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24/07/2024	Fabian Hois	ÖBB-INFRA/d-fine	Task 6.2 member	Review
24/07/2024	Victoria Guryn	RENFE	Leader of WP24 of FP1	Review
30/07/2024	Malcolm Lundgren	TRV	Internal reviewer	Review within WP6
30/07/2024	Joao Mira	GTSP	Task 6.2 Member	Review
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Executive Summary

Deliverable 6.3 reports on the requirements and design for the interface between Traffic Management Systems (TMS) and Passenger Information Systems (PIS) in WP6 of the EU-Rail FP6 FutuRe project. The interface will be demonstrated using a PIS developed in FP6 WP6 and a TMS developed in the FP1 MOTIONAL project.

The aim of the interface is twofold: On the one hand the interface facilitates to provide demand forecast data for train services from a PIS to a TMS so that on TMS side short-term traffic control actions can be taken and long-term replanning decisions can be made; on the other hand, the interface enables the TMS to send information about timetable updates via the interface to the PIS so that travellers can be informed in real time about changes impacting their journeys.

The TMS-PIS interface is specified based on four use cases. Three use cases are concerned with transferring demand forecast data for regional train services from a PIS to a TMS. The demand forecast data is calculated within FP6 WP6 by an analytics component of the PIS. The demand forecasts cover (1) the number of passengers between two stations within a defined time window, (2) the number of passengers on a train between subsequent stops, and (3) the number of passenger alighting/boarding at a given station of a train service. On TMS side, the forecast data are processed and used for supporting Traffic Controllers in case of short-term demand forecasts for the next hours and Timetable/Traffic Planners in case of long-term demand forecasts for the next days. A fourth use case describes timetable updates on TMS side, such as delayed departure times or platform changes, that are transferred to the PIS.

For each use case, functional and non-functional requirements are documented. A high-level architecture diagram sketches the specified solution and shows how the TMS-PIS interface is embedded in the overall architecture of the TMS on FP1 side and the PIS on FP6 side. Furthermore, sequence diagrams per use case illustrate the flow of data between involved actors and system components and indicate the functionalities of each component.

When searching for existing standard formats for the data to be transferred via the TMS-PIS interface, available standards such as SIRI ET were identified. However, current standards such as SIRI ET cannot completely cover the transfer of demand data. Hence, in a first implementation, alternative formats specifically designed in Task 6.2 will be used, additionally.

List of abbreviations, acronyms and their definitions

Abbreviation / Acronym	Definition
AI	Artificial Intelligence
CCS	Control-Command and Signalling
CMS	Capacity Management and Planning System
FP	Flagship Project
IL	Integration Layer (Shift2Rail TD2.9)
MaaS	Mobility-as-a-Service
PIS	Passenger Information System
S2R	Shift2Rail
SIRI	Service Interface for Real Time Information (CEN Technical Standard that specifies a European interface standard for exchanging information about the planned, current or projected services)
TCCS	TMS/CCS data model provided by System Pillar, Task 2
TCS	Traffic Control System
TMS	Traffic Management System
TSP	Travel Service Provider
UC	Use Case
US	User Story
WP	Work Package

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1. Introduction

Deliverable 6.3 reports on the requirements and design for the interface between Traffic Management Systems (TMS) and Passenger Information Systems (PIS) or Passenger Information Services at the state of development as of M20 of the EU-Rail project FP6 FutuRe within Task 6.2 of the WP6, which develops regional rail services. The aim of the present document is to provide the base for all future technical developments and the implementation of the developed solution, not only in the Final Release phase of WP6, but also in the subsequent WP11. Results from preceding S2R projects were considered and will be kept in mind for the development of the solution during the FP6 FutuRe project.

The deliverable is structured as follows: Some basic definitions are provided in Chapter 2. Chapter 3 describes four use cases based on the TMS-PIS interface and explains the relevant actors. In Chapter 4, requirements that have been derived for the use cases are documented. In Chapter 5, the logical architecture of the solution is outlined that has been specified for the bi-directional data exchange between TMS and PIS via the TMS-PIS interface. Sequence diagrams depict for each use case the respective data flow. Chapter 6 elaborates on standards suitable for the required data transfer and on their limitations especially for transport demand data sent from PIS to TMS. For the corresponding use cases, concrete data formats are specified. Chapter 7 contains the conclusion of the deliverable.

2. Definitions

The glossary of terms shown in Table 1 reflects the status of the work in M20 and covers crucial building blocks of the specification of the TMS-PIS interface. It is expected to be improved and expanded during the remaining work in WP11.

Table 1: Definitions

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.
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.

3. Use Cases

This section provides the definition of use cases and actors within the context of the specification of the requirements and design for the TMS-PIS interface in the regional rail scope. The purpose of this section is to establish a clear understanding of the functional requirements and stakeholders involved in the TMS-PIS interface.

In the regional rail scope, the interfacing between TMS and PIS plays an important role in informing travellers about operational changes of their trains at real-time time scales and to provide expected occupancy and expected travellers' demand back to TMS for improved, customer orientated traffic management decisions.

The actors are the entities or stakeholders (persons or external systems) that interact with the TMS and PIS connected by the TMS-PIS interface. Defining the actors as it is done in Section 3.1 helps to identify their roles, responsibilities, and perspectives, ensuring the interface meets their needs. It should be noted that all interactions between TMS Operators and the TMS and between the TMS and the PIS are non-safety critical. The interaction of Train Controllers with TCS (Traffic Control System) or TCS with interlocking systems is not addressed by the use cases introduced in this chapter.

The use cases represent the various functionalities or interactions of the demand analysis system. They are described in Section 3.2 through Section 3.4. They include information like the description of the use case, related project tasks/subtasks, involved actors, trigger, pre-conditions, input, result/requirement, sequence of steps, expected release date, involved components and the responsible partner to develop the use case.

All the detailed descriptions of the identified use cases and actors should be considered in the regional rail domain.

The following diagram identifies the use cases developed in Task 6.2 on the basis of use cases of Task 6.4 that supplies crucial input to Task 6.2 by providing demand forecast data. This provides a good overview of the actors and objectives of the work developed on this deliverable.

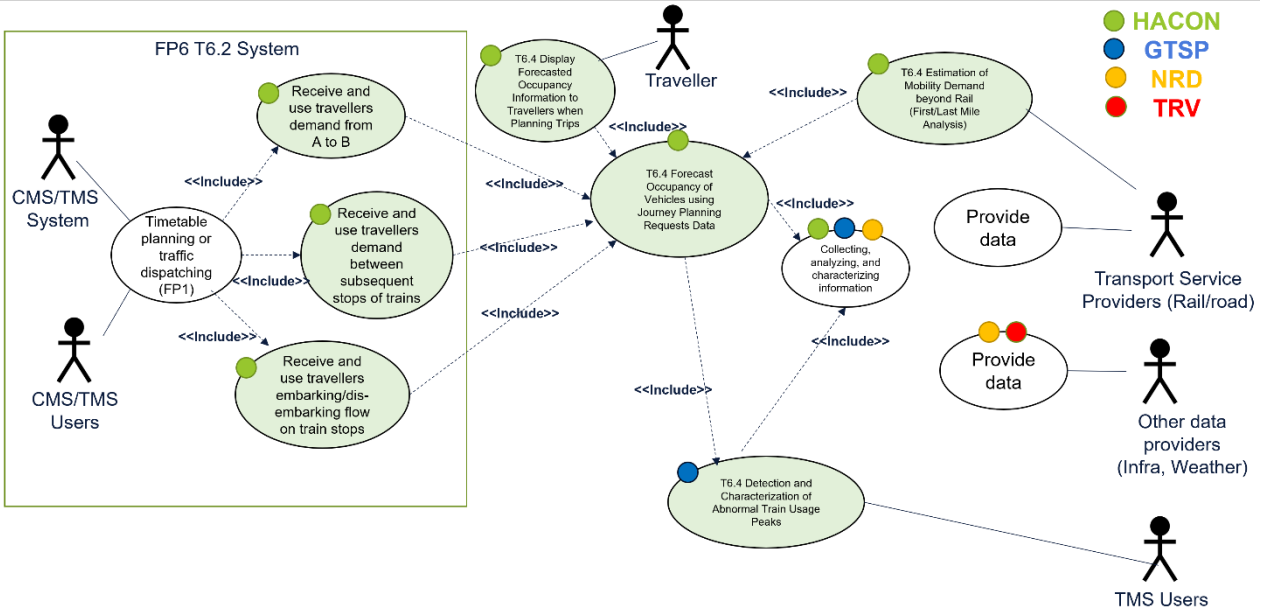

Figure 1: Use cases and system actors' identification

3.1. System Actors

The following Table 2 presents the description of actors involved in the use cases defined in this section.

Table 2: System actors' definitions

Actor	Description
CMS	A Capacity Management System (CMS) refers to a logical and integrated cycle of activities within a company or organization (IMs). Its purpose is to control and assure the competence of staff involved in rail operations. Essentially, it helps to manage infrastructure capacity effectively, considering the needs of all users across various time horizons.
Transport Service Provider (TSP)	Organization providing both physical services and means of transport: trains, metros, coaches, buses, bike-sharing, car-sharing, DRT...
Traveller	The traveller is the person making or planning a travel.
MaaS platform	A MaaS (Mobility as a Service) platform is a digital platform that integrates various transportation services into a single, user-friendly interface. It aims to provide seamless and convenient travel experiences by offering a range of transport options, such as public transit, ridesharing, bike-sharing, car-sharing, and more, all in one place.
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 24h time horizon.
Timetable/Traffic Planner	A user of the TMS supervising the traffic on a defined railway network and taking planning decisions to address train or network capacity requests and train conflicts or the impact of temporary infrastructure restrictions on trains before the 24h time horizon.

3.2. UC-FP6-WP6-2.1 Send updated operational plan and calculated forecast to PIS

The following use case was derived from user story US9 (see [Deliverable D6.1 of FP6 FutuRe]):

US9:
As an operator of a TMS (i.e., as a Traffic Controller), I want to send updated timetable data to the PIS so that the travellers can be kept informed.

Name	Sending updated operational plan and calculated forecast provided by the TMS to passenger information services/systems (PIS)
ID	UC-FP6-WP6-2.01
Description	Following the updates of the operational plan and the calculated forecast in the TMS, specific relevant information is derived and sent to the PIS: • Expected delay in arrival and departure times of the trains; • Platform track changes; • Full or partial cancellations; • Incident information in relation to trains.
Related to task/subtask(s)	T6.2
Impact on other task(s)	T6.1.1, T6.4
Interactions SP/FP	FP1 WP12 Task 12.2.7
Actor(s)	Traffic Controller, TMS, PIS end user
Trigger	Scheduled or event-based triggers
Pre-Condition(s)	• Available operational plan including trains and operational restrictions (planned or incident based) impacting trains.

	● Availability of TMS. ● Availability of integrated PIS / traveller application for the area covered by the TMS.
Input	● Baseline data for network topology and train characteristics, ● Public timetable containing the trains of the TMS area, ● Train position feeds (simulated), ● Trip request.
Result/Requirement	Delay, track change and incident information delivered to the PIS.
Sequence	1. (simulated) Train positions fed into TMS leading to the need for intervention by the Traffic Controller. 2. Update of operational plan in the TMS initiated by Traffic Controller. 3. Train running forecast calculation performed in TMS. 4. Information derived from operational plan and train running forecast is transferred via interface to the PIS. 5. Information received by PIS. 6. PIS End user receives information in conjunction with his trip information.
Involved components (System)	TMS, PIS, Journey planning application
Responsible partner/person	Rolf Gooßmann, Hacon
Notes	None

3.3. UC-FP6-WP6-2.2 Usage of the number of expected travellers for timetable planning or traffic dispatching

The following use case was derived from user story US10 (see [Deliverable D6.1 of FP6 FutuRe]):

US10:
As an operator of a TMS (i.e., as a Traffic Controller), I want to receive travel demand forecast data from a PIS so that I can adjust the timetable and provide updated timetable data.

Name	Usage of the number of expected travellers for timetable planning or traffic dispatching
ID	UC-FP6-WP6-2.2
Description	As part of the demand forecast information, the Traffic management System (TMS) or Capacity Management and Planning System (CMS) receives the number of expected travellers from A

	to B in defined time windows being visualized for decision support in (re-) planning the timetable in CMS and/or changing the Operational Plan in TMS.
Related to task/subtask(s)	T6.2
Impact on other task(s)	T6.1.1, T6.4
Interactions SP/FP	FP1 WP6 Task 6.3.1, WP7 Task 7.5.1 and 7.6 FP1 WP12
Actor(s)	Timetable/Traffic Planner, Traffic Controller, TMS, PIS
Trigger	Scheduled trigger in TMS or CMS for looking up newly delivered input being available.
Pre-Condition(s)	• Available timetable (CMS) and related Operational Plan (TMS) including trains for which demand forecast information is available, i.e., expected travellers for relation A-B where A and B are starting and destination stations of the trains. • Availability of CMS and related TMS. • Availability of integrated PIS providing demand forecast for the area covered by the CMS/TMS.
Input	• Baseline data for network topology and train characteristics. • Public timetable containing the trains of the CMS/TMS area. • Source data allowing to derive demand forecast for at least a part of the network covered with planned timetables for trains.
Result/Requirement	Changes applied to the timetable (CMS), or the Operational Plan (TMS) based on forecasted demand.
Sequence	1. The number of expected travellers from A to B in a defined time window is received by CMS. 2. Travel/transport demand window is generated in the CMS as part of the planning data and is available to CMS system logic and to the users of the CMS. 3. Different timetable change options are applied involving CMS timetable planner and the CMS: a. Let the planning system generate (an) extra train(s) from A to B with defined seat capacity. b. Decide a (partial) cancellation of a service due to non-sufficient demand. c. Decide on reducing or increasing the number of coaches for existing service(s) from A to B matching the demand. 4. CMS implements the change in the planned timetable. 5. CMS forwards the changed plan to TMS (if changes to be included in the current Operational Plan).

	6. TMS updates Operational Plan (if changes to be included in the current Operational Plan).
Involved components (System)	CMS, TMS, PIS, Integration Platform
Responsible partner/person	Rolf Gooßmann, Hacon
Notes	None

3.4. UC-FP6-WP6-2.3 Receive and use travellers demand between subsequent stops

This use case was also derived from user story US10 (see Section 3.3).

Name	Receiving and using the number of expected travellers between subsequent stops of a given train for timetable planning or traffic dispatching
ID	UC-FP6-WP6-2.03
Description	As part of the demand forecast information, the TMS/CMS receives the number of expected travellers between subsequent stops of a given train being visualized for decision support in (re-) planning the timetable in CMS and/or changing the Operational Plan in TMS.
Related to task/subtask(s)	T6.2
Impact on other task(s)	T6.1.1, T6.4
Interactions SP/FP	FP1 WP6 Task 6.3.1, WP7 Task 7.5.1 and 7.6 FP1 WP12
Actor(s)	Timetable/Traffic Planner, Traffic Controller, TMS, PIS
Trigger	Scheduled, regular trigger in TMS or CMS for looking up newly delivered input being available.
Pre-Condition(s)	• Available timetable (CMS) and related Operational Plan (TMS) including trains for which demand forecast information is available, i.e., expected travellers between subsequent stops A-B of a given train. • Availability of CMS and related TMS. • Availability of integrated PIS providing demand forecast for the area covered by the CMS/TMS.
Input	• Baseline data for network topology and train characteristics. • Public timetable containing the trains of the CMS/TMS area.

	• Source data allowing to derive demand forecast for at least a part of the network covered with planned timetables for trains.
Result/Requirement	Changes applied to the timetable (CMS), or the Operational Plan (TMS) based on forecasted demand.
Sequence	1. The number of expected travellers between subsequent stops of a given train is received by CMS. 2. The information is generated in the CMS and assigned to the respective train and its respective journey section A-B as part of the planning data. The information is available to CMS system logic and to the users of the CMS. 3. Timetable change involving CMS timetable planner and the CMS based on occupancy information between stops, decide on prioritization of trains and related re-planning (e.g., changing train sequence). 4. CMS implements the change in the planned timetable. 5. CMS forwards the changed plan to TMS (if changes to be included in the current Operational Plan). 6. TMS updates Operational Plan (if changes to be included in the current Operational Plan).
Involved components (System)	CMS, TMS, PIS
Responsible partner/person	Rolf Gooßmann, Hacon
Notes	None

3.5. UC-FP6-WP6-2.4 Receive and use travellers embarking/disembarking flow on stations

This use case was derived from user story US10 (see Section 3.3).

Name	Receiving and using the number of expected travellers embarking/disembarking at the stops/stations of a given train for timetable planning or traffic dispatching
ID	UC-FP6-WP6-2.04
Description	As part of the demand forecast information, the TMS/CMS receives the number of expected travellers embarking/disembarking at the stops of a given train being visualized for decision support in (re-) planning the timetable in CMS and/or changing the Operational Plan in TMS.
Related to task/subtask(s)	T6.2
Impact on other task(s)	T6.1.1, T6.4

Interactions SP/FP	FP1 WP6 Task 6.3.1, WP7 Task 7.5.1 and 7.6 FP1 WP12
Actor(s)	Timetable/Traffic Planner, Traffic Controller, TMS, PIS
Trigger	Scheduled, regular trigger in TMS or CMS for looking up newly delivered input being available.
Pre-Condition(s)	• Available timetable (CMS) and related Operational Plan (TMS) including trains for which demand forecast information is available, i.e., expected travellers embarking/disembarking at stops A, B, C… of a given train. • Availability of CMS and related TMS. • Availability of integrated PIS providing demand forecast for the area covered by the CMS/TMS.
Input	• Baseline data for network topology and train characteristics. • Public timetable containing the trains of the CMS/TMS area, • Source data allowing to derive demand forecast for at least a part of the network covered with planned timetables for trains.
Result/Requirement	Changes applied to the timetable (CMS), or the Operational Plan (TMS) based on forecasted demand.
Sequence	1. The number of expected travellers embarking/disembarking at the stops A, B, C, … of a given train is received by CMS. 2. The information is generated in the CMS and assigned to the respective train and its respective journey stops A, B, C, … as part of the planning data. The information is available to CMS system logic and to the users of the CMS. 3. Timetable change involving CMS timetable planner and the CMS decide on required exceptional dwell time at stations for consideration of unexpected number of people embarking/disembarking at the station. 4. CMS implements the change in the planned timetable. 5. CMS forwards the changed plan to TMS (if changes to be included in the current Operational Plan). 6. TMS updates Operational Plan (if changes to be included in the current Operational Plan).
Involved components (System)	CMS, TMS, PIS
Responsible partner/person	Rolf Gooßmann, Hacon
Notes	None

4. Requirements

This chapter lists the requirements for each use case. A requirement is a need that must be or should be satisfied by the solution to be developed to be an acceptable solution. Hence, a requirement is a necessary or desired capability or characteristic of the system specified in this document.

The requirements are documented following a template. Each requirement has an ID as a unique identifier. This ID indicates which use case the requirement was derived from and whether it is a functional or non-functional requirement. In case of a functional requirement, the ID contains the suffix "_FRQ". In case of a non-functional requirement, the suffix is "_NFRQ".

4.1. T6.2_UC2.1_FRQ01 TMS data provision to PIS

Requirement ID	T6.2_UC2.1_FRQ01
Requirement Name	TMS data provision to PIS
Use Case ID	UC-FP6-WP6-2.01
Category	Functional (TMS)
Priority	MUST
Main goal	The TMS needs to provide specific up-to-date information to the PIS. Passengers need to be informed about the latest status of their trains, possible incidents of relevance and the forecasted delay to adapt their personal travel plans or inform others about their travel status and related individual impact on private or business plans and activities.
Assumptions	● TMS and PIS are available; ● Available operational plan including trains and operational restrictions (planned or incident based) impacting trains; ● Availability of integrated PIS / end customer application for the area covered by the TMS.
Specification	Following the updates of the operational plan and the calculated forecast in the TMS, specific relevant information shall be derived and sent to the PIS: ● Expected delay in arrival and departure times of the trains; ● Platform track changes; ● Full or partial cancellations; ● Incident information in relation to trains; As far as possible, the existing SIRI standard shall be used for the data transmission.
Additional Notes	The SIRI standard possibly needs enhancement to especially cover appropriate incident information

4.2. T6.2 UC2.1_FRQ02 PIS data receipt from TMS

Requirement ID	T6.2_UC2.1_FRQ02
Requirement Name	PIS data receipt from TMS
Use Case ID	UC-FP6-WP6-2.02
Category	Function (PIS)
Priority	MUST
Main goal	The PIS needs to allow for receiving specific up-to-date information from the TMS. Passengers need to be informed about the latest status of their trains, possible incidents of relevance and the forecasted delay to adapt their personal travel plans or inform others about their travel status and related individual impact on private or business plans and activities.
Assumptions	● PIS and TMS are available. ● TMS has sent the relevant information, see T6.2_UC2.1_FRQ01. ● Availability of integrated PIS / end customer application for the area covered by the TMS.
Specification	After TMS has send the following information, the PIS shall receive and process it: ● Expected delay in arrival and departure times of the trains; ● Platform track changes; ● Full or partial cancellations; ● Incident information in relation to trains; As far as possible, the existing SIRI standard shall be used for the data transmission.
Additional Notes	The SIRI standard possibly needs enhancement to especially cover appropriate incident information.

4.3. T6.2_UC2.1_NFRQ01 Frequency TMS data provision to PIS

Requirement ID	T6.2_UC2.1_NFRQ01
Requirement Name	Frequency TMS data provision to PIS
Use Case ID	UC-FP6-WP6-2.01
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The TMS needs to provide specific up-to-date information to the PIS with a specified minimum frequency to allow for up-to-date information required by the end users.
Assumptions	● TMS and PIS are available; ● Available operational plan including trains and operational restrictions (planned or incident based) impacting trains;

	● Availability of integrated PIS / end customer application for the area covered by the TMS.
Specification	The transfer frequency of updated information to be sent from TMS to PIS shall be higher or equal to every 30 seconds.
Additional Notes	Depending on the traffic load, the minimum frequency threshold value could be varying in relation to different regional railways, areas or the current daytime, weekday or period.

4.4. T6.2_UC2.2_FRQ01 PIS traveller demand data provision to TMS/CMS

Requirement ID	T6.2_UC2.2_FRQ01
Requirement Name	PIS traveller demand data provision to TMS/CMS
Use Case ID	UC-FP6-WP6-2.02
Category	Functional (PIS)
Priority	MUST
Main goal	The PIS demand forecast module needs to provide specific up to date traveller demand information to the TMS/CMS. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date traveller demand data for two weeks before the current time is to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● Travel demand forecast is available in PIS for two weeks ahead of current daytime;
Specification	The PIS demand forecast shall send the number of expected travellers for A-to-B station relations and pre-defined daytime intervals in a timeframe of two weeks ahead of the current time to the TMS and CMS.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required. The demand forecast includes information for all days for the next two weeks, including the current day and the day before. However, it is expected that the information is more relevant for the CMS rather than the TMS. It is not intended to change existing services in the timetables but enhancing them e.g., by adding more coaches or a train set or to provide additional services making use of residual network capacity or already reserved capacity for addressing ad-hoc demands.

4.5. T6.2_UC2.2_FRQ02 TMS/CMS receives traveller demand data from PIS demand forecast

Requirement ID	T6.2_UC2.2_FRQ02
Requirement Name	TMS/CMS receives traveller demand data from PIS demand forecast
Use Case ID	UC-FP6-WP6-2.02
Category	Functional (TMS/CMS)
Priority	MUST
Main goal	The TMS/CMS needs to allow for receiving specific up to date traveller demand information from the PIS demand forecast module. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date traveller demand data for two weeks before the current time is to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.2_FRQ01. ● Travel demand forecast is available in PIS for two weeks ahead of current daytime.
Specification	The TMS/CMS shall allow to receive the number of expected travellers for A-to-B station relations and pre-defined daytime intervals in a timeframe of two weeks ahead of the current time from the PIS demand forecast module.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required. The demand forecast includes information for all days for the next two weeks, including the current day and the day before. However, it is expected that the information is more relevant for the CMS rather than the TMS. It is not intended to change existing services in the timetables but enhancing them e.g., by adding more coaches or a train set or to provide additional services making use of residual network capacity or already reserved capacity for addressing ad-hoc demands.

4.6. T6.2_UC2.2_NFRQ01 Frequency for provision of traveller demand data to TMS/CMS

Requirement ID	T6.2_UC2.2_NFRQ01
Requirement Name	Frequency for provision of traveller demand data to TMS/CMS
Use Case ID	UC-FP6-WP6-2.02
Category	Non-Functional (TMS)

Priority	MUST
Main goal	The PIS needs to provide specific up-to-date information to the TMS/CMS with a specified minimum frequency to allow for up-to-date information required by TMS/CMS users.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.2_FRQ01. ● Travel demand forecast is available in PIS for two weeks ahead of current daytime;
Specification	The transfer frequency of updated information to be sent from PIS to TMS/CMS shall be higher or equal every 15 minutes providing that new data updates are available.
Additional Notes	Depending on the traffic demand, the minimum frequency threshold value may vary in relation to different regional railways, areas or the current daytime, weekday or period.

4.7. T6.2_UC2.2_NFRQ02 Provision of anonymised information about traveller demand to TMS/CMS

Requirement ID	T6.2_UC2.2_NFRQ02
Requirement Name	Provision of anonymised information about traveller demand to TMS/CMS
Use Case ID	UC-FP6-WP6-2.02
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The PIS needs to provide anonymized up-to-date information to the TMS/CMS.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.2_FRQ01. ● Travel demand forecast is available in PIS for two weeks ahead of current daytime;
Specification	The updated demand forecast information to be sent from PIS to TMS/CMS shall be anonymized i.e., no personal details shall be included.
Additional Notes	-

4.8. T6.2_UC2.3_FRQ01 PIS numbers of expected travellers in trains provision to TMS/CMS

Requirement ID	T6.2_UC2.3_FRQ01
Requirement Name	PIS numbers of expected travellers in trains provision to TMS/CMS
Use Case ID	UC-FP6-WP6-2.03
Category	Functional (PIS)

Priority	MUST
Main goal	The PIS demand forecast module needs to provide specific up-to-date numbers of expected travellers in the trains. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date numbers of expected travellers in the trains between subsequent stops are to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● Numbers of expected travellers in the trains are available in PIS demand forecast module for at least 2 hours ahead of current daytime;
Specification	The PIS demand forecast module shall send the number of expected travellers in the trains between subsequent stops in a timeframe of at least 2 hours ahead of the current time to the TMS and CMS.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required.

4.9. T6.2_UC2.3_FRQ02 TMS/CMS receives numbers of expected travellers in trains from PIS demand forecast module

Requirement ID	T6.2_UC2.3_FRQ02
Requirement Name	TMS/CMS receives numbers of expected travellers in trains from PIS demand forecast module
Use Case ID	UC-FP6-WP6-2.03
Category	Functional (TMS/CMS)
Priority	MUST
Main goal	The TMS/CMS needs to allow for receiving specific up-to-date numbers of expected travellers in the trains. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date numbers of expected travellers in the trains between subsequent stops are to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.3_FRQ01. ● Numbers of expected travellers in the trains are available in PIS demand forecast module for at least 2 hours ahead of current daytime;
Specification	The TMS/CMS shall allow to receive the number of expected travellers in the trains between subsequent stops in a timeframe

	of at least 2 hours ahead of the current time from the PIS demand forecast module.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required.

4.10. T6.2_UC2.3_NFRQ01 Frequency for provision of numbers of expected travellers in trains to TMS/CMS

Requirement ID	T6.2_UC2.3_NFRQ01
Requirement Name	Frequency for provision of numbers of expected travellers in trains to TMS/CMS
Use Case ID	UC-FP6-WP6-2.03
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The PIS needs to provide specific up-to-date information to the TMS/CMS with a specified minimum frequency to allow for up-to-date information required by TMS/CMS users.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.3_FRQ01. ● Numbers of expected travellers in trains are available in PIS for at least 2 hours ahead of current daytime;
Specification	The transfer frequency of updated information about expected numbers of travellers in trains to be sent from PIS to TMS/CMS shall be higher or equal every 5 minutes providing that new data updates are available.
Additional Notes	Depending on the traffic demand, the minimum frequency threshold value may vary in relation to different regional railways, areas or the current daytime, weekday or period.

4.11. T6.2_UC2.3_NFRQ02 Provision of anonymised information about expected travellers in trains to TMS/CMS

Requirement ID	T6.2_UC2.3_NFRQ02
Requirement Name	Provision of anonymised information about expected travellers in trains to TMS/CMS
Use Case ID	UC-FP6-WP6-2.03
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The PIS needs to provide anonymized up-to-date information to the TMS/CMS.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has send the relevant information, see T6.2_UC2.3_FRQ01. ● Numbers of expected travellers in trains are available in PIS for at least 2 hours ahead of current daytime;
Specification	The updated information about expected numbers of travellers in trains to be sent from PIS to TMS/CMS shall be anonymized i.e., no personal details shall be included.
Additional Notes	-

4.12. T6.2_UC2.4_FRQ01 PIS provision of numbers of expected travellers embarking/disembarking a train at the stations to TMS/CMS

Requirement ID	T6.2_UC2.4_FRQ01
Requirement Name	PIS provision of numbers of expected travellers embarking/disembarking a train at the stations to TMS/CMS
Use Case ID	UC-FP6-WP6-2.04
Category	Functional (PIS)
Priority	MUST
Main goal	The PIS demand forecast module needs to provide specific up-to-date numbers of expected travellers embarking/disembarking a train at the stations. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date numbers of expected travellers embarking/disembarking a train at the stations are to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● Numbers of expected travellers embarking/disembarking a train at the stops are available in PIS demand forecast module for at least 2 hours ahead of current daytime;
Specification	The PIS demand forecast module shall send the number of

	expected travellers embarking/disembarking a train at the stations in a timeframe of at least 2 hours ahead of the current time to the TMS and CMS.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required.

4.13. T6.2_UC2.4_FRQ02 TMS/CMS receives numbers of expected travellers embarking/disembarking a train at the stations from PIS demand forecast module

Requirement ID	T6.2_UC2.4_FRQ02
Requirement Name	TMS/CMS receives numbers of expected travellers embarking/disembarking a train at the stations from PIS demand forecast module
Use Case ID	UC-FP6-WP6-2.04
Category	Functional (TMS/CMS)
Priority	MUST
Main goal	The TMS/CMS needs to allow for receiving specific up-to-date numbers of expected travellers embarking/disembarking a train at the stations. To support TMS decision making and to ensure appropriate transport capacity being made available by the CMS, the up-to-date numbers of expected travellers embarking/disembarking a train at the stations are to be transferred to the Traffic Management and Capacity Planning and Management Systems.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.4_FRQ01. ● Numbers of expected travellers embarking/disembarking a train at the stations are available in PIS demand forecast module for at least 2 hours ahead of current daytime;
Specification	The TMS/CMS shall allow to receive the number of expected travellers embarking/disembarking a train at the stations in a timeframe of at least 2 hours ahead of the current time from the PIS demand forecast module.
Additional Notes	Since SIRI is not covering this kind of information and is anyway relevant only for a timeframe of two hours before current time, a separate protocol for transmission is required.

4.14. T6.2_UC2.4_NFRQ01 Frequency for provision of numbers of expected travellers embarking/disembarking a train at the stations to TMS/CMS

Requirement ID	T6.2_UC2.4_NFRQ01

Requirement Name	Frequency for provision of numbers of expected travellers embarking/disembarking a train at the stations to TMS/CMS
Use Case ID	UC-FP6-WP6-2.04
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The PIS needs to provide specific up-to-date information to the TMS/CMS with a specified minimum frequency to allow for up-to-date information required by TMS/CMS users.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.4_FRQ01. ● Numbers of expected travellers embarking/disembarking a train at the stations are available in PIS for at least 2 hours ahead of current daytime.
Specification	The transfer frequency of updated information about expected numbers of expected travellers embarking/disembarking a train at the stations to be sent from PIS to TMS/CMS shall be higher or equal every 5 minutes providing that new data updates are available.
Additional Notes	Depending on the traffic demand, the minimum frequency threshold value may vary in relation to different regional railways, areas or the current daytime, weekday or period.

4.15. T6.2_UC2.4_NFRQ02 Provision of anonymised information about expected travellers embarking/disembarking a train at the stations to TMS/CMS

Requirement ID	T6.2_UC2.4_NFRQ02
Requirement Name	Provision of anonymised information about expected travellers embarking/disembarking a train at the stations to TMS/CMS
Use Case ID	UC-FP6-WP6-2.04
Category	Non-Functional (TMS)
Priority	MUST
Main goal	The PIS needs to provide anonymized up-to-date information to the TMS/CMS.
Assumptions	● TMS/CMS and PIS demand forecast module are available; ● PIS demand forecast module has sent the relevant information, see T6.2_UC2.4_FRQ01. ● Numbers of expected travellers embarking/disembarking a train at the stations are available in PIS for at least 2 hours ahead of current daytime;
Specification	The updated information about expected travellers embarking/disembarking a train at the stations to be sent from

	PIS to TMS/CMS shall be anonymized i.e., no personal details shall be included.
Additional Notes	-

5. Logical Architecture

5.1. High Level Architecture

The purpose of this section is to present the Logical Architecture diagrams in conjunction with the TMS-PIS interface, as defined within the framework of the *Arcadia* methodology. The Logical Architecture diagrams provide a comprehensive overview of the system's components, functions, and relations. This section will aid in understanding the structure and organization of the system, highlighting the interdependencies and interactions among its various elements.

The Logical Architecture diagrams presented distinguish between blue components and white components. Blue components represent external elements that are not developed within the scope of this deliverable task. These components may include external systems, interfaces, or dependencies that the system under analysis relies upon. On the other hand, white components denote the elements that are directly related to the scope of this task, i.e., the TMS-PIS interface.

The diagrams provide a visual representation that aids in communication and facilitates discussions among project teams, allowing for a more holistic and efficient analysis.

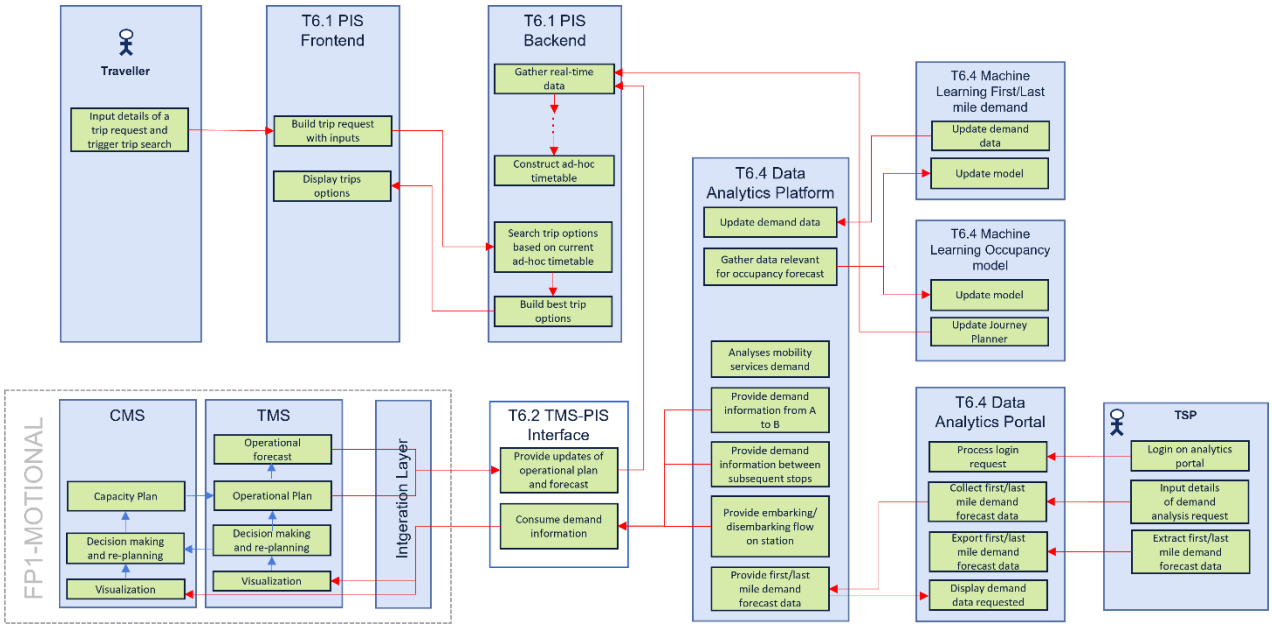

Figure 2: Architecture diagram for TMS-PIS interface in the context of FP1 and FP6

The diagram shown as Figure 2 above presents a high-level view of the components and functions involved in the use cases related to the TMS-PIS integration. The red arrows indicate FP6-Future related communication streams whereas the blue arrows refer to FP1-Motional related communications and process flows.

The TMS delivers the Operational Plan together with the operational forecast of the traffic to the

TMS-PIS interface making use of the TMS Integration Layer exposing the TCCS (TMS/CCS) data model as provided by Task 2 of the EU-Rail System Pillar. On the one hand, the Operational Plan is modified by traffic controllers taking and implementing traffic control decisions and by timetable updates received from the CMS system on the other. It is also expected that the demand information received via the TMS-PIS interface will be forwarded via the TMS Integration Layer which is originating from the former Shift2Rail projects in conjunction with the Technical Demonstrator TD2.9 and is also used as the basis for TMS developments of several partners in the workstream 1.2 (Operations) of the FP1-MOTIONAL project. The technical architecture used for development and demonstration of the TMS-PIS is involving components of Task 6.1 (PIS Backend) and Task 6.4 (Data Analytics) at the same time.

In the next section, the basic communication and process flow for the TMS-PIS use cases is illustrated by making use of Sequence Diagrams.

5.2. Sequence Diagrams per Use Case

This section focuses on describing the Sequence Diagrams for each use case at the logical architecture level, following the Arcadia methodology. These diagrams provide a detailed analysis of the information exchanges and interactions between components during the execution of each use case.

Understanding the Sequence Diagrams is crucial for comprehending the flow of information and dependencies within the system. By examining these diagrams, stakeholders gain insights into how the system handles inputs, processes data, and generates outputs in response to user actions or external events. The diagrams help to identify bottlenecks, dependencies, and areas for improvement, ensuring that the system meets requirements and delivers desired outcomes.
Each use case is individually analysed, and the corresponding Sequence Diagrams are presented in a structured manner. This approach enables focused examination of interactions and information flow, providing a concise representation of the system's behaviour.

5.2.1. SD-WP6-2.1 Send updated operational plan and calculated forecast to PIS

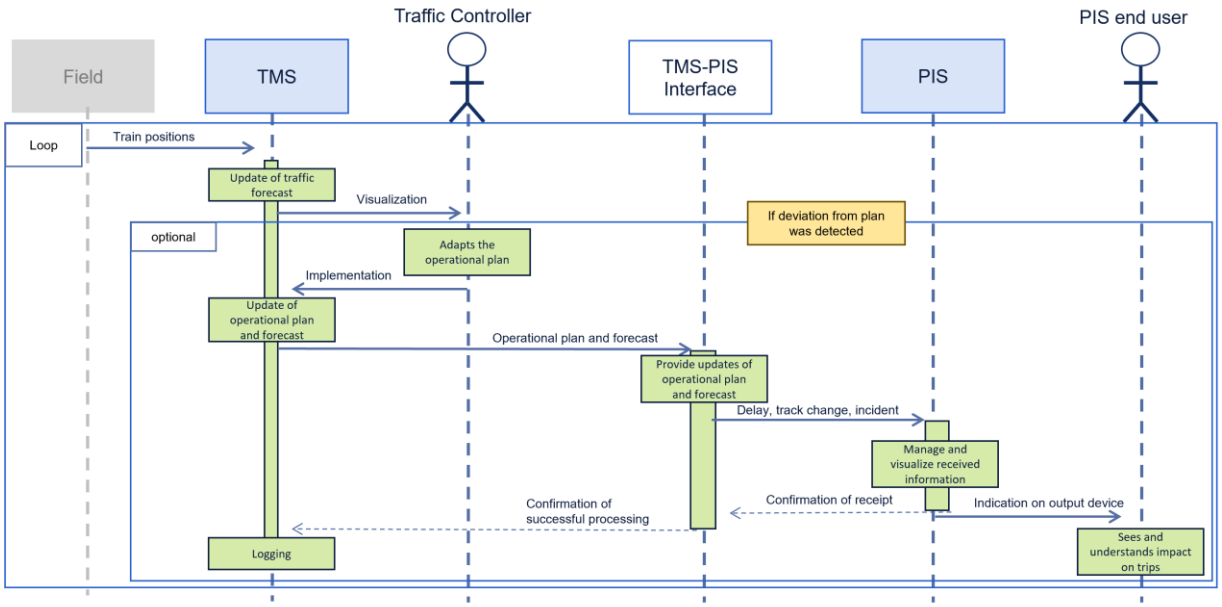

Figure 3: Sequence Diagram SD-WP6-2.1

The Sequence Diagram in Figure 3 illustrates the use case UC-FP6-WP6-2.1 that covers the transfer of the operational plan changes and traffic forecast to the PIS after a relevant deviation from the original operational plan is detected. The forecast calculation itself is invoked cyclically by the TMS based on train positions reported from the 'field' which usually involve trackside train detection devices such as Track Circuits or Axle Counters in conjunction with sectional release or in the future also from new, innovative positioning systems developed in WP3 for G1 lines and WP5 for G2 lines. It should be noted that the interface used for transferring the train positions from the field via a Train Control System to the TMS does not form scope of this use case.

The updated traffic forecast is visualized and presented to the Traffic Controller who takes action for updating the operational plan if a relevant deviation from the previous plan is detected. In today's TMS systems, a built-in deviation detection function supports the Traffic Controller by indicating situations of relevant deviations from the plan to trigger decision making for implementing one of usually multiple re-planning options. For reasons of simplicity, the deviation detection capability has not been considered explicitly as a separate TMS module.

Once the operational plan has been updated, a re-calculation of the forecast is performed to ensure that the changed plan is considered for deriving forecasted delay information, now being transferred via the TMS-PIS interface to the PIS component managing and visualizing the information received which finally is used to inform the PIS end user accordingly.

5.2.2. SD-WP6-2.2 Usage of the number of expected travellers for timetable planning or traffic dispatching

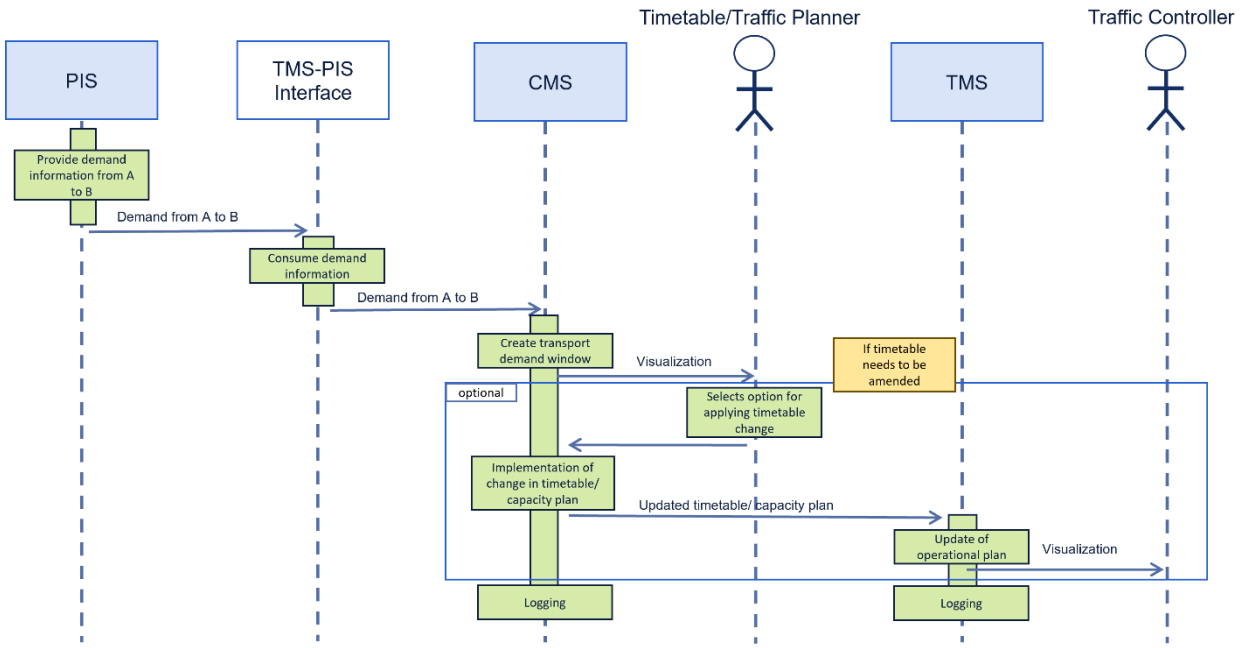

Figure 4: Sequence Diagram SD-WP6-2.2

Figure 4 shows the first out of three Sequence Diagrams covering the use cases for transferring different transport demand information to TMS and CMS systems. The diagrams refer to a process being triggered at any time when updated demand forecast information is available. The name 'TMS-PIS' interface is probably misleading in this case, because in our (and the System Pillar's) context, we understand the CMS belonging to the TMS domain since it acts as the instance for re-planning in case of required new or already planned train services. For use case UC-FP6-WP6-2.2, the demand for travels from one location A to another location B in a given time window is provided by the Data Analytics component of the PIS covered by Task 6.4. It is expected that the transfer will be invoked once certain conditions based on e.g., a minimum level of demand, are fulfilled in the PIS Data Analytics component. The transfer is performed using the TMS-PIS interface which consumes the received information resulting in a structure being conformant with CMS/TMS needs. The transferred information is not linked to existing train services and leads to generation of new or updating of existing transport demand windows as managed by the CMS. The CMS provides information about seat capacity of the planned trains so that the Timetable/Traffic Planner may decide to change the planned trains or plan additional trains in the timetable after having understood the transport demand vs. the overall transport (seat) capacity addressed from A to B by the current plan. The changes may involve

- activation of contingency trains which are already prepared but de-active in the current plan;
- extension of the route or addition of intermediate stops for an already planned train service;

- creation of a new train service in the timetable; and
- addition of coaches to planned train services;
- or combinations of the above.

At the same time the received demand updates may theoretically also involve a reduction of transport (seat) capacity for the given time window, if trains could be deemed as empty. These types of scenarios are more expected to be applicable for long term planning or for reverting to 'normal' demand situations, after the transport capacity has been upgraded and maintained for some time following the procedure above. Accordingly, this downgrade would then involve

- de-activation of activated contingency trains in the current plan;
- partial cancellation / reduction of the route or cancellation of intermediate stops for a planned train service;
- cancellation / deletion of a new train service in the timetable; and
- reduction of coaches of planned train services;
- or combinations of the above.

It is also important to note that the above activities will have to be decided carefully and jointly with the respective Railway Undertakings being responsible for the affected rolling stock and train crews.

5.2.3. SD-WP6-2.3 Receive and use travellers demand between subsequent stops

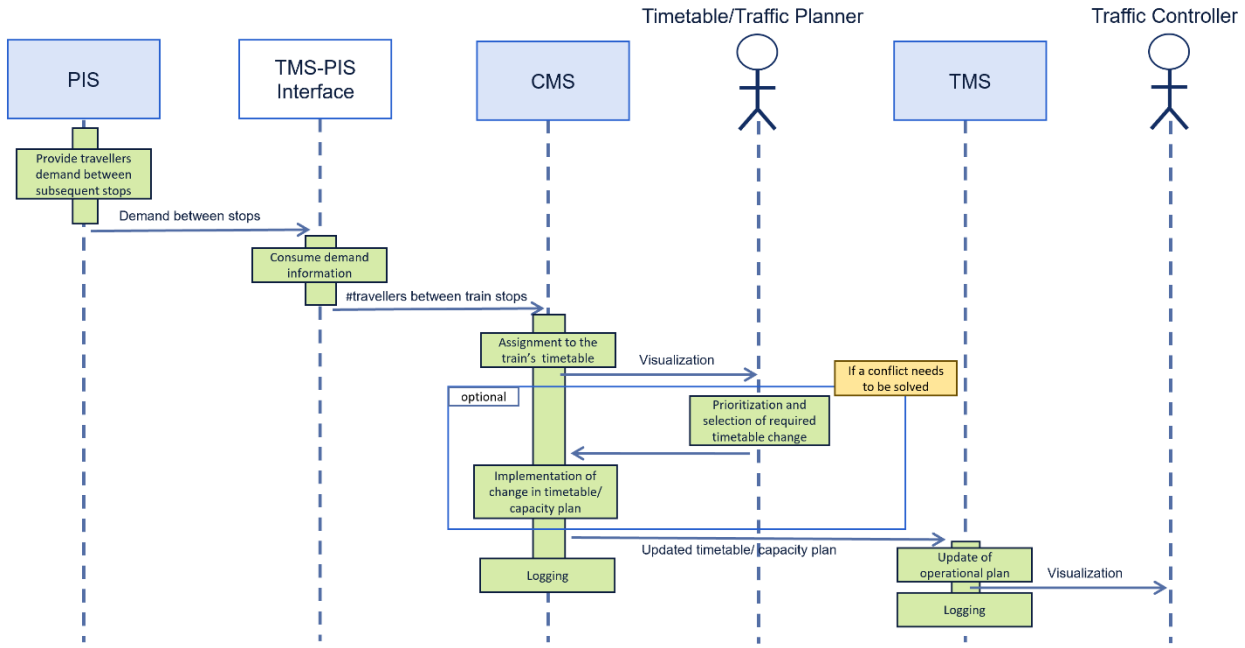

Figure 5: Sequence Diagram SD-WP6-2.3

The illustration of the use case UC-FP6-WP6-2.3 shown in Figure 5 presents the sequence of functions and interactions for transferring train service-related transport demand information to TMS and CMS systems, here: the traveller demand to use a specific train between two subsequent stops A and B. If travellers demand to embark the train at station A and disembark at station C, they will be considered for travel segments A to B and B to C as subsequent segments.

The Data Analytics component of the PIS covered by Task 6.4 provides the travellers' demand for using a specific train between one stop A and another stop B as required for this use case UC-FP6-WP6-2.3. The transfer of this updated information is expected to be initiated by the PIS in a cyclic manner. The transfer itself utilises the TMS-PIS interface which consumes the received demand information resulting in a data structure being conformant with CMS/TMS needs. The transferred information is linked to a planned train service and leads to assignment of the information to the segment A to B of the timetable for the respective train as managed and visualized by the CMS. During the (re-)planning process, required changes to timetables of different trains often lead to planning conflicts i.e., the timetables or two or more respective trains are not conformant with each other. In practice, these trains will require one and the same resource (e.g., a track section) at the same time which will lead to a delay due to the signalling system preventing this. In this situation, the Timetable/Traffic Planner needs to prioritize the trains for accessing the resource. In most of the today's situations in practice, the planner is following existing rules or best practice. However, since the rules are mostly referring to traffic categories of trains to be prioritized (e.g., long distance passenger, regional passenger, freight), there is still a need to decide on prioritization of two or more trains of the same category being in conflict. This especially holds for regional railways since their regional networks usually feature a high density of regional passenger trains.

Thus, the transparency of numbers of travellers expected to be in a regional train between two stations can be seen as a helpful information to support effective train prioritization during the (re-)planning process in CMS/TMS.
A typical change of the plan addressing the conflict identified would involve a later departure of the lower prioritised train or the use of another (platform) track potentially leading to adapted dwell times or arrival times at the next stop in the timetable or Operational Plan. It is also possible that changes to multiple timetables of trains are required to provide an optimum solution against the conflict to be solved.
Once the required changes have been triggered by the Timetable/Traffic Planner and implemented in the CMS, the updated timetable(s) are transferred to the TMS. This also applies if the demand information is updated in the timetable, but the plan is free of conflicts so that the updated demand information assigned to the plan can also be used by the Traffic Controller at any time.

5.2.4. SD-WP6-2.4 Receive and use travellers embarking/disembarking flow on stations

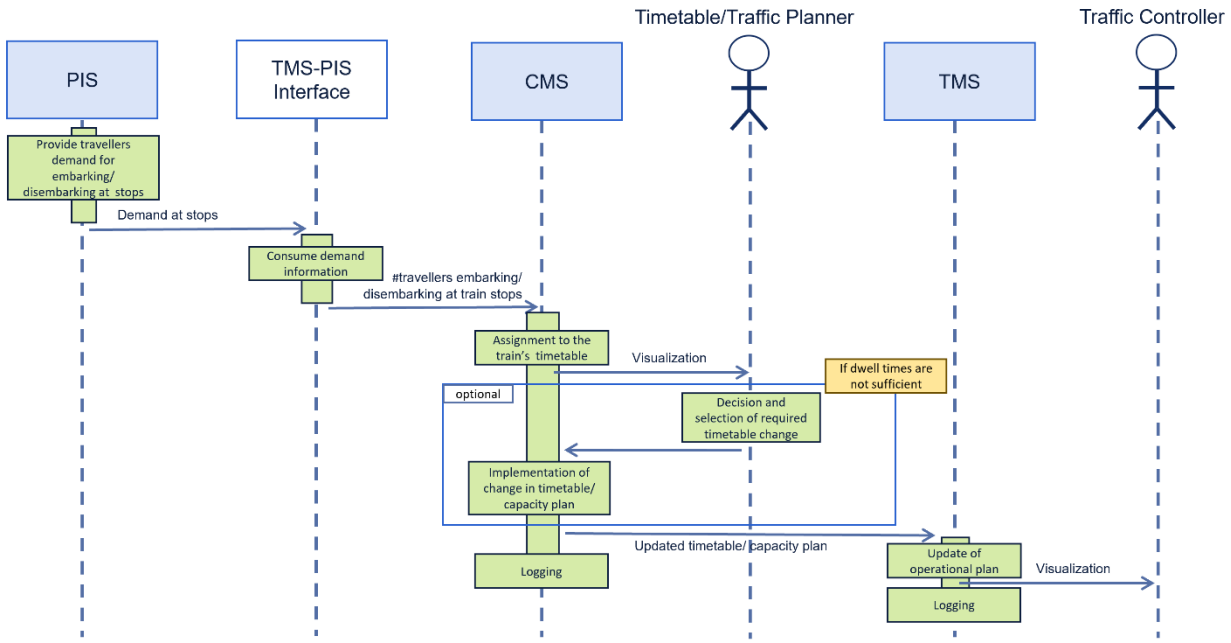

Figure 6: Sequence Diagram SD-WP6-2.4

Figure 6 presents the Sequence Diagram of the use case UC-FP6-WP6-2.4 showing required functions and interactions for transferring traveller demand for embarking/ disembarking a specific train at the stops A, B, C, … of the train. This train service-related transport demand information is provided to the TMS and CMS systems to support a more precise traffic forecast and an improved decision making in existing or anticipated train irregularity situations on a local level.

The use case UC-FP6-WP6-2.4 expects the Data Analytics component of the PIS to provide the

travellers' demand for embarking/ disembarking a specific train at its specific stops (A, B, C, …). The transfer of this updated information is expected to be initiated by the PIS in a cyclic manner. The transfer itself utilises the TMS-PIS interface which consumes the received demand information resulting in a data structure being conformant with CMS/TMS needs. The transferred information is linked to a planned train service and is automatically assigned to the stops A, B, C, … of the timetable for the respective train as managed and visualized by the CMS. Traffic Planners or Controllers acting on a local i.e., station or station area level, usually have a good experience in anticipating dwell time problems for specific trains stopping at the station at certain hours of the day e.g., traffic peak hours. Having the concrete number of travellers expected to disembark or embark the train at hand, helps them to anticipate delays in off-boarding, on-boarding, related doors closing and train readiness for departure. In (very) short term planning, this can be an important element for taking decisions early enough to ensure a minimization of expected delays. This may involve extensions of station dwell times or changes of platform tracks e.g., because another train is stopping at the same time at the same platform also featuring a high number of expected travellers to disembark/ embark. Also in this case, there may be changes to multiple timetables of trains required at the same time to provide an optimum solution against the anticipated issue to be addressed.
Once the required changes have been triggered by the Timetable/Traffic Planner and implemented in the CMS, the updated timetable(s) are transferred to the TMS. This also applies if the demand information is updated in the timetable, but the Traffic Planner does not decide to change the plan so that the updated demand information assigned to the plan can also be used by the Traffic Controller at any time.

6. Interfaces & standards

6.1. TMS (Integration Layer) to PIS: Operational plan and forecast

This part of the TMS-PIS interface facilitates the provision of updated operational plans and traffic forecast to the PIS component *Gather real-time data* of the PIS system which is addressed in WP6 Task 6.1. It enables provision of delay information or short notice platform track changes as well as offering best trip options to the travellers for new or already booked trips.

Data elements:

Name	Attributes Type	Description
`train_id`	Integer	Unique identifier for the train.
`train_type`	Integer	Indicates the type of train (e.g., regional/S-train, long distance passenger, freight)
`sequence`	Integer	The sequence number of the stop within the journey leg of the train.
`location_id`	Integer	The location identification for the stop within the journey leg of the train.
`track_id`	Integer	The identifier for the track used at the stop within the journey leg of the train.
`first_date_time`	DateTime	Date and time when the trip starts at the first stop.

arr_date_time	DateTime	The arrival date and time at the location according to the Operational Plan.
dep_date_time	DateTime	The departure date and time at the location according to the Operational Plan
arr_delay	Integer	Forecasted arrival delay against original plan in seconds
dep_delay	Integer	Forecasted departure delay against original plan in seconds
operational_status	Integer	The status of (planned) operation at this location, e.g., cancelled

Data Format:
A structured data solution will be used, like JSON (JavaScript Object Notation), example provided below.

```
{
    "train_id": 20153,
    "train_type": 1,
    "sequence": 3,
    "location_id": 176,
    "track_id": 13,
    "first_date_time": "2024-05-18T07:59:00",
    "arr_date_time": "2024-05-18T07:59:00",
    "dep_date_time": "2024-05-18T08:01:00",
    "arr_delay": 143,
    "dep_delay": 130,
    "operational_status": 12
}
```

The data transfer will make use of the TMS Integration Layer (IL) used by the EU-Rail project FP1-MOTIONAL, workstream 1.2 (Operations) and its underlying TCCS data model as provided by the EU-Rail System Pillar in the version 0.4.2 or higher. The IL development is originating from previous Shift2Rail projects in the context of Technical Demonstrator TD 2.9 such as e.g., X2Rail-4 (see [X2Rail-4 Project]).
It is planned to also assess and support the existing SIRI Standard as far as possible to allow for a wider usage of the interface in different other contexts. This will likely lead to a revision of data structures given in this document. The same holds for other already harmonized data format specifications available in respective documents such as e.g., Telematics TSI.

6.1.1. Service Interface for Real Time Information (SIRI)

The Service Interface for Real Time Information (SIRI) incorporates various national and proprietary standards from across Europe and specifies a European interface standard for exchanging information about the planned, current or predicted performance of real-time public transport operations. All SIRI services are provided over a standardised communications layer, based on a Web Services Architecture.

SIRI can be used to exchange information among various servers which may be located at traffic control centres, passenger information systems, etc. containing real-time information related to vehicles, trips, etc.

The SIRI messages may be exchanged as either XML documents with http POST or using Simple Object Access Protocol (SOAP). Data exchanged by SIRI services may either be used as an input to other computations, or be rendered into end user information views in another acceptable format, e.g., web (HTML, JavaScript, etc.), WAP (xHTML), SMS, Smartphones (j2ME, etc.), etc. It covers the two well-known patterns of client-server interaction request/response and publish/subscribe, and well-defined interfaces allow the systematic automated testing of each functional module.

An important benefit of SIRI is its flexibility provided by its modular structure as only the required subset of services needs to be implemented for a particular application. Over time the number of services and the range for supported options could be added as needed.

The SIRI schema is available for use free of charge against a small administrative fee and without warranty under public Licence. Copyright is retained by the respective national organisations that have developed SIRI. In line with CEN regulations, the Published Specification Documentation must be obtained through the respective National Standards Bodies such as the British Standards Institute, or industry bodies such as VDV or RTIG.

More detailed information can be obtained by visiting the [SIRI Management Overview-White paper].

6.2. PIS to TMS: Demand information

The capability of the TMS-PIS interface to facilitate the provision of transport demand to the TMS/CMS can be seen as an important innovation. There are three different functions of the Data Analytics platform as part of the PIS which are covered by WP6 Task 6.4 and are providing transport or travellers' demand to the TMS/CMS for minimizing the impact of unforeseen changes in the demand on the train timetables:

- Provide demand information from A to B in a defined time window
- Provide demand information between subsequent stops for a given train
- Provide embarking/disembarking flow on station for a given train

For these three functions, new structures for data transfer are outlined in the following Subsections 6.2.2 through 6.2.4 because existing standards do not support the transfer of the needed data elements so far. Before the new structures are introduced, existing standards will be discussed in Subsection 6.2.1 to point out their gaps with regard to the data transfer that is planned from the PIS to the TMS.

6.2.1. Existing standards and their ability to transfer demand forecast data

In this subsection, the capabilities of existing standards that could potentially be used to transfer occupancy data between a PIS and a TMS will be discussed. The standards SIRI/NeTEx, GTFS, VDV 454 and TRIAS are considered. These standards are widely used to transport information related to public transport services and support the transfer of at least some occupancy related information. All these aspects make them candidates to be used for the TMS-PIS interface.

The SIRI service that provides the status of running vehicle journeys is called SIRI Estimated Timetable (SIRI-ET). It informs about deviations from the planned timetable, especially regarding arrival and departure times at stops and stations. SIRI-ET currently allows to transfer an occupancy level which is defined by an enumeration comprising values such as “manySeatsAvailable”, “standingAvailable” and “full”. For the current part of the journey between the last stop that has been served and the next stop that will be served, the occupancy level can be the actual occupancy of the vehicle if, for example, automatic passenger counting systems are in place. For upcoming parts of the journey, the occupancy level represents the forecasted passenger load.

For SIRI version 2.1 a VehicleOccupancyStructure is foreseen that allows to transfer absolute numbers of passengers in the fields “AlightingCount” (number of passengers disembarking at a given stop), “BoardingCount” (number of passengers embarking at a given stop) and “OnboardCount” (number of passengers on-board after departing a given stop). In parallel, the new SIRI version foresees a PassengerCapacityStructure object to pass the seating and standing capacity of a vehicle, amongst others.[2] However, this new version of SIRI waits for approval and, consequently, operators and suppliers are cautious to adopt it before a formal acceptance. The current version 2.0 and the new version 2.1 of SIRI-ET do not allow to transfer estimated number of passengers for a origin-destination relation in a given time window.

Another issue is that SIRI-ET is a service designed to cover the current situation including a preview horizon of a few hours. The format and existing implementations are not designed to process data for all services in the next 10 or 20 days. Timetable information about those services is only available in static timetable data sets. The static data set that corresponds to the real-time data format SIRI is NeTEx. Though, NeTEx does not support the occupancy information needed for the use cases specified in this deliverable.

The GTFS Realtime feed provides the optional enumeration “occupancy_status” as part of the TripUpdate message and the VehiclePosition message. Like in case of SIRI-ET, this enumeration provides only broad categories such as “empty”, “many seats available”, “few seats available” and “full” but no absolute numbers[3]. In addition, GTFS Realtime offers the optional field “occupancy_percentage” indicating the occupancy level in a vehicle. Both data fields allow to capture the demand for a leg between subsequent stops but can neither be used to specify the travel demand between two arbitrary stops A and B in a defined time window nor to transfer the number of passengers embarking and disembarking at a stop. As both fields are part of the real-time feed, they can cover trips that are about to start in the next minutes or are on their way.

The GTFS schedule data can cover a timetable period of several months and hence would allow to transfer forecast data also for train services within the next two week. However, the GTFS standard for schedule data does not support the storage of any occupancy related information.

Another standard for real-time data that allows to transfer occupancy data is VDV 454. It is a national standard of the Association of German Transport Companies (Verband Deutscher

[2] To see how SIRI-ET is used within Europe, see , for example, the documentation of the Nordic SIRI profile documented on https://enturas.atlassian.net/wiki/spaces/PUBLIC/pages/637370392/SIRI-ET.

[3] See https://gtfs.org/documentation/realtime/reference/.

Verkehrsunternehmen, VDV). In its latest version 3.0, VDV 454 supports the transfer of capacity and occupancy data in absolute numbers for each carriage of a train.[4] Similar to GTFS Realtime, VDV 454 in version 3.0 does not support the transfer of the expected number of travellers between two stops A and B in a defined time window and the transfer of the number of passengers boarding and alighting from a train at a given stop. And like GTFS Realtime, VDV 454 is commonly used to cover the current situation looking only a few hours ahead but not several days.
As VDV 454 is a national standard, non-German railway undertakings from Europe tend to hesitate to implement it[5] and wait for a European standard, e.g. for an extension of SIRI. This extension of SIRI is already planned but not officially accepted and published. Though, it would also only cover the occupancy between subsequent stops of a given train.

Another established standard for transferring data related to a PIS, is TRIAS (Travellers' Realtime Information and Advisory Standard). The transfer of occupancy data was extended in the latest version 1.4. TRIAS foresees to optionally transfer an occupancy level for a service in the following structures: DatedJourneyStructure, CallAtStop structure, DatedCallAtLocationStructure (used for services such as DRT that may not only depart from stops but also from addresses), TripStructure, LegBoardStructure, LegAlightStructure and LegIntermediateStructure. In all structures, an enumeration is used that provides only the rough categories "low", "moderate", and "high".[6] Again, there is no support for a forecast regarding the travel demand between two arbitrary stops and regarding the number of passenger who embark/disembark at a stop for a given service.

There are further standards existing but to the best of the authors' knowledge, there is no existing standard which would provide all required structures needed for the use cases defined in this deliverable. The discussed standards have been created with a focus on Passenger Information Systems. They were not customized for the interfaces between a PIS and a TMS. This also explains why these standards do not cover all required data fields. Hence, a dedicated format that supports the defined use cases will be outlined in the following subsections.

6.2.2. Provide demand information from A to B

The travellers' demand is derived inter alia from the number of trip requests issued by travellers using the PIS system which is used as an input to a statistical / AI based method to estimate the number of people being interested to travel from A to B in a defined time window.

Data elements:

Name	Attributes Type	Description
`location_id_1`	Integer	The location identification for the start location of

[4] See VDV-Schrift 454 „Ist-Daten-Schnittstelle – Fahrplanauskunft Version 3.0" (available only in German so far), https://knowhow.vdv.de/documents/454/.

[5] This hesitance was observed by FP1 MOTIONAL where real-time capacity and occupancy data shall be transferred.

[6] See VDV-Schrift 431-2 "Real time communication and assistance platform EKAP - Part 2: EKAP interface description V1.4", https://knowhow.vdv.de/documents/431-2/.

		demanded trips.
location_id_2	Integer	The location identification for the destination location of demanded trips.
begin_date_time	DateTime	The begin date and time of the demand time window
end_date_time	DateTime	The end date and time of the demand time window
number_of_travellers	Integer	The estimated number of travellers demanding to travel from location 1 to location2 in the demand time window

Data Format:
A structured data solution will be used, like JSON (JavaScript Object Notation), example provided below.

```
{
    "location_id_1": 176,
    "location_id_2": 181,
    "begin_date_time": "2024-05-03T09:00:00",
    "end_date_time": "2024-05-03T11:59:59",
    "number_of_travellers": 514
}
```

6.2.3. Provide demand information between subsequent stops

A similar approach like described in Section 6.2.1 is used in the PIS system to map the travellers' demand against planned or already running train services to provide the number of travellers expected to use a specific train between subsequent stops A to B. Of course, in most cases, travellers will stay in the trains for multiple subsequent segments A to B to reach their desired destination.

Data elements:

Name	Attributes Type	Description
train_id	Integer	Unique identifier for the train on the day.
first_date_time	DateTime	Date and time when the train starts at the first stop.
sequence	Integer	The sequence number of the 'from' stop.
location_id	Integer	The location identification for the 'from' stop.
number_of_travellers	Integer	The estimated number of travellers demanding to use the train between the 'from' stop and the next stop following.

Data Format:

A structured data solution will be used, like JSON (JavaScript Object Notation), example provided below.

```
{
    "train_id": 20153,
    "first_date_time": "2024-05-03T07:59:00",
    "sequence": 3,
    "location_id": 113,
    "number_of_travellers": 87
}
```

6.2.4. Provide embarking/disembarking flow on station

The Data Analytics platform provided by WP6 Task 6.4 allows to measure the expected travellers' demand to disembark or embark a train at any given stop of the train. The resulting estimated numbers of travellers embarking or disembarking the train at all stops is transferred to the TMS/CMS to assign it to the respective planned or already running trains as managed by the systems.

Data elements:

Name	Attributes Type	Description
`train_id`	Integer	Unique identifier for the train on the day.
`first_date_time`	DateTime	Date and time when the train starts at the first stop.
`sequence`	Integer	The sequence number of the stop in relation to number of travellers (dis-) embarking.
`location_id`	Integer	The location identification for the stop in relation to number of travellers (dis-) embarking.
`number_of_travellers_disembark`	Integer	The estimated number of travellers demanding to disembark the train at the stop.
`number_of_travellers_embark`	Integer	The estimated number of travellers demanding to embark the train at the stop.

Data Format:

A structured data solution will be used, like JSON (JavaScript Object Notation), example provided below.

```
{
    "train_id": 20153,
    "first_date_time": "2024-05-03T07:59:00",
    "sequence": 3,
    "location_id": 113,
    "number_of_travellers_disembark": 55,
    "number_of_travellers_embark": 114
}
```

7. Conclusions

The aim of this deliverable is to report on the activities of Task 6.2 in WP6 of the EU-Rail FutuRe project to enable the demonstration of an integrated TMS/CMS-PIS system approach in WP11. This will complement the activities of Tasks 6.1 and 6.4 with their linked deliverables D6.2 and D6.5.

After having undertaken an assessment of available communication standards for interfaces between TMS and PIS, it was concluded that the existing interface standard *CEN/TS 15531 Service Interface for Real-time information (SIRI)* should be used as a general means to transfer operational plan changes and forecast information in relation to the Estimated Timetable concept of the SIRI standard. The SIRI standard is well-accepted by IMs, RUs and suppliers of TMS or PIS applications on the international level. On the other hand, it became obvious, that no suitable interface standard is available today to transfer traveller demand information to timetable/ network capacity planning systems (CMS) or traffic management systems (TMS).

The deliverable specifies how a CMS/TMS can receive demand forecast data from a PIS, apply this data to replanning and then send updated information about arrival/departure times and platform changes, for example, back to the PIS.

The activities in relation to Task 6.2 will be continued in WP11, Task 11.2, to develop and demonstrate the TMS-PIS interface in collaboration with the FP1-MOTIONAL, workstream 1.2.

The described capability to provide travellers' demand information to TMS/CMS systems will help to facilitate more customer friendly traffic (re-)planning or traffic control reactions on travellers' needs at real-time time scales.

8. References

- Deliverable D6.1 of FP6 FutuRe, Specification of Multimodal Travel Solution (Alpha Release), Version 2, March 2024
- SIRI Management Overview-White paper, CEN TC 278 Working Group 3 Sub Group 7.
- X2Rail-4 Project, Advanced signalling and automation system - Completion of activities for enhanced automation systems, train integrity, traffic management evolution and smart object controllers: Grant Agreement number: 881806 — X2Rail-4 — H2020-S2RJU-2019 / H2020-S2RJU-CFM-2019, https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-4