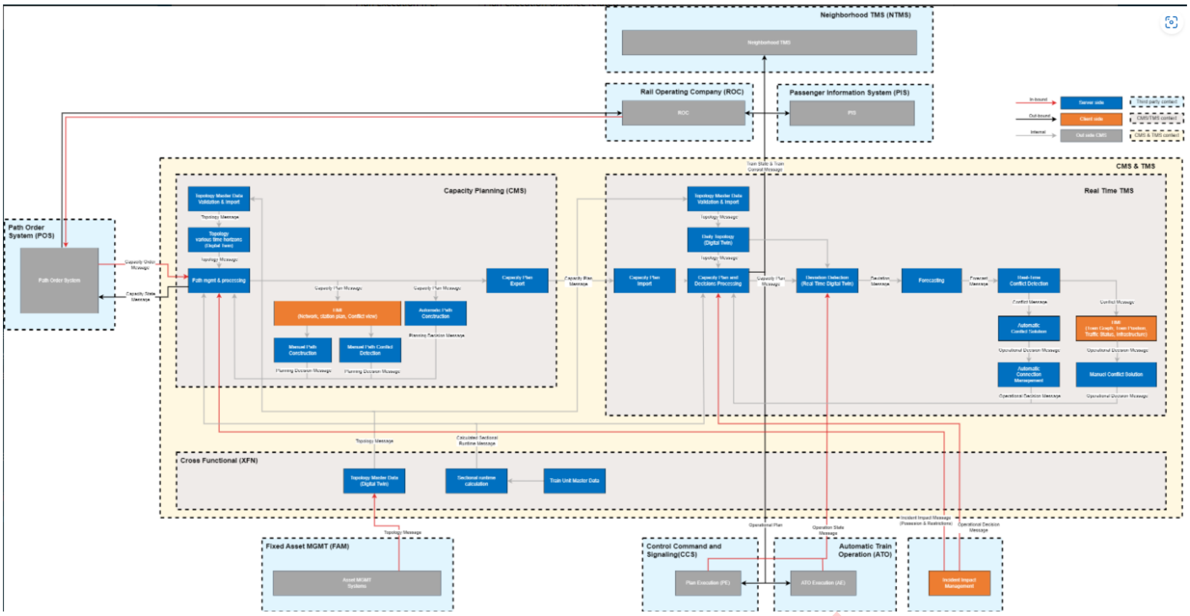
The glossary of terms shown in the following table reflects the status of the work and covers crucial building blocks of the specification of the TMS-CMS interface. It is expected to be improved and expanded during the future work in Domain 3. **[**SPT3TMS-16355 **]**

Actors	In a system engineering context, the actors of a use case refer to the entities that interact with the system being designed. An actor can be a person, group of people, another system, or a hardware device. Actors are external to the system and initiate or participate in one or more use cases. For sake of simplicity, with "Actor" here we mean both "Actors" and "Entity" according to Capella definition
System	The solution being developed refers to the software or hardware system that is being designed and built to meet specific user needs or requirements in a use case. This system can range from a simple standalone application to a complex network of interconnected components and may include both software and hardware components. The system being developed typically includes various subsystems, modules, and components that work together to perform specific functions and provide specific capabilities to users. It may also include interfaces and integrations with other systems, data sources, and external devices. Throughout the development process, the system is designed, implemented, tested, and validated to ensure that it meets the user needs and requirements identified through use cases and other methods.
Use Case	In system engineering, a use case refers to a description of a specific interaction between a user or external system and the system being developed. It can describe the sequence of events that occur when a user (or external system) performs a specific task or action using the system, including the input and output involved, as well as any relevant conditions or constraints. The use cases are often used to help identify and document system requirements and can also be used as a guide for the test cases of the functionality and usability of the system during development and implementation.
Scheduled plan	Theoretical future (re-)planning of capacity required by trains, infrastructure restrictions and activities on the track sent from CMS to TMS, developed in advance in the CMS environment according to the internal rules of CMS system, taking into account the needs and constraints previously known at the time of its preparation, agreed with the RU The Scheduled Plan can also be modified later by the CMS, if the need arises, and sent again to TMS; in this document the name of "scheduled" is also retained for the new "agreed" plan. The last Scheduled Plan received by TMS is the basis for measuring the deviations of the actual circulation. In this document it is kept distinct from the forecast and optimization plan subsequently developed by the TMS functions, based on the Scheduled plan produced by the CMS: the decisions of the TMS aim to maintain and comply with the Scheduled plan, minimizing deviations and bringing circulation back to what was initially planned.

[SPT3TMS-16358 **]**

Table 1: Definitions

5 Current CMS/TMS Architecture



[SPT3TMS-16347 **]**

Figure 1: CMS TMS Architecture description

Source of Figure 1: see [Ref. 6] T3-SystemArchitectureDescription, Chapt. 5.3.

This picture summarizes the assumptions and the choices which have been discussed by Task 3 Domain team and presented to the other System Pillars domains from the beginning of the initiative up to now; CMS and TMS are two separate and different systems whose functions are specific and described in the System Architecture referred above, and all the other specifications written in the following working years are consistent with this approach. **[**SPT3TMS-16907 **]**

The full description of the architecture depicted by the picture, with its building blocks and their input/outputs, is available in T3-SystemArchitectureDescription as indicate above. **[**SPT3TMS-16909 **]**

In this document the Granularity concepts and principles defined in “ARC-2.3 Granularity concepts and principles” are applied for the analysis of CMS and TMS subsystem functions and their interface in order to: **[**SPT3TMS-16354 **]**

1. Verify of the proper assignment of functions to CMS and TMS
2. Elaborate a proposal for a harmonization of the interface between CMS and TMS

[SPT3TMS-16350 **]**

The following diagram represents a high-level view of the functional split and the key data exchange between CMS and TMS, and provides a good overview of the actors and systems to be considered; it is the reference for the relevant operational Use Cases identified in the next section, according to which the apportionment of functions to CMS and TMS and the scope of harmonization of the interface between the two systems is validated. **[**SPT3TMS-16352 **]**

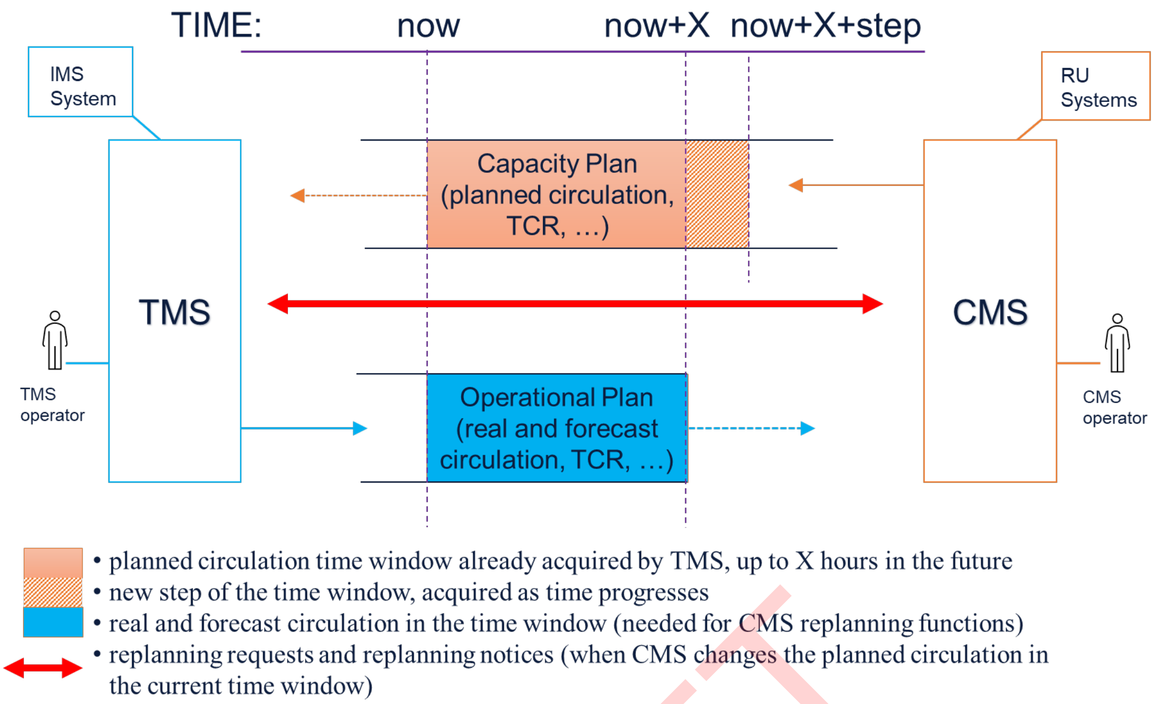


Figure 2: CMS TMS high-level view

6 Operational Use Cases

6.1 Structure of the Use Cases

This section describes the Use Cases deemed relevant to elaborate and validate the proposed functional capabilities of CMS and TMS and, as a consequence, the kind of data to be exchanged between the two systems. For the details of these capabilities, refer to [Ref. 6], chap. 5). A list of capabilities proposed for CMS and TMS, seen from the view point of the human actor, can be found in [Ref. 7], chap. 8 and 9. **[**SPT3TMS-16361 **]**

From an architectural viewpoint, the relevant scenarios mainly focus on the situation at the cross-borders, describing which are the reasonable contexts of application of one or more instances of CMS and TMS. **[**SPT3TMS-16360 **]**

From a functional view point, the scenarios of interest for the goal of this analysis focus on the planning and execution phases of the Operational Plan and on the effects which its execution might have and which are assumed to be given back to CMS in case they may have an impact on CMS time horizon. **[**SPT3TMS-16363 **]**

The Use Cases have been identified and described into a table with a set of several attributes which qualify them. When these attributes are not applicable, it will be specifically noted. **[**SPT3TMS-16362 **]**

6.2 Relevant Use Cases

6.2.1 UC_CMS-TMS.1 – CMS connected to a TMS inside the same Country

This is the simplest scenario, which corresponds to the traditional current architecture, where the jurisdiction area of the CMS is as wide as the area managed by TMS or wider, in this case managing another TMS or more, but in any case inside the same national scope. **[**SPT3TMS-16359 **]**

Name	CMS Provides Capacity Plan to a TMS of the same Country
ID	UC_CMS-TMS.1
Description	CMS provides TMS the Capacity Plan, and manages either annual, late path, rolling plan and ad-hoc requests.
Actors and Entities involved	TMS, CMS, Traffic Planner, Traffic Controller
Triggering action	Traffic Planner performs the sending of a new Capacity Plan or a change to an existing one, due to any late occurred need.
Pre-Condition(s)	1. Topological data model is agreed by both peers and its version is the same or compatible 2. Operational Processes have been defined and harmonized inside the same Country. 3. CMS and TMS are up and running. 4. CMS jurisdiction is as wide as TMS one, or wider. 5. The capacity plan is already into a validated state
Input	Capacity Plan or update drawn up and validated by CMS.
Data to be exchanged	• All dynamic data which fully characterize the Capacity Plan (movements and restrictions). • All static and quasi-static data which fully characterize the Capacity Plan (movements and restrictions) and which are available into the Digital Register
Result/Requirement	Capacity plan delivered to the TMS.

Final State	The TMS system integrates any received change into its database and updates the associated Operational Plan. TMS detects and proposes a solution for the conflicts which have been identified inside the detection and resolution time horizon defined for conflicts, if any.
Required level of harmonization	Nation-wide defined processes apply. No need to comply with neighbouring Railway organizations.
Notes	This context of application reflects the current situation for systems nowadays in Commercial Operation. Additional Entities (systems) which play a role in the specific national context, which may support for specific activities are up, configured and running and may interface CMS and TMS for providing specific additional information.

[SPT3TMS-16369 **]**

6.2.2 UC_CMS-TMS.2 – TMS connected to a CMS of a different Country

This scenario considers a national TMS which is connected to a CMS of another Country. The CMS can span its jurisdiction over one or more TMS of its Country and possibly of the other one. This use case highlights possible limitations which can derive from processes set up by the IM organizations of the two countries, which are likely to be inconsistent one another; these limitations could affect the functions allocation. **[**SPT3TMS-16368 **]**

Name	CMS Provides Capacity Plan to a TMS of another Country
ID	UC_CMS-TMS.2
Description	CMS provides TMS the Capacity Plan, and manages either annual, late path, rolling plan and ad-hoc requests.
Actors and Entities involved	TMS, CMS, Traffic Planner, Traffic Controller
Triggering action	Traffic Planner performs the sending of a new Capacity Plan or a change to an existing one, due to any late occurred need.
Pre-Condition(s)	1. Topological data model is agreed by both peers and its version is the same or compatible 2. At least a minimum set of Operational Processes are preliminarily agreed, harmonized and are followed by the two organizations which manage CMS and TMS. 3. CMS and TMS are up and running. 4. CMS jurisdiction is as wide as TMS one in TMS Country 5. The capacity plan is already into a validated state
Input	Capacity Plan or update drawn up and validated by CMS.
Data to be exchanged	• All dynamic data which characterize the Capacity Plan (movements and restrictions) and are agreed between the two participating railway organizations. • All static and quasi-static data which fully characterize the Capacity Plan (movements and restrictions) and which are available into the Digital Register Missing data necessary for TMS but not available in CMS (then neither agreed

	nor harmonized) shall be filled in later by TMS related tools.
Result/Requirement	Capacity plan delivered to the TMS.
Final State	The TMS system integrates any received change into its database and updates the associated Operational Plan. TMS detects and proposes a solution for the conflicts which have been identified inside the detection and resolution time horizon defined for conflicts if any.
Required level of harmonization	The two neighbouring Railway organizations shall agree on a minimum set of processes and data which make the instantiation of the Capacity Plan into Operational Plan feasible and effective.
Notes	This context of application mainly reflects the TO-BE situation for systems nowadays in Commercial Operation. Additional Entities (systems) which play a role in each specific national context, which may support for specific activities, are up, configured and running and may interface CMS or TMS for providing specific additional information.

[SPT3TMS-16371 **]**

6.2.3 UC_CMS-TMS.3 – CMS connected to two TMS at a cross-border

This scenario considers two national TMS connected to the same CMS, which therefore is configured to manage both countries. In this case this supranational CMS is in charge to plan both regional, national and international trains for both TMS. **[**SPT3TMS-16370 **]**

In this context of application, a supranational CMS is designed to centralize and deliver the overall capacity plan for more national TMS. **[**SPT3TMS-16365 **]**

Name	CMS connected to two TMS at a cross-border
ID	UC_CMS-TMS.3
Description	CMS provides TMS the Capacity Plan, and manages either annual, late path, rolling plan and ad-hoc requests to two TMS having jurisdiction on two different areas at cross-border.
Actors and Entities involved	TMS1, TMS2, CMS, Traffic Planner, Traffic Controller
Triggering action	Traffic Planner or a CMS system action triggers the sending of a new Capacity Plan or a change to an existing one, effecting either only one of the two TMS or both.
Pre-Condition(s)	1. Topological data model is agreed by all three peers and its version is the same or compatible 2. At least a minimum set of Operational Processes are preliminarily agreed, harmonized and are followed by the organizations which manage CMS and TMS. 3. CMS and both TMS are up and running. 4. CMS jurisdiction is as wide as the two TMS ones or wider 5. The capacity plan is already into a validated state
Input	Capacity Plan or update drawn up and validated by CMS.
Data to be exchanged	

	• All dynamic data which characterize the Capacity Plan (movements and restrictions) and are agreed between the participating railway organizations. • All static and quasi-static data which fully characterize the Capacity Plan (movements and restrictions) and which are available into the Digital Register. Missing data necessary for one or both TMS but not available in CMS (then neither agreed nor harmonized) or which are not available in Digital Register shall be filled in later by TMS related tools.
Result/Requirement	Capacity plan delivered to both TMS, cut out according to their controlled area.
Final State	Each TMS system validated the received data and updated the Operational Plan accordingly.
Required level of harmonization	The involved neighbouring Railway organizations shall agree on a minimum set of processes and data which make the instantiation of the Capacity Plan into Operational Plan feasible and effective. The two TMS should manage possible replanning on their own in the same time window, to keep the necessary level of homogeneity for capacity plans which span on both.
Notes	This context of application mainly reflects the TO-BE situation for systems nowadays in Commercial Operation. Additional Entities (systems) which play a role in each specific national context, which may support for specific activities, are up, configured and running and may interface CMS or TMS for providing specific additional information.

[SPT3TMS-16364 **]**

6.2.4 UC_CMS-TMS.4 – Regional and National CMS feeding a TMS

This scenario considers two CMS with a different scope but both planning the traffic over a jurisdiction of a TMS. It is assumed that these two CMS are partially overlapping because the first operates on a regional level which the TMS controlled area belongs to, while the second has a national scope which includes (but it is wider) the area managed by the regional level. **[**SPT3TMS-16367 **]**

In this context, a local CMS (Station/Depots or Yards) could be interpreted as Regional CMS; as related data might be slighly different, as for example track reservations might not be associated to TCR or linked trains ID might be not known yet, , it is likely that it will be necessary to perform a detailed analisys at a later stage. **[**SPT3TMS-16366 **]**

This kind of organization is not indeed spread all over Europe, but there are few examples of this system organization in larger European railway organizations, where a regional TMS has its own attached regional CMS. The scenario is here considered for sake of completeness but, also according to what has been established in the last year and foreseen in the frame of the TTR project, the TMS is connected to just the regional CMS; the Capacity Plan which is received is ensured to be consistent and aligned between regional and national CMS by a preliminary synchronization phase performed in advance. **[**SPT3TMS-16871 **]**

Name	Regional and National CMS with having scope on a TMS controlled area
ID	UC_CMS-TMS.4
Description	A Regional CMS, envisaged for the relevance of its controlled area, provides the Capacity Plan to a TMS, which is also managed by a national CMS.

	A National CMS provides the Capacity Plan for thw whole country, and is in charge of harmonizing this overall plan with its instantiation over the regional area. The TMS will receive the Capacity Plan from the Regional CMS once it has been made already compliant with the wider national plan.
Actors and Entities involved	TMS, CMS1 CMS2, Traffic Planner, Traffic Controller
Triggering action	The Regional Traffic Planner liaises with the National Traffic Planner and consolidates a consistent Capacity Plan which then sends to TMS.
Pre-Condition(s)	1. Topological data model is agreed by all three peers and its version is the same or compatible 2. Operational Processes are the same or compliant within the Regional and National organizations 3. National, Regional CMS and TMS are up and running, at least until the Regional and National CMS have completed the synchronization of the Capacity Plan for the area handled by TMS 4. At least the Regional CMS and TMS are up and running, in case the Regional CMS already owns a Capacity Plan agreed with National CMS 5. Regional CMS jurisdiction is as wide as the TMS one or wider
Input	Capacity Plan or update drawn up and validated by Regional CMS.
Data to be exchanged	• All dynamic data which characterize the Capacity Plan (movements and restrictions) and are agreed between the participating railway organizations. • All static and quasi-static data which fully characterize the Capacity Plan (movements and restrictions) and which are available into the Digital Register. Missing data necessary for one or both TMS but not available in CMS (then neither agreed nor harmonized) or which are not available in Digital Register shall be filled in later by TMS related tools.
Result/Requirement	Capacity plan delivered to TMS, cut out according to its controlled area.
Final State	Each TMS system validated the received data and updated the Operational Plan accordingly.
Required level of harmonization	The Regional and National Railway organizations share a minimum set of processes and data which make the instantiation of the Capacity Plan into Operational Plan feasible and effective. The two CMS should manage possible replanning on their own in the same time window, to keep the necessary level of homogeneity for the capacity plans forwarded to TMS.
Notes	This context of application reflects few instances of application belonging to the AS-IS situation for systems nowadays in Commercial Operation. It is foreseen that in the future the CMS shall have at least a national scope, and therefore this approach should be deprecated.

[SPT3TMS-16373 **]**

6.2.5 UC_CMS-TMS.5 – Two European and National CMS feeding a TMS

This scenario is quite similar to the previous one; it considers two CMS:

- the former with a national scope and defining a Capacity Plan regarding all trains whose full Operational Movements are inside a Country

- the latter operating on cross-border trains all over Europe, and then defining a Capacity Plan also for the same TMS, just limiting its scope to those trains which those trains that cross the national border

[SPT3TMS-16382 **]**

The importance of this kind of organization is likely to greatly increase during the next years; initiatives are in progress to define a European approach to the overall Capacity Planning for all cross-border trains, as the TimeTable Redesign, which should be accompanied by an increased level of harmonization in operational procedures.
[SPT3TMS-16270 **]**

As for the scenario described above, also this case of study is considered for sake of completeness. The European Commission published the draft Capacity Regulation in July 2023: this document keeps the principles defined into the TTR concept and then represents the legal basis for implementing TTR. Specifically, the draft Capacity Regulation defines the request process for applicants and its steps without involving other systems. **[**SPT3TMS-16376 **]**

It is then reasonable to assume that European and National CMS agree and synchronize on the capacity plan, from the annual request phase to the timetable allocation to the rolling plan, before publishing the final Capacity plan to TMS, which therefore shall have a single connection with the National CMS.
[SPT3TMS-16375 **]**

Name	National and European CMS with having scope on a Country-wide TMS
ID	UC_CMS-TMS.5
Description	A Country-wide CMS provides a TMS having jurisdiction over the same Country the Capacity Plan for all trains whose trip is fully inside national borders, while an European CMS provides the Capacity Plan for the cross-border trains which run also inside the Country.
Actors and Entities involved	TMS, CMS1 CMS2, Traffic Planner, Traffic Controller
Triggering action	The National Traffic Planner liaises with the European Traffic Planner and consolidates a consistent Capacity Plan which then sends to TMS.
Pre-Condition(s)	1. Topological data model is agreed by all three peers and its version is the same or compatible 2. Operational Processes are the same or compliant within the National Railways which share the trains paths. 3. European, National CMS and TMS are up and running, at least until the National and European CMS have completed the synchronization of the Capacity Plan for the area handled by TMS 4. At least the National CMS and TMS are up and running, in case the National CMS already owns a Capacity Plan agreed with European CMS
Input	Capacity Plan or update drawn up and validated by National CMS
Data to be exchanged	• All dynamic data which characterize the Capacity Plan (movements and restrictions) and are agreed between the participating railway organizations. • All static and quasi-static data which fully characterize the Capacity Plan (movements and restrictions) and which are available into the Digital Register. Missing data necessary for one or both TMS but not available in CMS (then neither agreed nor harmonized) or which are not available in Digital Register shall be filled in later by TMS related tools.
Result/Requirement	Capacity plan delivered to TMS, cut out according to its controlled area

Final State	Each TMS system validated the received data and updated the Operational Plan accordingly.
Required level of harmonization	The National and European Railway organizations share a minimum set of processes and data which make the instantiation of the Capacity Plan into Operational Plan feasible and effective. The two CMS should manage possible replanning on their own in the same time window, to keep the necessary level of homogeneity for the capacity plans forwarded to TMS.
Notes	This context of application shapes the TO-BE situation for systems even nowadays in Commercial Operation which shall evolve towards a tighter and better integration.

[SPT3TMS-16381 **]**

6.2.6 UC_CMS-TMS.6 - TMS receives the scheduled plan from CMS

As a TMS operator, I want to automatically receive the agreed capacity plan drawn up by CMS for the predefined time interval so that the TMS system always has the complete view of the expected theoretical circulation in his time window. **[**SPT3TMS-16380 **]**

The capacity plan itself is generated and managed independently by the CMS and should always be available, complete with all the data concerning the pre-established time window; the methods and logic used to generate the scheduled plan are not scope of this document. **[**SPT3TMS-16272 **]**

It is assumed that the whole scheduled plan for the time window affecting TMS is always available in due time, so the data transfer can occur without explicit actions from CMS or TMS operators. **[**SPT3TMS-16379 **]**

CMS makes available trains and unavailabilities data belonging to the configured time interval along with link related data. Some links/connections might affect trains and unavailabilities not yet sent (e.g. a train running today which is connected to a train running tomorrow): however, the receiving TMS shall handle this possibility. **[**SPT3TMS-16886 **]**

Name	TMS receives the scheduled plan provided by the CMS
ID	UC_CMS-TMS.6
Description	As time progresses, the agreed capacity plan pre-calculated by the CMS is made available to the TMS so that the TMS always has complete data for the predefined time window.
Actors and Entities involved	TMS, CMS
Triggering action	Advancement of the time
Pre-Condition(s)	1. Availability of TMS 2. Availability of CMS application for the area covered by the TMS 3. Available scheduled plan on CMS (trains path with related timings, shunting movements, restrictions).
Input	Scheduled plan drawn up by CMS.
Data to be exchanged	• Movements planned in the time interval, with full data • Operational restrictions, and their relation to trains

	• Links between movements, and between movements and restriction, which are relevant for a correct TMS forecast calculation and decision making as Next working, Splitting, Coupling, constraints between restrictions and trains, etc
Result/Requirement	Scheduled plan delivered to the TMS.
Final State	The TMS system has complete data for the predefined time interval and will use this information for its functions.
Required level of harmonization	The topological, infrastructural data model and structure is agreed and is the same for both TMS and CMS to the full extent of the controlled area. This data model is supposed to be harmonized and distributed by a third part and be the same for all systems involved into the implementation of the overall railway system. All data to be exchanged should be preferably modelled and grouped into classes which are harmonised to permit system exchangeability. At minimum, all data set necessary to exchange Capacity Plan and feedbacks from TMS to CMS about changes due to unforeseen disruptions impacting CMS temporal scope should be harmonized.
Notes	No action is required by TMS or CMS operators the process occurs automatically. At the first start of the TMS systems, or in case of restart or maintenance interventions, TMS shall retrieve the whole scheduled plan for the window time by using, for instance, the storage services of the communication infrastructure used to enable data exchange among all the railways systems.

[SPT3TMS-16384 **]**

6.2.7 UC_CMS-TMS.7 - External request of plan modifications (future time)

As an operator of an external system (like for instance, RU operator), I want to ask CMS to add, delete or modify trains for future time, in a time horizon which goes beyond the TMS time scope. In this case TMS is not involved. **[**SPT3TMS-16383 **]**

This UC has no direct impact on the data exchange between CMS and TMS, but nevertheless it is reported for completeness of analysis: the architectural solutions that will be defined must also be verified also against this UC. **[**SPT3TMS-16923 **]**

Name	Request to modify the CMS plan for future time by an external operator.
ID	UC_CMS-TMS.7
Description	Upon the request of an external operator, the CMS operator could modify the previous plan; the modified plan re-calculated by the CMS doesn't involve any train or restriction already handled by TMS.
Actors and Entities involved	CMS operator, CMS, external operator
Triggering action	External request
Pre-Condition(s)	1. Availability of CMS application for the area covered by the TMS

Input	External request.
Data to be exchanged	No data exchange between CMS and TMS: only internal CMS data are modified.
Result/Requirement	Nothing interesting for the scope of this document; the interface CMS-TMS is not involved.
Final State	A new plan within the CMS.
Required level of harmonization	No harmonization is required for internal CMS data.
Notes	NOTE: data exchange between external systems and CMS is not in the scope of this document and is not covered here. No data exchange is necessary between CMS and TMS. CMS will make the modified scheduled plan available at the appropriate time in the future.

[SPT3TMS-16385 **]**

6.2.8 UC_CMS-TMS.8 External request of plan modifications (very short time)

As an operator of an external system (like for instance, RU operator), I want to add, delete or modify trains scheduled in a near time or already running: these changes involve the time slot already handled by TMS. In this case TMS must handle a new scheduled plan. The entity in charge of the reschedule in this time slot might be in line of principle either CMS or TMS; a proposal shall be elaborated according to the outcomes of the analysis carried out in this paper; this function is indicated below with the acronym VSTP (Very Short-Term Planning). **[**SPT3TMS-16389 **]**

In line of principle, the external operator shouldn't need to be aware of the time slot handled by TMS, and its request procedure should be the same regardless of the concerned time interval.
[SPT3TMS-16388 **]**

In simpler railway organizational contexts, the operator in charge of the VSTP himself might detect the need for a change perhaps after having acquired information informally, such as a phone call, messages or e-mail. Anyway, this is not relevant in the context of the Use Case. **[**SPT3TMS-16387 **]**

The methods and logic used to modify the scheduled plan, accepting or rejecting the requested changes, are beyond the scope of this document: the TMS-CMS interface only deals with managing the subsequent data exchange, after the VSTP operator has processed the new Scheduled Plan. The final decision about accepting or rejecting the changes is always up to the VSTP operator. **[**SPT3TMS-16386 **]**

A key point in this Use Case compared to the previous one is that the VSTP process needs also

information about the real time traffic (i.e. current position of trains and current equipment faults) to build a feasible, conflict-free new plan, which are owned and handled by TMS, while all other data regarding the planned circulation (i.ie. shift of materials and personnel, Next working, Splitting, Coupling and constraints) are fully known only by CMS: in fact TMS knows them completely only in relation to his time slot, but if for example the continuation train is scheduled in two days, only CMS can evaluate the consequences of a cancellation and manage the need to find a new material ready in two days. Furthermore, some data not necessary for TMS may not be among those transmitted by CMS (i.e. economic evaluation, value of a train path).
[SPT3TMS-16393 **]**

Name	Request to modify the CMS scheduled plan already acquired by TMS by an external operator
ID	UC_CMS-TMS.8

Description	Upon the request of an external operator, the VSTP operator could modify the previous scheduled plan already acquired by TMS: the plan modified by the VSTP is made available to the TMS.
Actors and Entities involved	VSTP operator, TMS, CMS, external operator
Triggering action	External request
Pre-Condition(s)	1. Availability of TMS. 2. Availability of CMS application 3. Available scheduled plan on CMS (trains path with related timings, shunting movements, restrictions).
Input	External request. Data needed: • Actual scheduled plan. • Current circulation status. • All relevant data for replanning circulation.
Data to be exchanged	• New, deleted or modified operational movements (trains); • New, deleted or modified operational restrictions: • Links between movements, and between movements and restriction, which are relevant for a correct TMS forecast calculation and decision making as Next working, Splitting, Coupling, constraints between restrictions and trains, etc. NOTE: it is also necessary to communicate to TMS the cancellations, including train link cancellations, when the corresponding data had already been previously communicated , to ensure the correct alignment of TMS information. This need will have to be taken into account in the future detailed specification of the protocol; by istance, the indication could be transferred as a 'cancellation status information' which could be relevant for the whole train, a part of the train's journey or single stops. It is worth to stress the importance of the agreed capacity plan that VSTP sends TMS, because of its impact on the delay updating and TMS rescheduling. This agreed capacity plan defines when CMS needs to provide the update to TMS.
Result/Requirement	New scheduled plan delivered to the TMS.
Final State	The TMS system has complete and update data for the predefined time interval and can use this information for its functions.

Required level of harmonization	The topological, infrastructural data model and structure is agreed and is the same for both TMS and CMS to the full extent of the controlled area. This data model is supposed to be harmonized and distributed by a third part and be the same for all systems involved into the implementation of the overall railway system. Which data to be exchanged depends on which entity performs the very short-term replanning. Anyway, a minimum set of information providing feedback from TMS to CMS about changes which span beyond the very short-time horizon and so pertaining to CMS should be harmonized.
Notes	NOTE: data exchange between external systems and CMS is not in the scope of this document and is not covered here. CMS anyway needs to receive the update and must make the whole new scheduled plan available, with appropriate indication of the changes made, for alignment reasons. CMS may need to receive some of the changed data even just for informational purposes.

[SPT3TMS-16392 **]**

6.2.9 UC_CMS-TMS.9 - TMS internal plan modifications

As a TMS operator, I want to modify some data of the scheduled plan which I have the possibility to change, to obtain an optimized circulation, without asking the VSTP function for a reprogramming. CMS may eventually become aware of the changes, but there is no need for consent. **[**SPT3TMS-16391 **]**

A detailed analysis will have to define which data can be changed directly by the TMS and which data cannot be changed without CMS/VSTP involvement. Nowadays this distinction of data classes could change in various railways contexts, reflecting different local uses and regulations: this is a point to be taken into account, and is a key subject from the harmonization viewpoint, which could lead to a

recommendation to develop the system implementation which is parameterizable at some extent. A detailed analysis is beyond the scope of this document, but the general framework of the use cases described remains valid regardless of the definition of the specific data involved. **[**SPT3TMS-16390 **]**

Name	TMS internal scheduled plan modification by the TMS operator
ID	UC_CMS-TMS.9
Description	TMS operator modifies some data of the TMS internal scheduled plan for circulation optimization. There is no need to CMS consent. Specific relevant information: • Only internal TMS data.
Actors and Entities involved	TMS operator, TMS
Triggering action	TMS operator action
Pre-Condition(s)	1. Availability of TMS.
Input	TMS operator request

Data to be exchanged	Mainly only internal TMS data are modified. Possibly, changes impacting CMS time horizon should be given back to CMS.
Result/Requirement	TMS performs the required changes and updates the Operational Plan minimizing the possible disruptions with respect the original plan. In case, impacts to CMS time scope are communicated to CMS.
Final State	A modified plan within the TMS.
Required level of harmonization	To permit systems exchangeability, all data set necessary to align CMS about performed changes should be harmonized
Notes	CMS anyway needs to receive the update and must make the whole new scheduled plan available, with appropriate indication of the changes made, for alignment reasons. CMS may need to receive some of the changed data even just for informational purposes.

[SPT3TMS-16280 **]**

6.2.10 UC_CMS-TMS.10 - TMS to CMS request of plan modifications

As an operator of a TMS, I want to ask VSTP function for a rescheduling in case the traffic disturbances cannot be solved by the TMS optimization functions. Then TMS will receive the updated scheduled plan drawn up by VSTP with the changes set by VSTP operators. Once the scheduled plan has been acquired by the TMS, it is used by the TMS for its following elaborations and forecast re-calculation.
[SPT3TMS-16394 **]**

In today's TMS systems, built-in functions support the Traffic Controller by indicating situations of relevant deviations from the plan to trigger decision. Some examples of critical situations that need to update the Operational Plan could be for instance: definitive breakdown of a train, serious failure of the railway infrastructure, extension of scheduled works beyond the scheduled deadline, etc. Also in this case, the management of these situations could change in various railways contexts, reflecting different local uses and regulations, but the general framework of the use cases described remains valid regardless.
[SPT3TMS-16374 **]**

As well as the Use Case described at sect. 6.2.8, the VSTP process needs information about the real-time traffic to build a correct new plan and also of all other data regarding the planned circulation; the latter are fully known by CMS, and some as those related to capacity plan spanning beyond TMS time horizon, only by CMS (and not by TMS). **[**SPT3TMS-16372 **]**

The rescheduling request by TMS operator could be a formal or informal message and also contain information on the cause that generated the request; in any case, it cannot be connected to the updates resulting in the new scheduled plan, as the replanning could involve trains or restrictions not explicitly mentioned in the request. When the new plan is ready, the activated sequence of actions is the same as the previous Use case described at sect. 6.2.8. **[**SPT3TMS-16378 **]**

If the consequences of the critical situation to be managed exceed the time window of TMS interest, the procedures to modify the Capacity Plan even beyond this time limit must be activated and CMS must produce a modified scheduled plan, available at the appropriate time in the future, so the TMS will receive the updated data as usual.
[SPT3TMS-16282 **]**

From an organizational viewpoint, in some cases (low traffic, for instance) the TMS operator could also perform CMS functions from his workplace, also carrying out the role of CMS operator, but the two roles must still be kept distinct even if performed by the same person, as they involve different systems. Technology supports several possibilities to reach this goal, which anyway are out of scope of this specification.
[SPT3TMS-16283 **]**

Name	Request to modify the previous CMS scheduled plan by the TMS operator
ID	UC_CMS-TMS.10
Description	At the request of TMS operator, the VSTP operator should modify the previous scheduled plan and the plan modified by the VSTP is made available to the TMS.
Actors and Entities involved	TMS operator, VSTP operator, TMS, CMS
Triggering action	TMS operator request
Pre-Condition(s)	1. Availability of TMS. 2. Availability of CMS application. 3. Available scheduled plan on CMS (trains path with related timings, shunting movements, restrictions).
Input	TMS operator request. NOTE: it could be also an informal one (i.e. by phone) Data needed: • Actual scheduled plan. • Current circulation status. • All relevant data for replanning circulation.
Data to be exchanged	• New, delete or modified operational movements (trains); • New, delete or modified operational restrictions; • Links between movements, and between movements and restriction, which are relevant for a correct TMS forecast calculation and decision making as Next working, Splitting, Coupling, constraints between restrictions and trains, etc. NOTE: it is also necessary to communicate to TMS the cancellations, including train link cancellations, when the corresponding data had already been previously communicated , to ensure the correct alignment of TMS information. This need will have to be taken into account in the future detailed specification of the protocol; for instance, the indication could be transferred as a ‘cancellation status information’ which could be relevant for the whole train, a part of the train’s journey or single stops.
Result/Requirement	New scheduled plan delivered to the TMS.
Final State	The TMS system has complete updated data for the predefined time interval and can use this information for its functions.
Required level of harmonization	To permit systems exchangeability, all data defining the model for the new Capacity Plan transmitted by CMS should be harmonized.
Notes	CMS anyway makes the whole new scheduled plan available, with appropriate indication of the changes made, for information reasons.

[SPT3TMS-16377 **]**

7 Functions apportionment: assumptions ad options

In order to review, analyse and propose an optimal functional allocation for CMS and TMS, the following aspects and elements have been taken into account: **[**SPT3TMS-16400 **]**

- The several possible geographical contexts of application for CMS and TMS, together with the relevant interaction scenarios
- The initiatives already on-going at European level, aiming to redesign the timetable management and associated processes
- The experience and achievements derived by the consolidate use of a number of CMS and TMS different installations all over Europe, which show a number of different set of features implemented.
- The proposed organization of a modern control room, where a number of operators with different skills and roles are supposed to cooperate to handle planning and traffic with a national scope.

[SPT3TMS-16399 **]**

The current situation and way of working and, above all, the new ideas for an improved and maximized use of the railway infrastructure, which find a systematization with the definition of Common Business Objectives (see CommonBusinessObjectives) lead to confirm that a set of functions can be apportioned only to a CMS or TMS and their allocation cannot be modified, as it would result in an overall inconsistency of any system devoted to supervise and manage Capacity Planning and Production. Therefore: **[**SPT3TMS-16402 **]**

- The advanced Capacity planning, which is deployed into the phases of strategic planning, definition of a capacity model according the finalization of a suitable feasibility study, the coordination and the publication of the Temporary Capacity Restrictions are allocated to CMS: in synthesis:
    - Strategic Planning
    - Capacity modelling
    - Feasibility studies
    - Capacity Supply

[SPT3TMS-16401 **]**

- The handling of Annual requests, the management of the Rolling Plan and related requests for changes, the short-term ad-hoc requests for changing the capacity plan until a very short time before the coming into operation of the required service are equally to be allocated to CMS: in synthesis:
    - Annual requests
    - Handling of Rolling Plan
    - Management of Short-Term requests
    - Cancellation requests (not related to the Very Short-Term)

[SPT3TMS-16396 **]**

- On the other hand, all real-time functionalities devoted to handle the real-time and to execute the capacity production processes are clearly in charge of TMS:
    - Detailed Train Path construction for CCS use, and handling
    - Divergence Management
    - Conflict Detection and Solution
    - Incident impact management

[SPT3TMS-16395 **]**

An overall, high-level view of allocation of functions to TMS and CMS can be seen in [Ref. 6], T3-SystemArchitectureDescription, while a high level view of the proposed capabilities allocation to CMS and TMS can be found here: [Ref. 2] T3-OperationalEntitiesActorsRoles, chapt. 8 and 9. **[**SPT3TMS-16398 **]**

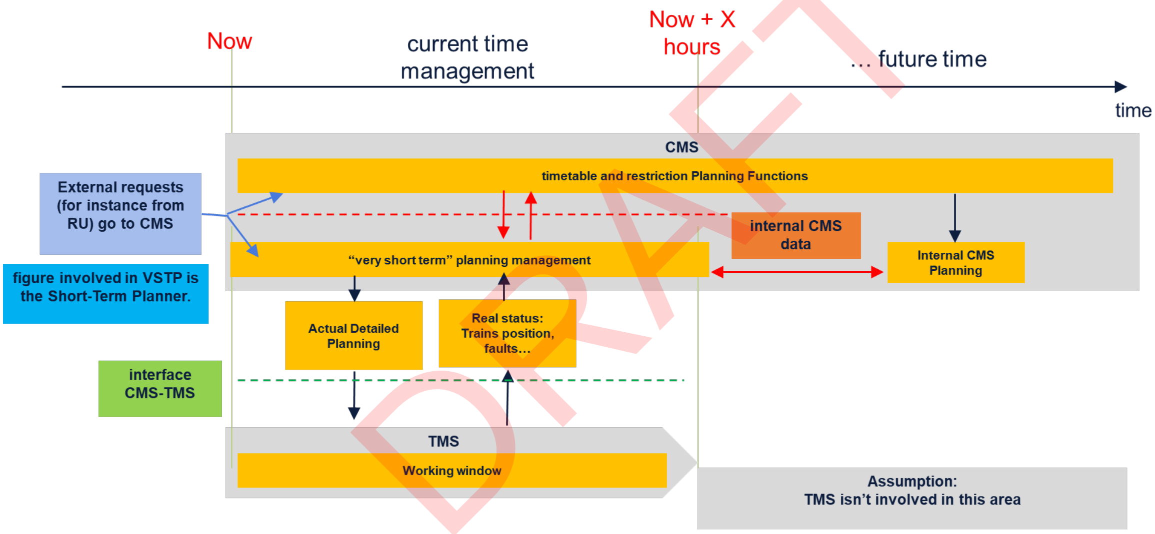
The analysis led to identify the handling of the so-called Very Short-Term Planning (VSTP) as the capability that potentially could be allocated either to CMS or TMS. VSTP should deal with operational planning in a time-horizon which spans from at most 72 hours afterthe present time (but maybe also only 48h or 24h), thus considering those late requests which impact on a Capacity Plan presumably already uploaded into TMS and on top of which on an Operational Plan already generated. **[**SPT3TMS-16286 **]**

The final allocation of VSTP capability has a direct influence on the specification of the data interface between the two systems and significantly influences the classes of data which must be exchanged between CMS and TMS. We may identify the options described in the next two sections. **[**SPT3TMS-16287 **]**

7.1 Option 1: VSTP is allocated to CMS

The integration of the VSTP capability into CMS would entail a smoother link of the Operational Processes derived from the TTR project dealing for all the phases of Capacity Planning, from the advance capacity planning phase to the timetabling phase, whose goal is to allocate capacity to applicants until the very last moment before the starting of the service and even later. **[**SPT3TMS-16397 **]**

The following picture shows graphically such functional arrangement: **[**SPT3TMS-16403 **]**



[SPT3TMS-16406 **]**

Figure 3: VSTP Capability allocated to CMS

When significant disruptions occur with respect to the Operational Plan which has been built by TMS and is currently in execution, which cannot be managed just solving conflicts or taking countermeasures which have an impact only in the very next future (in this case fully manageable just by TMS) or when not yet harmonized national rules explicitly envisage CMS involvement, then changes to the Capacity Plan should be performed which will have an effect on the VSTP time horizon. **[**SPT3TMS-16405 **]**

To enable VSTP to perform an effective reschedule and generate a feasible and agreed Capacity Plan, CMS needs a picture of the current state of the field; this means that TMS should provide the VSTP module of CMS at least: **[**SPT3TMS-16404 **]**

- the current trains position
- the forecasted trip of running trains (services), only if there are relevant constraints
- estimated unavailability of infrastructure over the controlled area (resources unavailability, restriction, …)
- actual unforeseen unavailability of infrastructures recorded in TMS
- temporary operational routing restrictions
- temporary timing restrictions

[SPT3TMS-16410 **]**

assuming that the train forecast is also performed by CMS with its internal algorithms, according to the updated status of the field. **[**SPT3TMS-16409 **]**

To reach an effective interoperability between instances of TMS and CMS, modelling and representation of these classes of data should be harmonized, as well as the interface specification which organizes this information into set of messages.
[SPT3TMS-16291 **]**

The VSTP function, inserted in CMS, has full access to the data normally necessary to develop a new plan; since it is part of the CMS itself, any modification or addition of new data types is inherited also by VSTP. This allows to freely develop new algorithms in CMS since its internal data does not necessarily need to be harmonized, and to evolve the function VSTP consistently in the environment. TMS is not affected by the future evolution of the CMS. **[**SPT3TMS-16408 **]**

The short-term capacity plan elaborated by VSTP shall be processed by TMS functions, and the result will be releasing VSTP capacity plan agreed changes; the TMS functions will update the Operational Plan consistently, taking TM decisions into account. **[**SPT3TMS-16919 **]**

In this architecture, VSTP is responsible for: **[**SPT3TMS-16407 **]**

- acquire the whole real traffic situation from the TMS when a replanning involving the TMS time window is requested (see 6.2.8, 6.2.10);
- perform an effective reschedule and generate an updated, feasible and agreed Capacity Plan;

NOTE: the definition of the replanning algorithm is not the subject of this specification, but in this option,

having all the CMS data available, it can reuse similar CMS planning logics if it is deemed useful

- the new modified plan must be exhaustive in the TMS time window and VSTP provides it to the TMS, with a harmonized or non-harmonized protocol, with the same methods envisaged for sending the original plan at the scheduled time (see 6.2.6);
- update the CMS internal data as they result from the new replanning; VSTP must guarantee that all internal data in CMS are always aligned and consistent with each other: since this architecture is managed internally by CMS, the how is no longer the subject of this document;
- since VSTP has access to all CMS data, it can also directly manage the consequences of changes that exceed the time limit of the TMS window, if there were any, updating the CMS data without involving TMS (i.e., a fault occurs to a train on Friday and the train is cancelled, but it was to come back on next Monday, then a spare rolling stock must be found or the train must be sent back empty to its original starting location);
- identify and dispatch to CMS the events whose consequences are long-lasting (i.e. an accidental fault whose expected duration extends long into the future), with the aim of also activating long-term replanning; in this way the future Capacity Plan can be reworked and will be available for the TMS at the appropriate time (see 6.2.10);
- acquire the changes made by TMS on the plan, for those changes that TMS is authorized to make without requiring VSTP's intervention, which must be reported in the CMS environment for alignment (see 6.2.9);

NOTE: the changes that TMS is authorized to make may depend on national rules and contexts, but but all changes in relation to the CMS data scope must be reported in the CMS.

- manage external change requests (i.e. a RU request) if they concern the time window already acquired by TMS, because actual traffic data may be needed to accept or reject the request

NOTE: in this architecture the external request is always be addressed to CMS, and it is the latter that involves VSTP; the how is not relevant to this analysis [see 6.2.7, 6.2.8); **[**SPT3TMS-16416 **]**

7.2 Option 2: VSTP is allocated to TMS

The integration of the VSTP capability into TMS represents another approach, and would entail a different interface between CMS and TMS. In this case the implementation of the Operational Processes derived from the TTR project and handling Late Path Requests, Rolling Plan, ad-hoc Requests, Path Cancellations, i.e. a relevant part of the timetabling phase would be in charge of TMS, in addition to the management of the Capacity Production phase. In this way, on the other hand, there would be a tighter and smoother coupling of the two phases of the planning in the very short time and the execution of the Operational Plan. **[**SPT3TMS-16415 **]**

The following picture shows graphically this functional arrangement: **[**SPT3TMS-16418 **]**

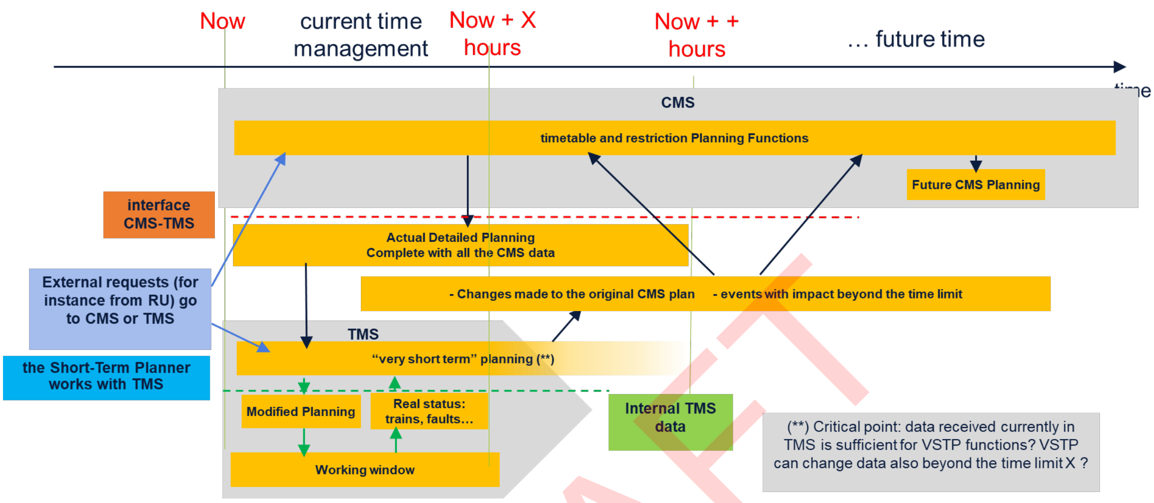


Figure 4: VSTP Capability allocated to TMS

In this case, when significant disruptions occur with respect to the Operational Plan which has been built by TMS and is currently in execution, even if they cannot be managed coming back to the nominal case in few hours but need actions which span till the next 48, 72 hours (and then have an effect on the VSTP time horizon), TMS only would be impacted, relieving CMS from any involvement. **[**SPT3TMS-16412 **]**

As a consequence, CMS would certainly need some information, which however would not imply an exchange of dynamic information, as trains position or trip forecast, but would be limited to the estimated unavailability of infrastructure over the controlled area (resources unavailability, restriction, …). These unforeseen limitations would then be re-elaborated by CMS leading to a replanning of the capacity of the overall state of the infrastructure. **[**SPT3TMS-16411 **]**

However, another set of data should be provided by TMS to CMS, as for example:

- modifies to be agreed (or already agreed) with the RU, as crew who will not be more available for the next shift or location where rolling stock will be set aside
- every modification at the window time limit which must also be reported in the following hours
- temporary operational routing restrictions
- temporary timing restriction

while other information should be provided by CMS to TMS, information that TMS does not need for its functions, as for example:

- crew planning
- rolling stock roster, to select what could be available for planning the next few days
- prices and costs, if it is necessary to evaluate the cancellation or modification of some train/ reservation

NOTE. Responsibility for crew and rolling stock management lies within the RUs, but IMs operator must be informed and accept the changes, ensuring planning consistency. Coordination between IMs and RUs shall permit to find the most suitable solution". **[**SPT3TMS-16414 **]**

This highlights a critical topic, because TMS and CMS are managed by IM while crew and rolling stock are handled by RUs, so this would very likely interfere with EU regulations regarding separate responsibilites of RUs and IMs. Therefore, crew and other data under the responsibility of RUs cannot me managed directly but their re-use has to be ruled with specific processes which have to be previously agreed (they are not in scope of this document), for example exchanging crew/rolling stock related train links for re-use of resources at specific train stops. It is then preferrable that RUs interface with only a system (in this case CMS). **[**SPT3TMS-16921 **]**

As for the previous option, to reach an effective interoperability between instances of TMS and CMS also in this case these classes of data should be harmonized, as well as the interface specification. **[**SPT3TMS-16420 **]**

The VSTP function inserted in TMS accesses the real traffic data it needs (actual movements, accidental faults) to develop a new plan; since it is part of the TMS itself, necessary data known in the TMS environment can be retrieved also by VSTP with a suitable internal interface or in any other way exploiting TMS already available features. **[**SPT3TMS-16424 **]**

This would theoretically allow the real traffic data to be more easily modeled in the TMS rather than in CMS since its internal data does not necessarily need to be harmonized, as the interface between VSTP and TMS is internal to the latter; the VSTP function can evolve consistently in the environment; however, it must be noted that this data is also provided by the TMS to many other systems (passenger information, maintenance, accident management and so on) and must be harmonized in any case with respect to other systems: therefore, this does not reduce the workload expected for the project deployment. **[**SPT3TMS-16423 **]**

In this option it is also necessary to define a data exchange between TMS and CMS (harmonized or not) which aligns the latter with all the changes made in the VSTP context since CMS must always be able to provide the complete Capacity Plan to all the other different systems which require this information. **[**SPT3TMS-16302 **]**

In this architecture, VSTP is responsible for: **[**SPT3TMS-16422 **]**

- acquire from the CMS all the data and constraints that produced the current theoretical Capacity Plan, when an operational replanning involving the TMS time window is required (see 6.2.8 and 6.2.10)];
- perform an effective reschedule and generate an updated, feasible and agreed Capacity Plan;

NOTE: the definition of the replanning algorithm is not the subject of this specification; in this option, however, it is necessary to identify and fix in advance the classes of data necessary to carry out this task, because a subsequent change also requires a modification of the CMS to make such data available;

- the new modified plan must be exhaustive in the TMS time window and VSTP provides it to the TMS, with an internal protocol, it can also use the same methods envisaged for sending the original plan at the scheduled time: see 6.2.6;
- in addition, provide the CMS with all the various planning data, with a harmonized or non-harmonized protocol, and CMS must update its internal data to ensure that its data are always aligned and consistent which each other;

NOTE: the changes that VSTP in TMS is authorized to make at the previous plan may depend on national rules and contexts, but what is of interest must be reported to CMS;

- since VSTP has not access to all CMS data, it cannot directly manage the consequences of changes that exceed the time limit of the TMS window, if there were any, and the CMS have to update its internal data without involving anymore the VSTP/TMS and avoiding loops;
- identify and dispatch to CMS the events whose consequences are long-lasting (i.e. an accidental fault whose expected duration extends long into the future), with the aim of also activating long-term replanning; in this way the future Capacity Plan can be reworked and will be available for the

TMS at the appropriate time (see 6.2.10), as in the previous option, but reporting these change requests to the CMS with a harmonized or non-harmonized protocol;

- acquire the changes made by TMS on the plan, for those change requests that TMS is authorized to make without requiring VSTP's intervention, which must be reported in the CMS environment for alignment (see 6.2.9), as in the previous option, but reporting these changes to the CMS with a harmonized or non-harmonized protocol;
- manage external change requests (i.e. a RU request) if they concern the time window already acquired by TMS: in this option the external request can always be addressed to CMS, and it is the latter that involves VSTP, or directly to TMS; this should be defined [see 6.2.7, 6.2.8);
- VSTP must always provide all the necessary information to the CMS so that the latter can guarantee that all its internal data are always aligned and consistent with each other; since in this option this data exchange is no longer internal at the CMS, the how must become the subject of analysis to be developed in subsequent documents, if it needs to be harmonized.

[SPT3TMS-16425 **]**

7.3 Comparison of options

The following table shows how the two options apply to the two Use Cases UC_CMS-TMS.8 (see 6.2.8) and UC_CMS-TMS.10 (see 6.2.10) and determine a different sequence of operations. **[**SPT3TMS-16419 **]**

7.3.1 UC_CMS-TMS.8

VSTP in CMS	VSTP in TMS
An external modification request is sent to CMS; CMS recognizes that VSTP is involved and activates it	An external modification request is sent to TMS if the external system knows that VSTP is to be involved; alternatively, CMS recognizes that VSTP is involved, and CMS calls TMS
VSTP acquires the real position of trains and the current faults	VSTP acquires all the theoretical data and restrictions necessary for the replanning in the time window
VSTP valuates the request and, if it is accepted, generates a new plan with its algorithms	
VSTP updates the CMS data (internal action), also beyond the TMS time window, ensuring data consistency	VSTP provides all changes to CMS, with formats and methods to be defined (and which may depend on the implementation choices made in the CMS). CMS has to manage the consequences of changes that exceed the time limit of the TMS window (or the limit known by VSTP), and updates this data without involving anymore the VSTP/TMS;
VSTP provides the modified plan to TMS, reusing the formats and methods expected to provide data in the usual ways over time	VSTP updates the plan used by TMS (internal action)

[SPT3TMS-16430 **]**

7.3.2 UC_CMS-TMS.10

VSTP in CMS	VSTP in TMS
TMS detects traffic needs that require changes to current planning data and calls the CMS to activate VSTP	TMS detects traffic needs that require changes to current planning data and directly activates VSTP
VSTP acquires the real position of trains and the current trackside status	VSTP acquires all the theoretical data and restrictions necessary for the replanning in the time window

VSTP in CMS	VSTP in TMS
VSTP evaluates the new traffic status and generates a new plan with its algorithms, also modifying data usually managed by the CMS (for instance, adding or deleting trains in the next hours)	
VSTP evaluates and updates the whole CMS data (internal action), also beyond the TMS time window, ensuring data consistency	VSTP provides all changes to CMS, with formats and methods to be defined (and which may depend on the implementation choices made in the CMS). CMS has to manage the consequences of changes that exceed the time limit of the TMS window (or the limit known by VSTP), and updates this data without involving anymore the VSTP/TMS;
if VSTP detects events that have long-term consequences, it updates the CMS data so that the CMS operator can activate short or long-term Capacity Plan	if VSTP detects events that have long-term consequences, it must send this information to CMS that will updates its data so that the CMS operator can activate short or long-term Capacity Plan
VSTP provides the modified plan to TMS, reusing the formats and methods expected to provide data in the usual ways over time	VSTP updates the plan used by TMS (internal action)

[SPT3TMS-16312 **]**

7.4 Information exchange

7.4.1 General considerations

As stated previously, further analysis is needed to determine which data can be changed directly by the TMS and which data cannot be changed without CMS involvement. As a guideline for this analysis, the information in the CMS plan could be classified according to these main types: **[**SPT3TMS-16429 **]**

- optional information which may be missing
- indicative information, which can be modified locally in the TMS
- restricted information which only CMS can change

[SPT3TMS-16431 **]**

As an example, the receiving platform at the station contained in the train plan, could be an example of optional or just indicative data (this means that TMS can choose another platform as long as it is compatible with the train service); the final station of the train should be instead a restricted data (only CMS can change it, because only CMS can verify the consequences on any passengers, crew, material shifts, etc.). **[**SPT3TMS-16427 **]**

If CMS needs some of the optional or indicative information to carry out its functions, it must consider that this information can change and must be kept updated deriving them from the data that TMS publishes; instead, no restricted information can change without CMS involvement. **[**SPT3TMS-16428 **]**

A point to be taken into account is that this distinction of data classes could change in various railways contexts, reflecting different local uses and regulations: this might lead to the recommendation to develop

the system implementation so that it is parameterizable to some extent. This analysis is outside the scope of this document; here we just stress that the general framework of the described use cases remains valid regardless of the definition of the specific data involved. **[**SPT3TMS-16437 **]**

7.4.2 Option 1: VSTP is allocated to CMS – Minimum dataset to exchange

The integration of the VSTP capability into CMS determines which are the classes of data that CMS and TMS must share. This architectural choice envisages that all planning capabilities are in scope of CMS, which means that CMS (VSTP) shall provide TMS the Capacity Plan for every time horizon in the future, with all possible updates and adjustments. On the other hand, to be able to provide a short-term reschedule of the plan due to disruptions that TMS cannot manage just by solving conflicts and imply cancellations of running trains or even adding new trains, TMS shall feed CMS (VSTP) with the current position of running trains and the list of planned or active restrictions issued by TMS. **[**SPT3TMS-16436 **]**

A high-level view of the macro classes of data to be provided by CMS (VSTP) to TMS is listed here below: **[**SPT3TMS-16438 **]**

- Capacity Plan (planned and agreed train paths used for initializing or updating the operational train movements of the Operational Plan in TMS)
    - This can be forwarded with different time-scopes, but it would be reasonable to be grouped on a daily basis
    - The plan is provided the first time in advance with respect the time-horizon configured to be in scope of TMS, and afterwards all updates until the train run and even when the run is in progress
    - This includes:
        - Trains Connections
        - Train Consists
- Capacity Plan (planned and agreed capacity restrictions used initializing or updating the operational restrictions of the Operational Plan in TMS)

[SPT3TMS-16433 **]**

This can be forwarded with different time-scopes: the only constraint is that the plan should be complete in the time scope which is defined in TMS real-time operating window **[**SPT3TMS-16319 **]**

A high-level view of the macro classes of data to be provided by TMS to CMS (VSTP) is listed here below: **[**SPT3TMS-16432 **]**

- Trains Position
- Trains ScheduledArrival
- Operational Restrictions
- TracksOperationState

[SPT3TMS-16435 **]**

This is a subset of the overall Operating State that TMS continuously receives from Traffic Control and Supervision System; not all information is necessary, as possibly the operation state of the tracks (which then could be excluded after a deeper review) but only those which permit CMS to elaborate a snapshot of the state of railway, which permits to elaborate a new plan to be proposed. **[**SPT3TMS-16434 **]**

The detailed data model which permits to define an interface specification is not in scope of this document; according the conclusion of this analysis and the consequential decisions which shall be taken, the detailed design of the data model shall be planned. **[**SPT3TMS-16439 **]**

7.4.3 Option 2: VSTP is allocated to TMS - Minimum dataset to exchange

Similarly to what anticipated above, also the integration of the VSTP capability into TMS determines which are the classes of data that CMS and TMS must share. This architectural choice envisages that the planning capabilities are partly apportioned to TMS and partly to CMS. This means that TMS is autonomous in replanning the very short-term traffic in case of those disruptions which need to change the nominal plan of movements and restrictions, without having to share the current real-time traffic situation with CMS through their interface. On the other hand, all changes to operational services which imply a different path, a change in the destination of a train service with the consequent change in the first departure or later (for joining, splitting or other reasons) stations for the rolling stock which the service is made of (e.g. later in time of the next day), a replanning of the crew assigned to that services have to be forwarded to CMS, as CMS must keep alignment with TMS. Similarly, all changes in the availability of infrastructural resources which are estimated to span beyond VSTP time horizon must be forwarded to CMS, which will decide how to manage them in the medium-long term. **[**SPT3TMS-16443 **]**

Every Capacity replan with a time horizon which spans beyond the VSTP time horizon must be forwarded by CMS to TMS as envisaged in the previous option. **[**SPT3TMS-16442 **]**

A high-level view of the macro classes of data to be provided by CMS to TMS (VSTP) is listed here below: **[**SPT3TMS-16441 **]**

- Capacity Plan (planned and agreed train paths used for initializing or updating the operational train movements of the Operational Plan in TMS)
    - This can be forwarded with different time-scopes, but it would be reasonable to be grouped on a daily basis
    - The plan is provided only in advance with respect the time-horizon configured to be in scope of TMS; subsequent updates related to the time-horizon in scope of TMS are not elaborated

This includes:

- Trains Connections
- Train Consists

- Capacity Plan (planned and agreed capacity restrictions used initializing or updating the operational restrictions of the Operational Plan in TMS)
    - As above, the plan is provided only in advance with respect the time-horizon configured to be in scope of TMS; subsequent updates related to the time-horizon in scope of TMS are not elaborated

[SPT3TMS-16440 **]**

A high-level view of the macro classes of data to be provided by TMS (VSTP) to CMS is listed here below: **[**SPT3TMS-16446 **]**

- Changes to Capacity Plan (new or changed planned train paths)

This includes:

- Services cancellations
- New services
- Trains Connections updates
- Train Consists updates

- Changes to Capacity Plan (new or changed planned capacity restrictions)
- Changes to final destinations of trains services (in the VSTP time-horizon)
- Locations and planned timing for trains parking (in the VSTP time-horizon)
- List of changed planned location and timing of parked rolling stock vehicles
- Crew descriptor for trains whose final destination has been changed

[SPT3TMS-16445 **]**

The same considerations done at sect. 7.4.2 apply, about when the detailed data model has to be designed. See also the note at chapter 7.2 about the responsibility for crew and rolling stock management between the RUs and IMs. **[**SPT3TMS-16444 **]**

8 Validation against granularity principles

This section is based on the document [Ref. 3], "ARC-D2.3 Granularity Concepts and Principles" produced and published by Task 2 Architectural workgroup and provides an analysis to demonstrate compliancy with the objectives drawn in that specification. **[**SPT3TMS-16447 **]**

Both objective and rules defined in [Ref. 3] are applied to the two options identified above, to recommend the CMS/TMS architecture which better fits with the defined principles. **[**SPT3TMS-16449 **]**

8.1 Objectives

For every relevant objective, which is deemed applicable to this context, few considerations are done which show benefits and risks for the two options which are compared; as this analysis aims to support an interface specification to be implemented as a SW component, some objectives are not applicable; this will be explicitly justified. **[**SPT3TMS-16448 **]**

8.1.1 Objectives analysis

Objective	SPT2ARC-942 - **Interoperability for cross border operation / open network access**
• **Applicability**	Yes. Every modern supervision system over a large area is implemented by a modern TMS which is based on a plan generated by a CMS. TMS and CMS need each other and are tightly coupled. For a smooth passage of national borders or, more generally, from an area managed by a supervision system to an area handled by another one, this coupling is even more critical. Therefore, interoperability and exchangeability are expected for both systems.
• **Specific benefits**	Interoperability can be achieved with different apportionments of functionalities between CMS and TMS, but the benefits increase as much as this apportionment is clearly defined, and as a consequence also the data to be exchanged are well bounded. CMS and TMS are becoming more and more SW IT components whose development make a large use of COTS products and rely on commercial and widely used network stacks, which permits to focus mainly on the application layer of the interface. The harmonization of TMS-CMS interface would enhance the possibility for a smooth integration at cross-borders supporting a number of different configurations and scenarios at cross-borders, as are described by specific Use Cases UC_CMS_TMS_1, UC_CMS_TMS_2, UC_CMS_TMS_3, facilitating the use of CMS and TMS products delivered by different suppliers.
• **Specific risks**	An over-harmonization of the interface might reduce the flexibility to adapt specific contexts of application. Changes to the harmonised CMS-TMS interface need to be agreed across the sector.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS:* This approach would bring a clear and complete functional separation of the planning phase from the real-time execution phase. To enable a proper re-elaboration of the capacity plan necessary to recover from a disruption which cannot be handled simply solving conflicts, the interface between TMS and CMS must be supplemented with the picture of the current state of the field that TMS must feed CMS. As VSTP has planning related functions but with real time information, it brings a difference in RAM requirement between CMS and VSTP which should be taken into account. *Option 2: VSTP implemented as part of TMS:* This approach would make TMS autonomous in managing the very-short term reschedule of the plan, relieving CMS from processing the current state of the field. On the other hand, when rolling stock replanning, crew handling and related costs for crew rearranging are affected, the RU coordinates with the IM to find the most suitable solution, but TMS must see and verify the coordinated suggestions verify the feasibility of the proposed solution and be sure that all CMS data is kept aligned. This would envisage the addition of a large number of heterogeneous data to be exchanged inside the CMS-TMS interface specification.

[SPT3TMS-16326 **]**

Objective	SPT2ARC-941 - **Cost Reduction at the LCC level**
• **Applicability**	Yes. CMS and TMS importance is growing more and more. In the past decades, safety was the target to ensure and the main effort was devoted to reach it. Nowadays, this goal is of course continued to be pursued, but the key driver is more and more getting the optimal

Objective	SPT2ARC-941 - Cost Reduction at the LCC level
	exploitation of the infrastructure to support a greater number of trains running at the same time with a reduced headway, which needs the development of sophisticated techniques and algorithms for traffic regulation and optimization. CMS and TMS systems play a central role to achieve this objective and the optimal functional allocation is a key driver.
• **Specific benefits**	A proper functional allocation for CMS and TMS can simplify and make more effective their development and maintenance, reducing related costs. This also determines the content of the interface to be designed between them, which can be harmonized to a certain extent to promote interchangeability at the same time leaving the necessary flexibility to be suitable for a number of specific contexts of application. These kinds of development don't foresee large volumes, considering the approach proposed in [Ref. 8], but this interface is complex and must be maintained for many years. It is likely that new needs shall raise during its lifetime, which might imply some new versions, considering the long lifetime of interfaced subsystems, so bespoke implementations should be avoided.
• **Specific risks**	A non-optimal functional allocation could result into an unnecessarily complex interface design, while a too extended harmonization might lead to higher, not justified costs. Furthermore, the design of a harmonized interface takes longer time than several bespoke improvements.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: The need to feed CMS with a snapshot of the status of field adds highly dynamic data to the interface; on the other hand, it is necessary a snapshot at a given time and not a continuous refresh, so the additional load should be reduced. *Option 2: VSTP implemented as part of TMS*: This approach needs TMS be aware of a set of data necessary to manage the replanning side effects, which are not used for TMS key functions, and which usually TMS doesn't manage. As replanning is shared between CMS and TMS and may partially overlap, synchronization between them must be granted, envisaging the involved data as part of the dataset to be exchanged.

[SPT3TMS-16327 **]**

Objective	SPT2ARC-958 - Creating open markets for sub-systems and ensure competition
• **Applicability**	Yes
• **Specific benefits**	The standardization of the assigned functions and interface creates a market for CMS and TMS and the two of them are independent. Harmonisation of an agreed set of data will foster competition while keeping flexibility for interface customization where required for specific purposes. Even if there’s not a big market for CMS and TMS (especially for CMS which can reasonably cover a wider area than TMS), this harmonization would be a key factor in achieving a smooth interface between border for cross-border trains.
• **Specific risks**	The small volume for CMS or TMS systems will not probably lead to a significant cost reduction. Moreover, some instances, even a national level, of interfaces between CMS and TMS are in place with an acceptable level of performances, which makes questionable whether the new harmonized proposal is purchased, considering the cost to develop, implement and test a new interface.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: Up to now this is the traditional, most widespread solution. The current implementation of the interface nowadays in commercial operation are not envisaging the snapshot of the current state of the field, but the other data are usually taken into account. This means that the gap towards a new harmonized interface is probably not a big deal, and therefore this approach might be the most appreciated. *Option 2: VSTP implemented as part of TMS*: This approach is less widespread than the previous one, and the interface should envisage a set of data that TMS doesn’t deal with and the interfaces in service today don’t expose. This option would likely envisage a greater gap towards a new harmonized interface than the previous and then could be an obstacle towards interoperability at least in the short-term.

[SPT3TMS-16452 **]**

Objective	SPT2ARC-957 - Create broader supplier base
• **Applicability**	N/A. Whichever is the allocation of VSTP to CMS or TMS and the consequent proposal for an harmonization of the interface, this will not foster a broader supplier base for TMS and CMS systems.
• **Specific benefits**	N.A.
• **Specific risks**	N.A.
	For both options 1 and 2 there is nothing specific to be highlighted.

Objective	SPT2ARC-957 - Create broader supplier base
• Comparison of the options	

[SPT3TMS-16453]

Objective	SPT2ARC-956 - Support integration of new systems into existing environments
• Applicability	Yes.
• Specific benefits	CMS and TMS systems are both necessary and complementary in realizing an effective traffic regulation and optimization system. A harmonized interface between CMS and TMS will support and simplify the integration of products provided by different suppliers and shall ensure exchangeability fostering competitiveness at the same time. This is valid for both existing and new generation products and well fits in the existing environment because there's the need to rearrange only CMS and TMS without impacting other railway systems.
• Specific risks	As existing products don't support newly harmonised interfaces, their upgrade or the introduction of adaptors shall be envisaged, which will increase the costs. This shall be minimized if the product gaps with the new harmonized interface, i.e. with the defined function apportionment is also the minimum possible.
• Comparison of the options	*Option 1: VSTP implemented as part of CMS:* As recalled for SPT2ARC-958– "Creating open markets for sub-systems and ensure competition", this is the approach nowadays followed by most of the existing systems. The evolution towards a harmonized interface consistent with this functional apportionment or the development of an adaptor seems to have the lower gap to be covered. *Option 2: VSTP implemented as part of TMS:* The evolution towards a harmonized interface consistent with this functional apportionment supports the integration of new generation CMS and TMS in the existing environment as well as the previous option, even if it needs to cover a greater gap. As the existing CMS are generally providing the whole planning features, their evolution and the development of adaptors are likely to be more expensive and might take longer time, so hindering the short-term interoperability.

[SPT3TMS-16455]

Objective	SPT2ARC-953 - Support Migration
• **Applicability**	Yes
• **Specific benefits**	The new generation CMS and TMS will bring more advanced features necessary to improve the traffic regulation on wide areas and contribute to achieve the defined CBOs; they will be designed to be consistent with the on-going initiatives and innovations (i.e. TTR) and take advantage of the achievements reached by several innovation programs focusing on AI, ATO introduction etc. A harmonized CMS-TMS interface will facilitate the smooth integration of TMS and CMS in the existing environment also within different times and exploit these benefits for the whole railway system since the very beginning.
• **Specific risks**	As the interface impacts only on CMS and TMS, the risk of inconsistencies is limited to TMS and CMS; anyway, this might have the consequence that the overall railway system will not reach the envisaged benefits. If the allocation of functions is not consistent between TMS and CMS (in case only one of the two is introduced in an existing environment while the other remains the legacy one), an adaptor might be necessary, which increases costs and hampers the rollout. On the other hand, this risk would be present even if a new TMS or CMS is added into an existing environment.
• **Comparison of the options**	The two options are equivalent from the migration viewpoint: • Both new generation CMS and TMS are introduced at the same time: in this case consistency should be ensured if they have been developed according to the harmonized specification • Only one of the two is introduced into an existing environment where the other remains unchanged. In this case an adaptation to the harmonized interface must be developed and added on the legacy side.

[SPT3TMS-16454]

Objective	SPT2ARC-951 - Long term sustainment of the service SPT2ARC-949 -Manage different lifecycles of systems
• **Applicability**	Yes. The life cycle of systems as CMS and TMS is usually 15 years or more. These systems are based on a strong IT infrastructure, which uses commercial HW and OS, can run on customer premises as well as on cloud environment and which continuously evolves in time, much faster than other railway safety related products.

Objective	SPT2ARC-951 - Long term sustainment of the service SPT2ARC-949 -Manage different lifecycles of systems
	These characteristics along with the availability of powerful development tools and environment make the evolution of CMS and TMS simpler than other railway products; on the other hand, new needs and demands are arising frequently to further improve features and performances or achieve a greater level of protection from to incoming new threats.
• **Specific benefits**	The harmonized split of functions between CMS and TMS with the consequential definition of the interface between the two facilitates the decoupling of the lifespan of TMS and CMS and will contribute to keep homogeneity among all contexts of application over the SERA. In all the cases where a CMS or TMS evolution occurs which envisages the restructuring of the internal components without impacting on the types of data to be exchanged, sustaining and lifecycle management can be pursued independently and exchangeability is facilitated.
• **Specific risks**	A CMS or TMS evolution or replacement might imply a change of the peer system. Furthermore, the long lifespan of CMS and TMS will likely imply few installations of the new systems and interfaces and, once rolled-out, the subsequent generation systems are likely to be rolled out much farer in time. This might make convenient a strategy based on bespoke solutions, even if this should surely be an obstacle in cases where more instances of TMS are connected to a single instance of CMS (see UC_CMS-TMS.3, UC_CMS-TMS.4, UC_CMS-TMS.5) To be noted that the harmonization of the CMS-TMS interface might be limited to all common functions to be implemented by all TMS and CMS and the realization of a specific function is still possible for managing specific national needs.
• **Comparison of the options**	When reached a complete rollout of the new generation CMS and TMS towards the implementation of SERA, the two options will be equivalent in term of sustainability. During the migration period, sustainability seems easier for the option which is more consistent with the nowadays most widespread CMS and TMS architectures.

[SPT3TMS-16328]

Objective	SPT2ARC-947 – Interchangeability
• **Applicability**	No. Both CMS and TMS are strongly IT-based pure SW systems, running on COTS HW and using COTS Host and Virtual O.S.,

Objective	SPT2ARC-947 – Interchangeability
	deployed by using commercial widespread development tools, and communicating with the external world by using Ethernet standard connections to commercial network devices as high-speed switches and routers. CMS and TMS can run on HW owned by the final customer at his own premises as well as in a cloud environment, and environmental requirements are quite similar for all suitable equipment.
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	For both options 1 and 2 there is nothing specific to be highlighted.

[SPT3TMS-16457 **]**

Objective	SPT2ARC-1632 – Exchangeability
• **Applicability**	Yes
• **Specific benefits**	As large volumes are not expected for CMS and TMS, harmonization will not bring a substantial benefit in terms of cost reduction. However, harmonization is key to foster and maintain an open market, where all possible contexts of application are supported. This applies to the simplest configurations, where a single instance of CMS is connected to another single instance of TMS (see 6.2.1), to more complex schemas where for example a single instance of CMS feeds two (or more) instances of TMS, or in case of a single instance of TMS is fed by a national and an European instances of CMS (see UC at par. 6.2.3, 6.2.4, 6.2.5). In all these cases, a harmonized interface among homogeneous systems will make easier the evolution or replacement of a system keeping unchanged the other, to the extent to which the harmonization applies. Migration shall be simplified, too, and the reduced effort for the migration shall reduce also the downtime Bespoke data exchange shall need a specific, context-wise adaptation, which shall be as easier as limited.

Objective	SPT2ARC-1632 – Exchangeability
• Specific risks	CMS and TMS interfaces must be harmonized in order to make effective the expected benefits. For applications nowadays in commercial operations where just a CMS or TMS is upgraded while the other remains unchanged, an adaptor must be developed, which entails additional costs, likely to be recurrent for every different context of application. Otherwise, if no adaptor is developed and the new harmonized interfaces are applied only to the new generation CMS and TMS, the deployment towards SERA shall be cumbersome.
• Comparison of the options	Two scenarios are possible: 1. Both new generation CMS and TMS are introduced at the same time: in this case consistency should be ensured if they have been developed according to the harmonized specification, i.e. according to the designed functions apportionment 2. Only one of the two is introduced into an existing environment where the other remains unchanged. In this case an adaptor to the harmonized interface must be developed and added on the legacy side. In case 1, the two options are equivalent from the exchangeability viewpoint. In case 2, in addition to the interface adaptor, an upgrade is necessary for the system which is not upgraded, whose complexity depends whether the VSTP allocation is consistent or not with the newly harmonized added peer system.

[SPT3TMS-16456]

Objective	SPT2ARC-945 – Independent changeability for non-safe and safe sub-systems
• Applicability	N/A. Both CMS or TMS are no safety-related systems. No safety requirements are then assigned to CMS and TMS.
• Specific benefits	
• Specific risks	
• Comparison of the options	For both options 1 and 2 there is nothing specific to be highlighted.

[SPT3TMS-16458]

Objective	SPT2ARC-943 – Different Performance or RAM requirements of sub-systems
• **Applicability**	Yes. Planning functions (generally allocated to CMS) don't need to respect demanding real-time constraints: the capacity plan is elaborated in advance with respect to its coming into service, with a time window which spans from some years before to few hours. Even if a new capacity plan has to be rescheduled due to a detected disruption, its delivery to TMS will presumably occur within an time range of minutes. This means that a short downtime can be acceptable, without having significant effects on traffic regulation. Hot stand-by architectures are not necessary and generally not required, which results in a cheaper design, On the other hand, real-time functions (allocated to TMS) need tight real-time constraints and must be always-on, to continuously monitor the controlled area and react immediately to any event coming from field and notified by TCS (subsystem PES or ATO-TS). This means that even a short downtime can have important consequences on traffic regulation, especially in geographical areas and day times where many trains are running at the same time. Hot stand-by architectures are then necessary and fault-tolerant driven design is mandatory, which is expensive both form the design and V&V viewpoint.
• **Specific benefits**	A clear distinction between functions which need an high availability and reliability from functions which can accept a short downtime will simplify the development of subsystems and permit economic savings.
• **Specific risks**	Even minor differences in RAM requirements for some subsystem functions might imply overdesign or overengineering.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS:* the allocation to CMS of all planning related functions, even VSTP, leaving TMS only real-time related functions, clearly distinguishes functions with different performance or availability requirements, permitting to develop CMS with less demanding performance or availability requirements and limiting the most demanding requirements to TMS only. *Option 2: VSTP implemented as part of TMS:* In this case TMS shall implement functions with a different level of RAM requirements between sub-systems or, if deemed more convenient from an overall perspective, will be designed according to the most demanding RAM requirements even for those functions which don't need it. Anyway, implementing functions with a different level of RAM requirements is not a big deal and this is shot a discriminant facror for the two options.

[SPT3TMS-16459 **]**

Objective	SPT2ARC-959 – Independent changeability of shared functionality
• Applicability	No: the interface between CMS and TMS is designed to be instantiated only among two or more instances of them and not for other different subsystems. The design of CMS and TMS envisages an harmonization of functions apportionment; this means that regardless of how many instances of TMS and CMS are connected (see for example sect. 6.2.3, 6.2.4, 6.2.5) there are no functions that two or more subsystems might share.
• Specific benefits	
• Specific risks	
• Comparison of the options	For both options 1 and 2 there is nothing specific to be highlighted. However, it is necessary to underline that, for option 2, the division of the planning functions by placing the VSTP function in TMS, in case of modification of this functionality, could increase the risks of unexpected side effects in CMS when it receives new data, creating a hidden dependency between the two systems that cannot be verified by testing the TMS alone.

[SPT3TMS-16460 **]**

Objective	SPT2ARC-1028 - Maintain and upgrade legacy systems not supported by the original supplier
• Applicability	Yes
• Specific benefits	Harmonizing CMS and TMS functions and consequently their interface supports an easier replacement of one of the two sub-systems by another provided by a different supplier.

Objective	SPT2ARC-1028 - Maintain and upgrade legacy systems not supported by the original supplier
• **Specific risks**	As legacy and new CMS and TMS are pure SW systems, based on COTS technologies which are continuously evolving offering more and more advanced infrastructure where to run services, new CMS or TMS might not match the interface of the legacy system. During migration phase, an adaptor is likely to be necessary for this purpose and for making consistent the functional characteristics of the two systems. The adaptor shall be easier the more the legacy system is functionally consistent with the newly introduced system.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS:* As stated for the SPT2ARC-958 objective, up to now this is the traditional, most widespread solution. This means that this option might permit a simpler implementation of the adaptor with the legacy system. In this case, if the replaced system is CMS and the legacy TMS already transmits the real time status of the field, an adaptor added in the CMS can receive it; vice versa if legacy TMS does not transmit it, not having the real time status in CMS results in a forecast function elaborated for VSTP without this data, which in turn means for TMS receiving a possibly non-optimal operational plan: but since this also happened with the previous CMS system, legacy TMS evidently already had the features to re-elaborate the plan. Nevertheless, the overall system will continue to operate. In case it is TMS to be replaced and CMS remains the existing one, it will likely not use the real time information from field and the very-short term planning will have no improvements. *Option 2: VSTP implemented as part of TMS:* In this case, in addition to the adaptation of the interface, an implementation should be necessary for the existing legacy system to handle the new classes of data to be provided by VSTP (in TMS) to CMS which might substantially impact the existing system architecture.

[SPT3TMS-16461 **]**

8.2 Rules

The following section is based on the document "ARC-D2.3 Granularity Concepts and Principles" produced and published by Task 2 Architectural workgroup and provides an analysis to demonstrate compliancy with principles and rules drawn in that specification.

For every relevant principle, few considerations are done which show how this has been considered in this analysis; as this analysis aims to support an interface specification to be implemented as a SW component, many principles are inherently satisfied by a correct design and implementation; nevertheless, all of them have been reported and even for some of those considered not applicable few remarks are given.

8.2.1 Rules analysis

Rule	SPT2ARC-1283 - Interface only with justifiable data
• **Applicability**	Yes
• **Specific benefits**	Concentrate all and only all relevant and necessary parameters to exchange between CMS and TMS, minimizing those data which vary very slowly along time and that can be retrieved separately and autonomously by CMS and TMS in specific centralized data repositories as Digital Register.
• **Specific risks**	There could be an overspecification of the interface, envisaging parameters not necessary, which could unnecessarily increase data traffic and elaboration time of both peers.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: CMS must be fed with a snapshot of the status of field so it must access dynamic data from its interface; on the other hand, these data are just a subset of the data that TMS already has to provide to other systems and, therefore, are already published. *Option 2: VSTP implemented as part of TMS*: This approach needs TMS be aware of a set of data necessary to manage the replanning side effects, which are not used for TMS key functions, and which usually TMS doesn't manage; as result involved data will become part of the dataset to be exchanged.

[SPT3TMS-16462 **]**

Rule	SPT2ARC-1282 - Avoid mixing functions of different quality attributes
• **Applicability**	Yes
• **Specific benefits**	CMS and TMS have different goals and scopes, which are clearly distinguished. Therefore, CMS and TMS must implement two distinct and disjointed sets of capabilities, and this interface is key in supporting their implementation defining the appropriate set of parameters to be exchanged.

Rule	SPT2ARC-1282 - Avoid mixing functions of different quality attributes
• Specific risks	Data might be incomplete or, if not properly specified, might not lead to a correct separation of functions between CMS and TMS.
• Comparison of the options	*Option 1: VSTP implemented as part of CMS*: CMS could use its optimization functions for the replanning in the VSTP time window as well, provided that it starts with a snapshot of the field state; on the other hand, TMS doesn't need to know these logics. *Option 2: VSTP implemented as part of TMS*: This approach requires TMS to manage the replanning functions, and these planning algorithms are shared between CMS and TMS and may partially overlap.

[SPT3TMS-16331 **]**

Rule	SPT2ARC-1279 - Isolate optional functions
• Applicability	Yes
• Specific benefits	The implementation of optional functions might be necessary (even if not recommended) for managing specific needs. This implementation is not in scope of the interface definition, but the interface shall envisage all messages and data necessary to implement them (when it is not possible to retrieve this information from another source, as the Digital Register).
• Specific risks	A number of optional and context-dependent functions might lead to the definition of a number of messages not in line with the harmonization purpose, with an overspecification of the interface and an higher traffic volume. It is recommended to avoid the specification of optional functions or at least to minimize their number, and its universal applicability should be explored, maybe with minimal changes or extensions.
• Comparison of the options	*Option 1: VSTP implemented as part of CMS*: All planning and re-planning logics are within the CMS, so optional functions that they may require can be isolated and will not impact the interface or the TMS. *Option 2: VSTP implemented as part of TMS:* In this case, any optional function that might be required for planning management needs to be analyzed to understand whether TMS or CMS (or both) are involved and there might also be impacts on the data exchanged by the interface with drawbacks in terms of interoperability and exchangeability.

[SPT3TMS-16463 **]**

Rule	SPT2ARC-1278 **- Ensure independent life-cycles**
• Applicability	Yes
• Specific benefits	As CMS and TMS will likely evolve in the future, functional decomposition and functional allocation should ensure coherent and consistent sub-system life-cycles.
• Specific risks	A non-harmonized protocol may make the parallel evolution of CMS and TMS more complex.
• Comparison of the options	*Option 1: VSTP implemented as part of CMS*: CMS and TMS can have independent life cycles: the only data exchanged deals with the capacity plan and the actual circulation data, which is also shared with other external systems and therefore if it is modified this would already require a review of all the systems as well. *Option 2: VSTP implemented as part of TMS*: In this approach, adding new data into the CMS planning logics requires the alignment of the corresponding TMS functions, so changes made in the CMS lifecycle are not completely independent for the TMS.

[SPT3TMS-16467 **]**

Rule	**SPT2ARC-1276 - Aim at realizing functions in software**
• Applicability	Yes
• Specific benefits	No specific benefits. This is a good practice which should apply wherever possible. CMS and TMS are IT strongly-based systems, not linked to any specific HW and are natively designed according to this principle.
• Specific risks	A non-harmonized solution, or a solution with particular configurations, may be applicable (even if it is unlikely to happen) only to specific hardware.
• Comparison of the options	Modern software standards allow for complete hardware independence, and CMS and TMS do not require any special hardware equipment. No difference between the two options is found for this rule.

[SPT3TMS-16333 **]**

Rule	SPT2ARC-1275 -Aim for balanced integration effort
• **Applicability**	Yes
• **Specific benefits**	CMS / TMS architecture already shows a balanced allocation of functions and for both systems it is possible a modular design.
• **Specific risks**	Non-harmonized or partially non-harmonized protocols might not lead to a correct integration between CMS and TMS.
• **Comparison of the options**	There is no relevant difference between the two options for this aspect, although *Option 2: VSTP implemented as part of TMS* seems to require a little more integration effort, due to the larger amount of data involved.

[SPT3TMS-16466 **]**

Rule	SPT2ARC-1270 - Aim for balanced certification effort
• **Applicability**	Yes
• **Specific benefits**	CMS and TMS are non safety-related systems and don't need a specific certification. Anyway, the proposed architecture is not much different from many CMS and TMS already in Commercial Operation and the validation and certification effort seems to be well-propotioned to the complexity of the systems.
• **Specific risks**	Non-harmonized or partially non-harmonized protocols might result in different certification requirements for CMS and TMS.
• **Comparison of the options**	There is no relevant difference between the two options for this aspect.

[SPT3TMS-16465 **]**

Rule	SPT2ARC-1271 - Aim for balanced maintenance effort
• **Applicability**	Yes
• **Specific benefits**	The proposed architecture is not much different from many CMS and TMS already in Commercial Operation and the validation and certification effort seems to be well-propotioned to the complexity of the systems. Anyway, a new harmonised interface will facilitate maintenance activities on a system without impacting the other one..

Rule	SPT2ARC-1271 - Aim for balanced maintenance effort
• Specific risks	In case of non-harmonized solutions, maintenance and evolution of CMS and TMS could become more complex.
• Comparison of the options	Standard maintenance procedures can be defined and implemented for both options; there does not appear to be a significant difference in effort required between the two solutions.

[SPT3TMS-16335]

Rule	SPT2ARC-1272 - Aim for a strict separation of hardware and software
• Applicability	Yes
• Specific benefits	CMS and TMS have no specific HW constraints or needs, Since many years, existing CMS and TMS products run on COTS products, using host and virtual COTS operating systems, and the trend is to go along this way, taking more and more advantage of the always newer and more powerful platforms available on the market.
• Specific risks	A non-harmonized solution could be tied up to a specific hardware.
• Comparison of the options	Modern software standards allow for complete hardware independence, and CMS and TMS are pure-software systems and surely satisfy this requirement. There is no difference between the two options for this rule.

[SPT3TMS-16336]

Rule	SPT2ARC-1281 - Effort of changing products only for harmonisation
• Applicability	Yes
• Specific benefits	An initial effort to adapt legacy systems to a harmonized interface must be taken into account, which however shall simplify next maintenance activities.
• Specific risks	If a system is already in Commercial Operation and integrated in its context of execution, harmonization is an additional expense and needs a set-up phase with

Rule	SPT2ARC-1281 - Effort of changing products only for harmonisation
	possible reduction of services, even if this will lead to future benefits (exchangeability etc.).
• **Comparison of the options**	The introduction of harmonized CMS and TMS systems, in line with the new European specifications, will need systems upgrades which cannot be avoided; in some of these systems the effort required may vary and be greater or lesser depending on which option is chosen between the two, but these singular evaluations cannot lead to a single conclusion that is valid in general.

[SPT3TMS-16468 **]**

Rule	SPT2ARC-1280 - Evolution vs. stability of interfaces
• **Applicability**	Yes
• **Specific benefits**	A harmonized interface is designed to be complete and therefore stable. In case of specific needs, an integration of the application layer with specific messages can be done, leaving the harmonized core unchanged. This will permit to have and keep a common core without preventing the possibility to bring customizations where needed (which should be anyway reduced at minimum)
• **Specific risks**	Evolutions have to be considered in a roadmap because backward compatibility is needed.
• **Comparison of the options**	The need to foresee evolutions in both CMS and TMS leads to foster solutions in which the two systems are as independent as possible and the data exchange is minimized (see also SPT2ARC-1278) to have an interface that is as stable as possible. *Option 1: VSTP implemented as part of CMS*: CMS and TMS can have independent evolutions: data exchanged for interface use only are minimized, the others are data commonly used in the system which are supposed to be the most stable ones *Option 2: VSTP implemented as part of TMS*: In this approach, evolution of CMS planning logics could impact the data exchanged with the VSTP inside the TMS, leading to the need for modifications that make the interface more unstable.

[SPT3TMS-16469 **]**

Rule	SPT2ARC-1274 - Consider current granularity specifications
• **Applicability**	No. There are no existing harmonized European specifications for CMS and TMS
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	The VSTP allocation does not change the granularity of CMS or TMS, but just the way a feature (planning) is allocated. From this viewpoint, the two options are equivalent.

[SPT3TMS-16502 **]**

Rule	SPT2ARC-1273 - New major enhancements as separate subsystem
• **Applicability**	Yes
• **Specific benefits**	Keeping TMS and CMS functions fully disjointed and sharing data through a harmonized and stable interface will support independent enhancements and/or the design and development of new features.
• **Specific risks**	The division of functions between systems must be clearly defined to allow independent evolution.
• **Comparison of the options**	A non-harmonized interface could mask a unclear division of functions, which could compromise this goal. *Option 1: VSTP implemented as part of CMS*: VSTP becomes a CMS subsystem with a clearly defined function and can have an independent upgradeability in the CMS environment; its evolution is not tied to TMS modifications. *Option 2: VSTP implemented as part of TMS*: VSTP becomes a TMS subsystem, but there is a risk that sharing of functions with CMS has a partial overlap, which could compromise the goal of an independent evolution; furthermore some upgrades may require a consequent update of the data to be exchanged with the CMS.

[SPT3TMS-16501 **]**

Rule	SPT2ARC-1603 - Avoidance to decompose subsystems for already established subsystems retrospectively
• Applicability	No
• Specific benefits	
• Specific risks	
• Comparison of the options	CMS and TMS remain two systems which (apart from the two options related to VSTP) have completely different goals and functions, and no further decomposition has been found viable up to now.

[SPT3TMS-16503 **]**

Rule	SPT2ARC-1277 - Critical mass of a sub-system
• Applicability	No.
• Specific benefits	
• Specific risks	
• Comparison of the options	CMS and TMS instances nowadays in Commercial Operation show that have a critical mass suitable for their purposes.neither their evolution nor the two depicted options will not significantly change this mass.

[SPT3TMS-16508 **]**

Rule	SPT2ARC-1289 - Evaluation to use parametrisation
• Applicability	No;
• Specific benefits	

Rule	**SPT2ARC-1289 - Evaluation to use parametrisation**
• **Specific risks**	
• **Comparison of the options**	From the viewpoint of the parametrization, the two options are equivalent. The flexibility of the harmonized interface shall be achieved defining a smart semantic, where for example parameters not necessarily to be forced are defined as optional.

[SPT3TMS-16509 **]**

Rule	**SPT2ARC-1288 - Avoidance of options**
• **Applicability**	Yes
• **Specific benefits**	Options are limited to the possible allocation of VSTP feature, which is relevant from the harmonization viewpoint
• **Specific risks**	A non-harmonization of the VSTP allocation would lead to an incompatibility among systems, which in turn implies the development of adaptor and related costs
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: All the variants that might need to be introduced in the planning functions to comply with local regulations or uses are limited to the CMS only; the consequences on the capacity plan generated can be limited to the data contained (see considerations in paragraph 7.4.1). *Option 2: VSTP implemented as part of TMS*: In addition to the consequences on the data contained in the capacity plan, for which the previous considerations apply, any evolution or variant introduced in the planning functions must also be present in the TMS as well as the CMS, spreading the variant effects.

[SPT3TMS-16338 **]**

Rule	SPT2ARC-1287 - Ontologies to define semantics
• **Applicability**	Yes
• **Specific benefits**	The consistency with the existing ontologies (e.g. RINF, TSI telematics) and the complete definition of the semantics for data exchange and for the expected behavior of systems shall foster the integration of data designed to be exchanged and facilitate the adherency to standard interfaces
• **Specific risks**	Unclear data semantics; semantics contain ambiguities or implied definitions.
• **Comparison of the options**	Less defined semantics are needed whith simpler interfaces. There are no relevant differences between the two options from this viewpoint, although *Option 2: VSTP implemented as part of TMS* seems to have a small greated complexity of the classes of data to be exchanged.

[SPT3TMS-16339 **]**

Rule	SPT2ARC-1607 - Harmonisation for functional apportionment
• **Applicability**	Yes
• **Specific benefits**	The harmonization of the interface facilitates the independent integration of innovative CMS and TMS improvements for the advanced functions, keeping conformity to the interface and discouraging bespoke evolutions which would prevent exchangeability and get a more difficult maintenance.
• **Specific risks**	Harmonisation might be expensive to align all CMS and TMS to the new functional allocation and might imply a tough rework according to the existing SW architecture.
• **Comparison of the options**	Since some specific application conditions are expected, harmonization for the VSTP functional apportionment is necessary in both options. *Option 2: VSTP implemented as part of TMS* seems to require a little more specification effort, due to the split of planning function between CMS and TMS.

[SPT3TMS-16510 **]**

Rule	SPT2ARC-1606 – Independent changeability of interfaces
• **Applicability**	Yes
• **Specific benefits**	A well-designed harmonized interface brings benefits in terms of maintainability, adaptability, exchangeability, upgradeability: see SPT2ARC-1231 - Benefits for maintainability; and SPT2ARC-1241 - Benefits for adaptability, changeability, updateability and upgradeability .
• **Specific risks**	Despite harmonization, improvements in one sub-system might require new data from/to one or multiple other sub-systems.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: Data exchange is limited to the Capacity Plan and a snapshot of the status of field therefore it is easier to reach an independent changeability of CMS or TMS. *Option 2: VSTP implemented as part of TMS*: This approach needs a wider set of data to be exchanged to handle the planning function in VSTP; this increases the risk of introducing more dependencies between TMS and CMS creating constraints for their interchangeability.

[SPT3TMS-16511]

Rule	SPT2ARC-1605 - Decomposition only if linked to a harmonisation level
• **Applicability**	No. Apart from the definition and allocation of the VSTP, which is the subject of the analysis, no any further decompositions of CMS and TMS have been identified.
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	From this viewpoint, for options 1 and 2 there is nothing specific to be highlighted.

[SPT3TMS-16340]

Rule	SPT2ARC-1593 - Avoidance of SRACS
• **Applicability**	No. There is no SRACs (Safety-related Application Conditions) between CMS and TMS.
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	From this viewpoint, for options 1 and 2 there is nothing specific to be highlighted.

[SPT3TMS-16512 **]**

Rule	SPT2ARC-1594 - Separation of shared functionality
• **Applicability**	Yes
• **Specific benefits**	The introduction of a new possible CMS or TMS subsystem (the “Very Short Term Planning” subsystem) must be analyzed in the context of each system; this is the only functionality which might be reasonable to separate. As this feature is tightly coupled with all planning features, keeping it separated would require a continuous and relevant exchange of information between the new subsystem VSTP and TMS/CMS
• **Specific risks**	Sharing VSTP would increase the complexity of the overall system as a separate subsystem interposed between CMS and TMS would require two interfaces to be harmonized and not only one.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: VSTP may or may not be a separate subsystem within CMS, this choice becomes an internal architectural choice: as mentioned in the analysis, the VSTP operator interface could also be provided to TMS operators, depending on RU organizational needs, and this could still recommend that VSTP be a separate subsystem; in any case, TMS is not involved in any changes made in VSTP. *Option 2: VSTP implemented as part of TMS*: VSTP should be a separate subsystem of TMS but even so planning is shared between CMS and TMS and may partially overlap and it is difficult to ensure that any change to the VSTP does not also result in changes to the CMS. See also SPT2ARC-1273 - New major enhancements as separate subsystem. A good approach could be to provide a TMS user with a VSTP application integrated into

Rule	SPT2ARC-1594 - Separation of shared functionality
	his workplace, so as to permit him to use both TMS and CMS if requested by his role in a specific railway organization.

[SPT3TMS-16341]

Rule	SPT2ARC-1595 - Consideration of proven in use solutions
• **Applicability**	Yes
• **Specific benefits**	SP design aims to innovate and specify a new generation of CMS and TMS. So, there are no complete and already available solutions proven in use. However, Option 1 is more in line with current functions apportionment for CMS and TMS, so the evolution towards future CMS and TMS should be facilitated.
• **Specific risks**	A strategy aiming to upgrade an existing product, especially if proven to work well, might result in keeping some design drawbacks and preventing the design and development of the optimal architectural solution.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS:* this is the strategy nowadays followed by most of the existing systems. Reusing this approach might be an advantage to reduce costs and impacts on the organization of operational roles in RU. *Option 2: VSTP implemented as part of TMS:* As there are less instances of this implementation, development and validation might require an higher effort.

[SPT3TMS-16513]

Rule	**SPT2ARC-1598 - Reduce railway specific requirements**
• **Applicability**	No. There are no specific railway requirements for the interface. Requirements common to all software developments have been identified only.
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	For both options 1 and 2 there is nothing specific to be highlighted.

[SPT3TMS-16514 **]**

Rule	**SPT2ARC-1597 - Reduce interfaces between safety relevant subsystems**
• **Applicability**	No. CMS and TMS are not safety relevant subsystems, and the interface between them is not safety-related.
• **Specific benefits**	
• **Specific risks**	
• **Comparison of the options**	Both options 1 and 2 are not related to this rule..

[SPT3TMS-16515 **]**

Rule	**SPT2ARC-1599 - Adapt the environment or existing subsystems for newly defined interfaces**
• **Applicability**	Yes
• **Specific benefits**	A harmonized interface supports facilitates faster integration of new subsystems; this means cost and effort reduction for the initial deployment.
• **Specific risks**	Harmonisation might be expensive to align all existing CMS and TMS already in Commercial Operation and already well integreated into their environment: see SPT2ARC-1607 - Harmonisation for functional apportionment.
• **Comparison of the options**	In any case, the preparation/modification of the existing environment or subsystems must be foreseen; this workload cannot be avoided when introducing newly defined systems and interfaces. The possible choice of maintaining the current non-harmonized protocols on a case-by-case basis is certainly a quick and economical solution, but it does not allow for future updates / upgrades and cannot be the definitive solution. As a general statement: *Option 1: VSTP implemented as part of CMS* is clearly preferable if CMS is delivered before TMS, because it allows the complete management of planning environment to be immediately available, and the existing TMS is likely to be able to receive a rescheduled plan from CMS. If in the existing TMS there is a subsystem that already performs the VSTP functions, this can be inhibited or temporarily left unused on the existing TMS. Conversely: *Option 2: VSTP implemented as part of TMS* might be preferable if TMS is delivered first, but using the TMS VSTP feature requires verifying that the existing CMS can provide the necessary data. Furthermore, if the existing CMS is not able to receive and manage the changes made by the TMS VSTP, misalignments could be created in the CMS capacity data.

[SPT3TMS-16342 **]**

Rule	**SPT2ARC-1602 – Harmonised requirements**
• **Applicability**	Yes
• **Specific benefits**	SP specifications for TMS and CMS aim to define and approve a harmonized set of relevant requirements.

Rule	**SPT2ARC-1602 – Harmonised requirements**
• **Specific risks**	For TMS and CMS and its interfaces national add-ons or other customer specific requirements may be requested. Their real usefulness must be carefully analyzed before accepting. Anyway, even if few bespoke characteristics are at the end implemented, they shall be limited and not impact the core features of both systems.
• **Comparison of the options**	There are no relevant differences between the two options: in both cases national add-ons in the VSTP may be required and will need to be analyzed, and the context in which the VSTP operates (CMS or TMS) is of little relevance. Note that without a harmonized interface, it is much more likely that national and customer-specific requirements are introduced.

[SPT3TMS-16343 **]**

Rule	**SPT2ARC-1627 - Intermediate step for migration**
• **Applicability**	Yes
• **Specific benefits**	The introduction of a new interface needs an adaptor for the legacy system, but it is an intermediate step which arranges the railway environment for the migration to the final SERA architecture.
• **Specific risks**	The development of an adaptor will increase the time and cost of migration.
• **Comparison of the options**	In order to avoid unnecessary steps, the introduction of a harmonized protocol allows the system to be already set towards a stable final state. The development of an adaptor in an intermediate step of the evolution can be the best option for the migration, but the cost / benefit analysis depends on each specific context. As a general statement, *Option 1: VSTP implemented as part of CMS* would be preferable if CMS is delivered before TMS, because it allows the entire planning system to be available immediately. Conversely, *Option 2: VSTP implemented as part of TMS* might be preferable if TMS is delivered first, but in this case the use of the VSTP function might be very limited if CMS cannot provide all the necessary data. An adaptor shouldn't solve this issue unless it is designed to be also a source of data, which should be retrieved anyway from elsewhere.

[SPT3TMS-16516 **]**

Rule	SPT2ARC-1626 - Common ontology for data element in a domain architecture
• **Applicability**	Yes
• **Specific benefits**	Supports consistency with all other data elements in terms of a common semantic dictionary to avoid misunderstandings and different interpretations.
• **Specific risks**	Some data might be not defined and require a following step of specification which might delay the introduction of the harmonized interface.
• **Comparison of the options**	*Option 1: VSTP implemented as part of CMS*: The data related to the real circulation and the status of field, which CMS needs, must already have a common ontology because this data is already provided by TMS to other systems and, therefore, already required standardization. *Option 2: VSTP implemented as part of TMS*: In this option there is a set of data necessary to manage the replanning function, which is shared between TMS and CMS and might likely request its own additional ontology.

[SPT3TMS-16344]

8.3 Quantitative analysis conclusions

Considering the objectives mentioned in the previous paragraph, specifically the **exchangeability objective**, which is a goal that would be desirable to achieve, and the need to manage in the future the **sustainment of the systems** and the possible **different lifecycles of CMS and TMS**, the first evidence is that the best change is to have a harmonized CMS-TMS interface. Even in the few cases where a non-harmonized one seems to bring some advantages (see *SPT2ARC-1281 - Effort of changing products only for harmonisation* and *SPT2ARC-1599 - Adapt the environment or existing subsystems for newly defined interfaces*) especially for the initial effort of changing current products and for a faster integration of new systems, these advantages are only temporary and generate higher workloads on maintenance and subsequent systems upgrading / evolution, limiting future interoperability and exchangeability. These long-term disadvantages seem to outweigh the initial gains in time and costs.

Keeping in mind the comparisons mentioned in the previous paragraph between the *Option 1: VSTP implemented as part of CMS* and *Option 2: VSTP implemented as part of TMS*, this preliminary analysis of the pro's and cons' leads to the conclusion that option *Option 1: VSTP implemented as part of CMS* seems to meet better the objectives examined.

It is worth to mention:

- Ensure a clear and complete functional separation of the planning phase from the real-time execution phase (see SPT2ARC-942 and also SPT2ARC-959 for the risks connected);
- Avoid exchanging a large amount of heterogeneous data in the CMS-TMS interface (see SPT2ARC-942, SPT2ARC-941);
- Lower gap between the new harmonized interface and the actuals ones (see 958 956) minimizing the need of adaptors on the legacy system (see SPT2ARC-95, SPT2ARC-949, SPT2ARC-1018).

Even the analysis of the granularity and decomposition rules, carried out following what is indicated in the document [Ref. 3], and [Ref. 4] as an example, suggests the convenience of having VSTP implemented as part of CMS; although for many rules the two options are comparable and do not present major differences, in those cases where a preference for one of the two can be highlighted, this preference leads towards *Option 1: VSTP implemented as part of CMS*.

This consideration is motivated in particular by:

- a greater and clearer functional separation between CMS and TMS (see SPT2ARC-1282, SPT2ARC-1273, SPT2ARC-1594);
- a smaller quantity and type of data to be shared between CMS and TMS (see SPT2ARC-1283, SPT2ARC-1280);
- the greater possibility of having independent evolutions of CMS and TMS (see SPT2ARC-1279, SPT2ARC-1278, SPT2ARC-1606);

All these reasons can lead to lower integration, definition and development efforts and costs for CMS and TMS systems.

9 Conclusions

The purpose of this document was to carry out a preliminary analysis of the use cases and problems relating to the interface between CMS and TMS. During the Use Cases study, the very short-term planning process (VSTP) emerged as a critical process. **[**SPT3TMS-16505 **]**

Indeed, VSTP operates in a time slot common to both CMS and TMS, involving both in the consequent modification of the original capacity plan elaborated by CMS: while there is general consensus on how the other tasks to be performed are divided between CMS and TMS, there has been no common agreement so far on whether VSTP should be allocated in one of the two systems and on the resulting assignment of tasks for both systems, and how to divide them. **[**SPT3TMS-16504 **]**

Two possible solutions architectures were designed and compared. Ther overall consideration of Pro's and Cons' leads to conclude in this preliminary analysis that the option to have the VSTP Capability integrated in CMS is that which fits with the best integration and effectiveness of the operational processes to be put in place between CMS and TMS. **[**SPT3TMS-16507 **]**

This conclusion is now proposed for the necessary verification and discussion and, once approved and assessed, could be the starting point for an interface specification describing in detail the data exchanged and the resulting actions. **[**SPT3TMS-16506 **]**

Considering the interest that the analysis raised and the relevance of the subject a further more specific technical analysis, starting from this document and the elements provided inside, might be useful to further deepen the topic and reach a final agreement, on top of which to start the specification of the interface between CMS and TMS. **[**SPT3TMS-16982 **]**

This analysis should consider a key point which already emerged during this analysis and comes even clearer from the raised comments, which is the variety of operational processes now existing among the various European railways; as some relevant examples (already referred to while writing the analysis) we can mention "Train on demand", platform change inside a station, train path change, for a limited extent or applied to a wider one (as rerouting a high priority train from the high speed line to the normal line). **[**SPT3TMS-16981 **]**

This analysis should also lead to define to which extent to carry out the harmonization of processes and define if and which parametrizations should be envisaged for the TMS CMS interface specification and implementation to accomplish the various sector expectations. **[**SPT3TMS-16983 **]**