Deliverable 19.1
Specification Report of Enablers 18-27

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1. Executive Summary

This document, deliverable D19.1, belongs to Europe's Rail FP1 MOTIONAL specification phase from Work Package (WP) 19. FP1 MOTIONAL project focuses on improving network management planning and control, as well as rail mobility management in a multimodal environment in Europe. Research and innovation activities are broken down into several areas grouping the TEs (Technical Enablers) identified in the MAWP (Multi Annual Working Plan). The present document addresses features associated with WS (Work Stream) 1.3 "Integration of rail traffic with door-to-door mobility", namely TEs 18 to 27. Within MOTIONAL, the team in charge of this area is known as SG3 (Subgroup 3).

D19.1 (due at M12) is elaborated during the first phase of the project with the objective to provide the required inputs for the next phases, namely development and demonstration.

This document starts with a review of the TEs with a dedicated highlight on associated past innovation projects, the objective being to establish a clear baseline for the specification work.
It then proposes an analysis of the system architecture inspired by AF (Architecture Framework) guidelines. This analysis starts with a view of the targeted operational objectives of the system in the form of a set of use cases associated with TEs. It moves next to a general description of how the system should implement these operational objectives through the elaboration of system functional analysis consisting in the definition of high-level capabilities and requirements. The following step, logical architecture, aims at identifying the logical components of the system, their interactions in the perspective of the implementation of use cases and the interfaces and standards in scope when applicable.
D19.1 ends with the transition towards the next phases of the project with the definition of the planned work for development and demonstration phases.

2. Abbreviations and acronyms

Abbreviation / Acronym	Description
ASP	Apportionment and Settlement Platform
ABT	Account Based Ticketing
B2B	Business-to-Business
B2C	Business-to-Customer
BLE	Bluetooth Low Energy
CEN	European Committee for Standardization
DRT	Demand Responsive Transportation
ERA	European Union Agency for Railways
FCM	Face Capture Module
FP	Flagship Project
FRS	Face Recognition Server
GA	Grant Agreement
GPS	Global Positioning System
GTFS	General Transit Feed Specification
HFCS	Hands Free Control System
HMI	Human Machine Interface
IAMS	Intelligent Asset Management System
ID	Identification
MaaS	Mobility as a Service
MAWP	Multi Annual Work Programme
MCT	Minimum Connection Time
NeTEx	Network Timetable Exchange
OCC	Operation Control Centre
OJP	Open Journey Planning API
OSDM	Open Sales and Distribution Model
PRM	Person with Reduced Mobility
RTLS	Real Time Location Service
S2R	Shift2Rail
SG	Subgroup
SIRI	Service Interface for Real Time Information
TE	Technical Enabler
TRL	Technology Readiness Level
TSP	Transport Service Provider
UC	Use Case
UWB	Ultra Wide Band
WP	Work Package
WS	Work Stream

3. Background

The present document constitutes the Deliverable D19.1 “Specification Report of Enablers 18-27” in the framework of the Flagship Project 1 – MOTIONAL as described in the EU-RAIL MAWP.

FP1 MOTIONAL research and innovation activities are broken down into several areas grouping the TEs (Technical Enablers) listed in the MAWP. D19.1 addresses the features associated with multimodal integration, namely TEs 18 to 27. An overview of each TE is included in the MAWP.

The solutions that will be developed and demonstrated in FP1 MOTIONAL as responses to the TEs are outlined in the GA (Grant Agreement) as part of the WPs (Work Package) description. However, the description in the GA is limited to a general scoping that needs to be refined in order to form the specification of the solutions.

D19.1 addresses this objective by collecting the specification outputs including especially system operational analysis, system capabilities and requirement analysis, system logical architecture as well as the transition to development and demonstration steps.

D19.1 complies with the GA in that sense that it refines and expand the business and technical requirements expressed in the GA.

4. Objective/Aim

4.1 Objectives

This document has been prepared to provide the outcomes of MOTIONAL WP19 "Alignment of Specifications for Enabler 18-27" (tasks 19.1 to 19.9). The objective is to give a complete overview of WS1.3 "Integration of rail traffic with door-to-door mobility" by providing:

- Use cases as guidelines for the planned developments.
- High-level design and architectures.
- Data analysis and interfaces.
- Overview of the status quo of existing technologies, developed in previous projects.

The specific outcomes for WS1.3 stated in the GA are listed below:

- Integration of Rail with other transport modes: the focus is on the improvement and development of B2B platforms and services to foster the expansion of the cooperation between mobility providers in various technical topics, such as data sharing, providing of common services in sales and distribution. This is supported by a dedicated activity on standardised interfaces (expansion of existing standards and development of new ones for recommendation when necessary).
- Services for inclusive rail-based mobility: the services in scope focus on the environment in railway hubs to facilitate customer journeys and allow an efficient cooperation between rail and other transport mobility providers through connected services. Those services include travel assistance across modes (esp. PRM), hands-free solutions, smart information, and platform-based guidance.
- Anticipate demand and improved resource utilisation: passenger demand analysis and coordinated response of the mobility solutions as a whole. Areas of study include short-term and long-term demand forecast calculation, simulation of demand and associated reaction of the mobility networks using Digital Twins, rail capacity improvement and information on disruption across modes.

The solutions designed in this specification document aim at improving railway efficiency and quality in different aspects:

- Eliminating barriers to interoperability and providing solutions for complete integration.
- Study of travel assistance across modes and guidance solutions for an inclusive mobility.
- Demand forecast combined with disruption management across modes for more reliable transport systems.

4.2 Methodology

Concerning the document methodology, the structure is described in the following diagram.

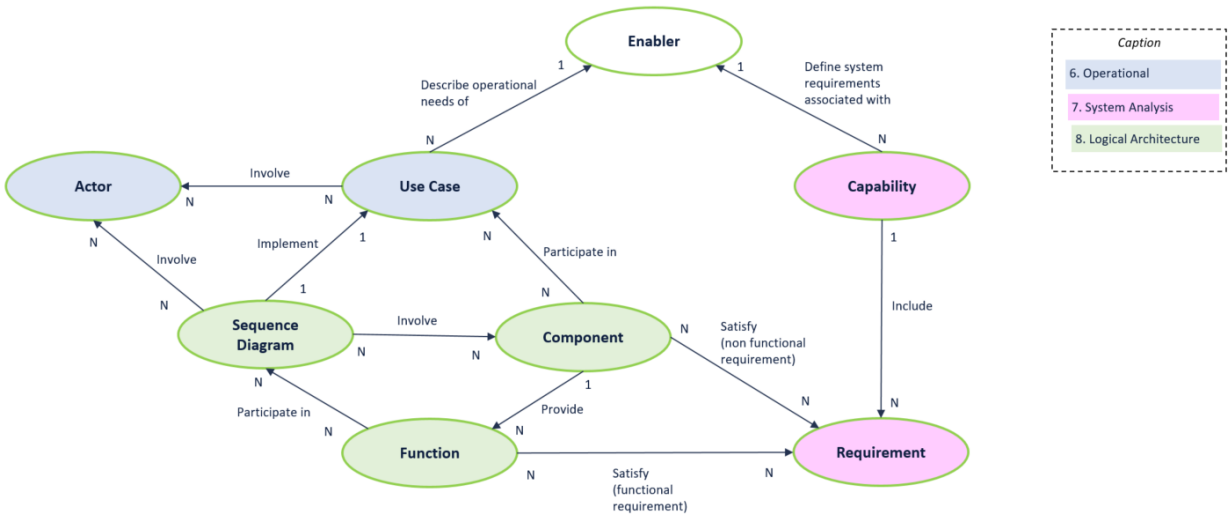

Figure 1: Artifact diagram of D19.1 structure

Figure 1 shows the pattern followed for this specification phase: each colour represents a specific chapter of the deliverable where that topic is dealt with. The starting points are the Technical Enablers (TEs), included in WS1.3, described in chapter 5.
The structure is then divided in three main chapters:

- Chapter 6 - Operational consists of use cases, actors and interactions among them. From an operational point of view the development of use cases allows to describe the needs of a TE. Each use case identifies its own involved actors and components (to be developed within the project).
- Chapter 7 – System Analysis introduces system capabilities and requirements. From a system point of view, TEs are validated through the implementation of high-level functions, named capabilities, which consist of functional requirements (FRQ), that describe what the capability does, and non-functional requirements (NFRQ), that express how the capability works.
- Chapter 8 - Logical Architecture shows sequence diagrams, components and their functions. Each sequence diagram describes a use case and explains the exchanges between actors and/or components, which are responsible for certain functions. Components and functions are described and linked with non-functional and functional requirements identified in the system phase.

5. Technical Enablers

The present chapter introduces the Technical Enablers (TEs) referred to MOTIONAL WS1.3 "Integration of rail traffic with door-to-door mobility". The starting point is the analysis and possible reuse of methodologies and technologies carried out in previous European research projects and innovation activities.

MOTIONAL WS1.3 TEs are listed in the table below.

#	Technical Enabler
18	Improve rail integration using B2B intermodal services
19	Develop standardized interfaces
20	Travel assistance across modes
21	Hands-free solutions & smart information
22	Platform based guidance
23	Short term demand forecast
24	Long term demand forecast
25	Integrate demand forecast into digital twin
26	Optimize rail capacity to better match the demand
27	Manage/inform disruption across modes

Table 1: MOTIONAL WS1.3 Technical Enablers

The following figure illustrates the mapping of the TEs to MOTIONAL WPs.

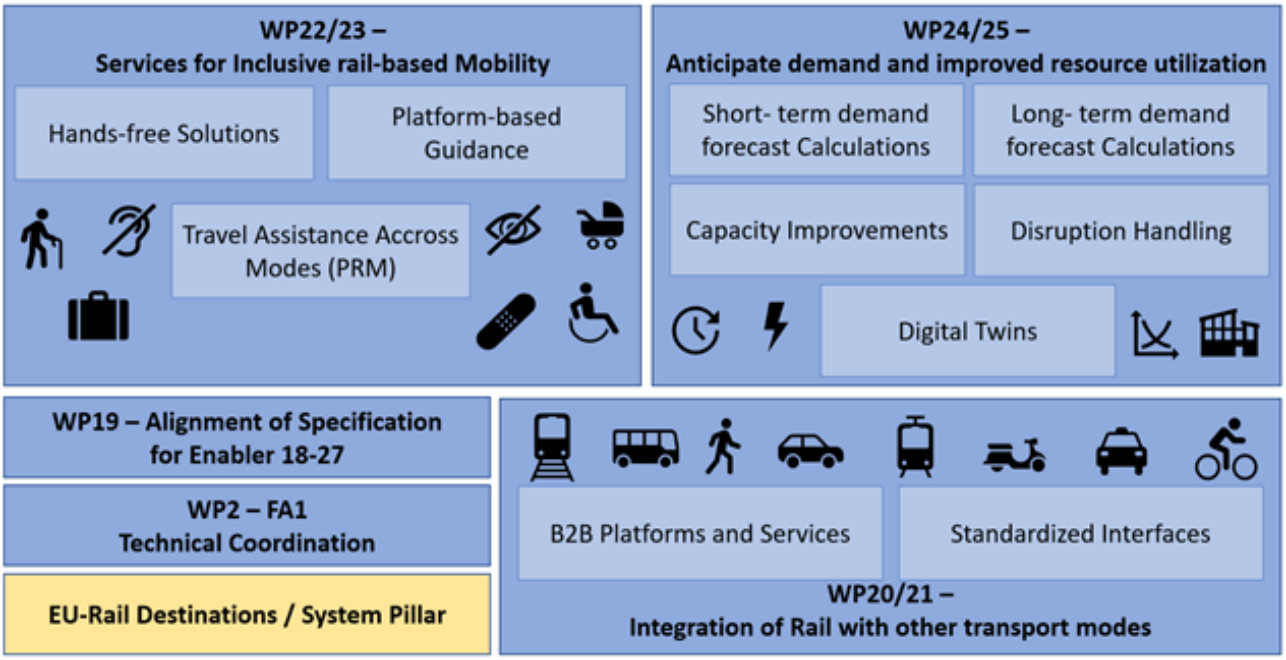

Figure 2: MOTIONAL WS1.3 TE to WP mapping

5.1 Technical Enabler 18

MOTIONAL WP19 Task 19.1 is linked to TE 18. This enabler focuses on improving rail integration through B2B intermodal services. This enabler aims to analyse technical requirements and specifications related to interfaces, information, and data structure for B2B intermodal services. The task covers the creation of general use cases that guide the more detailed design and all technical developments in WP20 and demonstrations on WP21. The initial results of this enabler are the high-level design of the MaaS Platforms and the planned intermodal services, which focus is on providing multimodal travel services that include ticketing, tracking, and disruption management. In the development stage the result should be focused on the provisioning of MaaS platforms with integration (B2B) and synchronization of rail with other mobility modes towards a coordinated multimodal traffic management system allowing to improve accessibility to multimodal travel services (e.g. DRT). In the later stage a demonstration should be executed proving that the interoperability (B2B integration) between the provided platforms is able to reach TRL 6-7.

5.1.1 Knowledge transfer from previous projects

TE 18 is linked with the following past projects and innovation activities:

- Shift2Rail IP4 (Co-Active, Attracktive, Maasive, CONNECTIVE, ExtenSive, COHESIVE): Standardization need identified in all projects as crucial for the success of multimodal integrations within MaaS ecosystems.
- MaaS4EU. Frameworks and tools to enable the MaaS concept. MaaS4EU business models and data models will support and contribute to the development of Enabler 18.
- MaaS Alliance papers and recommendations.
- FSM, Full Service Model initiative. Full Service Model and its convergence with OSDM will be used in in the area of the development of standardized interfaces and support the implementation of B2B workflows and processes in the domain of Sales & Distribution.

5.2 Technical Enabler 19

MOTIONAL WP19 Task 19.2 is associated with TE 19. The objective of this Technical Enabler is to develop interfaces based on Standards (OSDM, OJP, ERA, CEN, etc.) to develop and optimise B2B integration of rail with other mobility service providers and foster their collaboration. In particular, the Enabler is meant to work on interfaces related to services related to distributed Journey planning, Sales & Distribution and Customer information.

Reservation and inventory systems interoperability will be implemented allowing sales and distribution. Within this implementation, the external interface (incoming from the distribution partners) and outgoing interface (towards the inventory of other operators) will be designed, implemented, and validated following the OSDM standard. If the current version of the OSDM standard become insufficient to cover all use cases an active involved in the definition of the enhanced specifications is expected. The demonstrations should reach TRL 7-8.

5.2.1 Knowledge transfer from previous projects

TE 19 is linked with the following past projects and innovation activities:

- CONNECTIVE: CONNECTIVE is a S2R project that developed the Interoperability Framework that was in charge of facilitate the conversion between components developed within IP4 and services from TSPs. The experience in interacting with different components and Travel Services needs to be taken into account in the TE.
- MaaS4EU**.** MaaS4EU data models will contribute to the work standardized interfaces.
- Open Sales and Distribution Model (OSDM) will be used as a reference for work on Sales and Distribution interfaces and flows.

5.3 Technical Enabler 20

MOTIONAL WP19 Task 19.3 is linked to TE 20. The objective of this Technical Enabler is to provide guidance and seamless validation access control within stations to improve the assistance with special focus in the Subtask 22.1.2 to persons with disabilities and with reduced mobility. The demonstrations should reach TRL 4-5.

Definition of person with disabilities:
"Person with a disability" and "person with reduced mobility": any person with a physical, mental, intellectual or sensory impairment, permanent or temporary, which, in interaction with different barriers, may hinder their full and effective use of transport on equal terms with other travellers or whose mobility when using transport is reduced by age."

Source: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017PC0548

5.3.1 Knowledge transfer from previous projects

TE 20 is linked with the following past projects and innovation activities:

- Shift2Rail CoActive, ATTACkTIVE, MaaSive and ExtenSive: S2R-IP4 has analysed and developed in certain uses cases that are associated to guidance and seamless validation. The conclusions and output of these projects needs to be taken into account in this TE.
- Shift2Rail In2STEMPO studies on customer experience improvement at Railway Stations and especially analysis of accessibility problems
- Totem designed by Ineco: T-Ais is a Registered property product of Ineco. It is a result of an Ineco research & development project. The scope of that project got to mark the intention to create an Information Totem for disabled passengers' guidance, accessible for wheelchair users, blind and audition handicapped passengers.

5.4 Technical Enabler 21

MOTIONAL WP19 Task 19.4 is associated with TE 21. This enabler deals with Hands-free solutions at multimodal hubs and underlying services and technologies. The main target consists of travellers using rail services and transferring between rail and other mobility modes. The objective is to create value for the transport operators and enhance traveller UX. Main features include seamless validation, assistance to passengers with special needs, automatic opening of access gates, guidance and next generation of white label apps supporting B2B and B2C channels. The demonstrations for this TE should reach TRL 7-8.

Enabler 21 contributes to Enabler 20 (Travel assistance across modes) by providing technologies and services enabling seamless validation, guidance and PRM specific information.
Enabler 21 cooperates with Enabler 22 (Platform based guidance) by providing interaction services with platform-based devices and signs.

5.4.1 Knowledge transfer from previous projects

This section lists past research and innovation activities the outputs of which will contribute to the baseline of Enabler 21 specifications. These previous R&I include Shift2Rail activities as well as other European initiatives.

- Shift2Rail ATTRACkTIVE, MaaSive, ExtenSive Travel Companion concepts provide key design features for the baseline of mobile applications that that will participate in the objectives of Enabler 21:
    - Technical concepts
        - Modular architecture increasing the flexibility of the solution.
        - Indoor positioning.
        - Traveller identity management and authentication.
        - Connectivity to cloud back-end.
        - Interactive notifications.
        - Guidance mechanisms.
    - Passenger point of view
        - User centricity.
        - Travel assistance (navigation).
        - Access to information.
- Additional concepts developed in Shif2Rail ExtenSive and candidate to be incorporated into Enabler 21 design include:
    - Indoor navigation in relation with station infrastructure.
    - Indoor route management.
    - Assistive tools, especially voice assistance.
    - Interoperability.
    - Seamless validation.

- Shift2Rail In2STEMPO Station sub-project outputs will benefit Enabler 21 design in the area of customer experience in intermodal hubs. Elements of interest are focused on “Future Station Solutions” as addressed by In2STEMPO and especially the studies on customer experience improvement at Railway Stations.
- Interreg Europe projects, the outputs of which might be of interest for Enabler 21 design are the following:
    - ClimobCity (Climate friendly mobility) action plans.
    - PriMaas (Prioritizing low carbon mobility services for improving accessibility) knowledge hub on MaaS accessibility.
- EEA, European Environment Agency studies & reports, especially First and Last mile EEA studies, lessons learnt provides guidelines for Enabler 21.

5.5 Technical Enabler 22

MOTIONAL WP19 Task 19.5 is associated with TE 22, with TRL 4-5. The Technical Enabler 22 encompasses different elements that will improve general approach to platform-based guidance in railway platforms oriented to passengers, including persons with disabilities.
Special interest is to be given to users with different types of disabilities, promoting greater autonomy and accessibility for them.
Guidance of passenger to and from the platform and a better distribution on the platform in order to increase the capacity and optimize the boarding process of the train is a special point of interest.
The interaction with passengers and especially interfaces allowing platform-based solutions to provide dynamic information are part of the study. Technical and structural solutions that can process and display data are to be examined.

5.5.1 Knowledge transfer from previous projects

TE 22 is linked with the following past projects and innovation activities:

- Traveller interaction. ATTRACkTIVE Travel Companion concepts will participate in the design of mobile applications part of FP1-MOTIONAL WP22 (inclusive rail-based mobility).
- Station infrastructure, Disruption management methods and analysis. ExtenSive WP9&10 focused on management of station infrastructure from traveller's perspective will contribute to FP1-MOTIONAL WP20 and 22.
    - D9.1-Infrastructure on stations and their surroundings
- Improved customer service at stations. In2STEMPO Station sub-project outputs will benefit FP1-MOTIONAL WP 22 in the area of customer experience in intermodal hubs.
- Mobility, sustainability. Interreg projects outputs will contribute to WS1.3 in term of smart mobility and multimodal integration. This will especially benefit FP1-MOTIONAL WP20 & 22.
- Totem designed by Ineco: T-Ais is a Registered property product of Ineco. It is a result of an Ineco research & development project. The scope of that project got to mark the intention to create an Information Totem for disabled passengers' guidance, accessible for wheelchair users, blind and audition handicapped passengers.

5.6 Technical Enabler 23

MOTIONAL WP19 Task 19.6 is linked to TE 23, with TRL 6-7. This enabler covers short term demand forecast calculation using run time data (e.g., ticketing data, short term weather forecast, passenger density) where support service providers with detailed and reliable data to improve their service offers oriented to real-time data on one hand and will develop a short-term profiling information system.

5.6.1 Knowledge transfer from previous projects

TE 23 is linked with the following past projects and innovation activities:

- Shift2Rail CONNECTIVE: CONNECTIVE Business analytics concepts and design will benefit FP1-MOTIONAL WP24 data analytics solutions.
- Shift2Rail IN2SMART2: Assets' status forecast. IN2SMART2 outputs will be reused and enhanced when applicable in FP1-MOTIONAL WP24 as part of the interaction with FP3.
- Eurostat data: Transport statistics. Eurostat data will be one of the potential data sources for demand forecast development in FP1-MOTIONAL WP24.
- EEA, European Environment Agency studies & reports: Transport and environment, First and Last mile. EEA studies, especially in the transportation industry will contribute to challenge FP1-MOTIONAL WS1.3 concepts and developments and provide more sustainable value propositions.

5.7 Technical Enabler 24

FP1 MOTIONAL WP19 Task 19.7 is associated with TE 24. Enabler 24 is focused on the long-term demand forecast with focus on data analytics based on a variety of sources (e.g., public events, holiday calendar) and operators' data (e.g., fare, passenger density data) and historical information for predictive models related to passenger clustering.
This Technical Enabler, with TRL 4-5, encompasses long-term demand forecast calculation supporting service providers with detailed and reliable data, elaborating component for long-term forecast and including some long-term passenger flow multimodality technology.

5.7.1 Knowledge transfer from previous projects

TE 24 is linked with the following past projects and innovation activities:

- Shift2Rail CONNECTIVE: Interoperability framework, business analytics. Concepts used in CONNECTIVE Interoperability Framework will be further enhanced in FP1-MOTIONAL WP20 activities related to standardized interfaces CONNECTIVE Business analytics concepts and design will benefit FP1-MOTIONAL WP24 data analytics solutions.
- Shift2Rail IN2SMART2: Assets' status forecast. IN2SMART2 outputs will be reused and enhanced when applicable in FP1-MOTIONAL WP24 as part of the interaction with FP3.
- Eurostat data: Transport statistics. Eurostat data will be one of the potential data sources for demand forecast development in FP1-MOTIONAL WP24.
- EEA, European Environment Agency studies & reports: Transport and environment, First and Last mile. EEA studies, especially in the transportation industry will contribute to challenge FP1-MOTIONAL WS1.3 concepts and developments and provide more sustainable value propositions.

5.8 Technical Enabler 25

MOTIONAL WP19 Task 19.8 is linked to TE 25. The Technical Enabler 25 is focused on a Digital Twin of a multimodal transport network integrating both traffic simulation and demand forecast in order to help to optimise offer, passenger occupancy, connection time and other service-related elements (optimising offer as such is not part of the enabler).
Its scope is limited to the urban transport offer and demand.

It's based on 2 levels of simulation:

- Macro simulation using passenger long term demand and planned offer to analyse impacts and to contribute to the optimisation of the offer at a macro level.
- Micro simulation using passenger short term demand and current offer forecast to simulate flows of passengers across the different transport systems. The micro simulation includes passenger exchange time models, crowd flow models, and passenger behaviour models in case of incident. Thus, an Enabler 25 connected to operation enables short-term flow prediction and helps operator to perform corrective actions (service reinforcement for example) and manage incidents on the network.

During the demonstration phase, this enabler shall reach TRL 4-5.

5.8.1 Knowledge transfer from previous projects

TE 25 is linked with the following past project and innovation activity:

- Shift2Rail CONNECTIVE: a passenger flow simulator and some visualizations have been identified. With the Passenger Flow Simulator, the goal is to work not only at a station level and at micro-level as in the previous data generation system, but also to obtain a macro-level simulation that works for the whole network. The simulation aims to provide transport planners with tools to optimize train timetables by considering demand forecast as identified by predictive analytics. And, as the timetables are used by Metro Traffic Management (aka Automatic Train Supervision), the simulator can be also integrated with a supervision system in order to help operator to modify for example, current train movement strategies (dwells) in near real time according to unexpected observation of passenger flow (platform density, train density). This tool helps identifying conflicts between transport offer vs passenger demand and computes forecast KPIs for a defined transport service.

5.9 Technical Enablers 26-27

MOTIONAL WP19 Task 19.9 is associated with TE26 and TE27.
TE 26 is focused on optimised rail capacity to better match the demand. Adapting the transport service to the real needs of passengers is essential to increase user satisfaction and save money. In the development phase the focus will be on the design and development of a multi-modal management framework and a strategic mobility manager for rail capacity optimization. During the demonstration phase the solutions addressed to this enabler shall reach TRL 4-5.

TE 27 covers disruption management across different mobility modes enabling operators to collaboratively solve the disruption and properly inform passengers. Disruptions in transport systems have a strong impact on the quality, efficiency and safety perceived by passengers. To mitigate these impacts, it is necessary to support the operators by providing a system that suggests quick and effective mitigation strategies and informs passengers accordingly. The development phase will focus on the design and development of a multi-modal management framework and a strategic mobility manager to deal with disruption management and information. During the demonstration phase this enabler shall reach TRL 6-7.
These two enablers are covered by the same specification task since TE 27 can be assumed to be an extension of TE 26 (optimization due to disruptions).

5.9.1 Knowledge transfer from previous projects

TEs 26-27 are linked with the following past projects and innovation activities:

- Shift2Rail CONNECTIVE: technical framework and a set of tools to foster the digital transformation of rail and all the transport ecosystem. The project addresses two Technology Demonstrators: Interoperability Framework and Business Analytics. The latter aims at providing a common business intelligence foundation to monitor, analyse and generate data and is linked with TEs 26-27.
- Shift2Rail ExtenSive: traveller experience enhancement and travel services improvement (in the areas of travel shopping, trip tracking, booking and ticketing). ExtenSive WP7-8 focuses on specification and implementation phases for the development of decision support algorithms to support operators with disruption management through multimodal alternative paths (TRL 4): it is linked with the TE 27 (disruption management).
- Shift2Rail IN2SMART2: implementation of Dynamic Railway Information Management System, Railway Integrated Measuring and Monitoring System and Intelligent Asset Management Strategies (IAMS). The definition of a scalable framework for asset management systems can provide input data needed to manage predicted disruptions (TE 27).
- EEA, European Environment Agency studies & reports: transport and environment, first and last mile. EEA studies, especially in the transportation industry, will contribute to challenge FP1-Motional WS1.3 concepts and developments and provide more sustainable value propositions.

6. Operational Aspects

This chapter aims at providing a general description of the system, in terms of purpose, identified actors and use cases for development and demonstration WPs.

6.1 Actors

This section introduces all actors and entities, identified in the specification phase, that will interact with the system.

Actor	Description
City Transit Operators	Business participant (private) managing public transit services with a municipality scope (e.g., Shuttle services, local minibuses etc.)
Consumer of data	User, application or system that uses data collected by other systems or stored in repositories.
Data Analyst	Representative of the TSP who accesses the Demand Analytics Dashboard to inspect past and forecasted demand of Travellers within the MaaS platform of the TSP.
Distributor	Means an undertaking providing legal and technical capacity to issuers to sell rail products or to provide online-facilities to customers to buy rail products. Besides, the distributor can offer services to issuers by assembling O-Ds carried out by different carriers into complete journeys as required by the traveller. The distributor may be a carrier
Infrastructure Operators	Municipal organization responsible for maintenance of infrastructure such as roads, electricity, etc.
Issuer	Means an undertaking selling the ticket and receiving payment. May be a carrier and/or a distributor. The issuer is the undertaking indicated on the ticket with its code and possibly its logo
Entities specialized in accessibility	Collaborating accessibility entities or enhancers
Metro Service Provider	Specific Transport Service Provider that provides metro services and means of transports.
Mobility Account Provider	Derivation from retailer. Business participant owning the Mobility Account.
Municipal Independent Operators	Business participant (private) managing public transit services with a municipality scope (eg., Shuttle services, local minibuses etc.)
Municipality management personnel	Representatives of e.g., road management reporting on roadworks, city council reporting on festivals, etc. Generally trusted sources from municipal governing or affecting bodies.
OCC Operator	Person who is responsible for monitoring and

	controlling the systems and processes within the Operation Control Centre (OCC). The operator's role may include tasks such as: - Monitoring the status of equipment, systems, and processes in real-time. - Responding to alerts and alarms generated by the monitoring systems. - Coordinating and managing traffic. - Troubleshooting issues and resolving problems that arise. - Communicating with other operators, technicians, and stakeholders to coordinate activities and resolve issues. - Following established procedures and protocols to ensure the safe and efficient operation of the control centre.
Other multimodality operators	Business participant offering non-public services for multimodal travel (e.g., Taxi operator, bike rentals, scooter rental, car sharing)
Person with Disabilities or Person with Reduced Mobility	Any person who has a permanent or temporary physical, mental, intellectual or sensory impairment which, in interaction with various barriers, may hinder his or her full and effective use of transport on an equal basis with other passengers or whose mobility when using transport is reduced due to age
Purchaser	A purchaser represents the entity which has booked an offer. It is the person to contact in case of changes to the booking primary. A purchaser does not need to travel.
Rail Administrator / Infrastructure Manager	Body or firm responsible in particular for establishing, managing and maintaining railway infrastructure, including traffic management and control-command and signalling». In addition, the management of royalties.
Railway Service Provider	Specific Transport Service Provider that provides railway services and means of transports.
Retailer	Means a person or an undertaking that sells to the customer a ticket without or with a reservation for a rail service. A retailer can be a railway undertaking (agent) or an accredited travel agent
Service Provider (SP)	Role of an organization offering service(s), especially but not exclusively to transportation.
Station Operator	Entity responsible for administration and operation of railway station building and related infrastructure (focus especially on station building not platforms)
Transport Service Provider (TSP)	Organization providing both physical services and means of transport: aircrafts, trains, metros, coaches, buses, bike-sharing, car-sharing, etc.

Traveller	The traveller is the person making a travel in accordance with the terms and conditions of the entitlement(s)
Urban Transport Service Provider	Company that provides public transportation services, such as buses, trains, trams, and subways.
Weather station	Facility equipped with instruments for measuring atmospheric conditions such as temperature, pressure, humidity, wind speed, wind direction, and precipitation.

Table 2: List of actors included in MOTIONAL WS1.3 use cases

6.2 Use Cases

The use cases, identified in MOTIONAL WS1.3, are shown in the table below. Each use case is linked with the reference WPs pair (WP20-21 Integration of Rail with other transport modes, WP22-23 Services for Inclusive rail-based Mobility, WP24-25 Anticipate demand and improved resource utilization). All use cases identified in MOTIONAL project are detailed in the deliverable D2.3 "Use Cases for planned technical developments of the project".

Use Case Id	Use Case Name	WP	Responsible partners
UC-FP1-WP19-01	Journey Planning as a B2B intermodal service	20-21	HACON, INDRA
UC-FP1-WP19-02	Retailer as ticket vendor selling a product provided by a TSP as distributor via OSDM API	20-21	HACON, DB, INDRA
UC-FP1-WP19-03	Enable TSPs to visualise mobility demand (UI)	20-21	HACON
UC-FP1-WP19-04	Financial Services. Mobility Offer apportionment	20-21	GTSD
UC-FP1-WP19-05	Financial Services. Pay as-you-go apportionment	20-21	GTSD
UC-FP1-WP19-06	Financial Services. Distributed Ledger	20-21	GTSD
UC-FP1-WP19-07	Financial Services. Processing of CEN NeTEx Fare data	20-21	GTSD
UC-FP1-WP19-08	Exchange of disruptions and mitigation strategies information	20-21	STS
UC-FP1-WP19-09	Unified multimodal information storage and update	20-21	PKP
UC-FP1-WP19-10	Accessing multimodal information data for creating multimodal travel plans between on municipal level	20-21	PKP
UC-FP1-WP19-11	Support for multimodality related decisions for station operator	20-21	PKP
UC-FP1-WP19-12	Totem T-Ais. 1 specific spot for people with visual disability	22-23	ADIF, MALAGA
UC-FP1-WP19-13	Totem T-Ais. 1 specific spot for people with hearing impairment, PRM, motor disability, cognitive impairment, language misunderstanding and some visual impairments.	22-23	ADIF, MALAGA

UC-FP1-WP19-14	Gap filler	22-23	ADIF
UC-FP1-WP19-15	Gobo	22-23	ADIF
UC-FP1-WP19-16	Accessible Robot	22-23	ADIF
UC-FP1-WP19-17	Guiding Accessible Software	22-23	ADIF, MALAGA
UC-FP1-WP19-18	Guiding Accessible Intelligent Tool with physical complementary signalling in different languages	22-23	ADIF
UC-FP1-WP19-19	Frictionless validation	22-23	INDRA
UC-FP1-WP19-20	Indoor guidance	22-23	INDRA
UC-FP1-WP19-21	Account based ticketing	22-23	INDRA
UC-FP1-WP19-22	Hands Free. UWB Walk-in	22-23	GTSD
UC-FP1-WP19-23	Hands Free. UWB Walk-out	22-23	GTSD
UC-FP1-WP19-24	Hands Free. UWB Intermodal transfer	22-23	GTSD
UC-FP1-WP19-25	Hands Free. UWB In station assistance	22-23	GTSD
UC-FP1-WP19-26	Hands Free. Face Recognition Walk-in	22-23	GTSD
UC-FP1-WP19-27	Hands Free. Face Recognition Walk-out	22-23	GTSD
UC-FP1-WP19-28	Illuminated Platform Edge “Attention”	22-23	DB
UC-FP1-WP19-29	Illuminated Platform Edge “Orientation”	22-23	DB
UC-FP1-WP19-30	Illuminated Platform Edge “Capacity”	22-23	DB
UC-FP1-WP19-31	Notices for other modes of transport with connections at the railway station	24-25	ADIF, INDRA, MALAGA
UC-FP1-WP19-32	Notifications for activation of passenger flow management protocols	24-25	ADIF, INDRA
UC-FP1-WP19-33	Disruption management through Transport Data Hub	24-25	INDRA
UC-FP1-WP19-34	Reporting of external events influencing the multimodal transport on the municipal level	24-25	PKP
UC-FP1-WP19-35	Information exchange between disparate mode operators allowing swift and through propagation of disruption specification	24-25	PKP
UC-FP1-WP19-36	Ex-ante timetable punctuality	24-25	FS
UC-FP1-WP19-37	Timetable optimization based on MCT (Minimum Connection Time)	24-25	FS, STS
UC-FP1-WP19-38	Railway disruption management through optimization processes	24-25	FS, STS
UC-FP1-WP19-39	Generation of the library of situations	24-25	ETRA I+D
UC-FP1-WP19-40	Detection of situations	24-25	ETRA I+D
UC-FP1-WP19-41	Supporting timetabling decisions with visualisation and severity estimation of present disturbances in the municipality	24-25	PKP
UC-FP1-WP19-42	Decision support for incidents management	24-25	GTSD
UC-FP1-WP19-43	Sandboxing for test of incident mitigation scenarios	24-25	GTSD
UC-FP1-WP19-44	Alert for Possible Overcrowding Situations based on Occupancy Forecast Data	24-25	HACON
UC-FP1-WP19-45	Request Journey alternatives to avoid crowded	24-25	HACON

	routes		
UC-FP1-WP19-46	Training of the Short-term Prognosis Model	24-25	ETRA I+D
UC-FP1-WP19-47	Short-term prognosis	24-25	ETRA I+D
UC-FP1-WP19-48	Decision support system for short term forecasting on municipal level.	24-25	PKP
UC-FP1-WP19-49	Forecast Occupancy of Vehicles using Journey Planning Requests Data	24-25	HACON
UC-FP1-WP19-50	Display Forecasted Occupancy Information to Travellers when Planning Trips	24-25	HACON
UC-FP1-WP19-51	Estimation of station staff required to provide quality customer service	24-25	ADIF, INDRA
UC-FP1-WP19-52	Decision support system for long term forecasting on municipal level.	24-25	PKP
UC-FP1-WP19-53	Transport offer optimisation	24-25	GTSD
UC-FP1-WP19-54	Analysis of Travel Demand Data based on Forecasted Data	24-25	HACON

Table 3: MOTIONAL WS1.3 Use Cases list

The use cases introduced in the list above have the following release dates.

- Q1 2024 (UC-FP1-WP19-28 and UC-FP1-WP19-29).
- Q2 2024 (UC-FP1-WP19-30).
- June 2024 (UC-FP1-WP19-01).
- November 2024 (all the other UCs).

The interactions between use cases and actors/entities are shown in the following use cases diagrams (divided by development WPs):

- Integrate Rail with other transport modes (WP20-21)

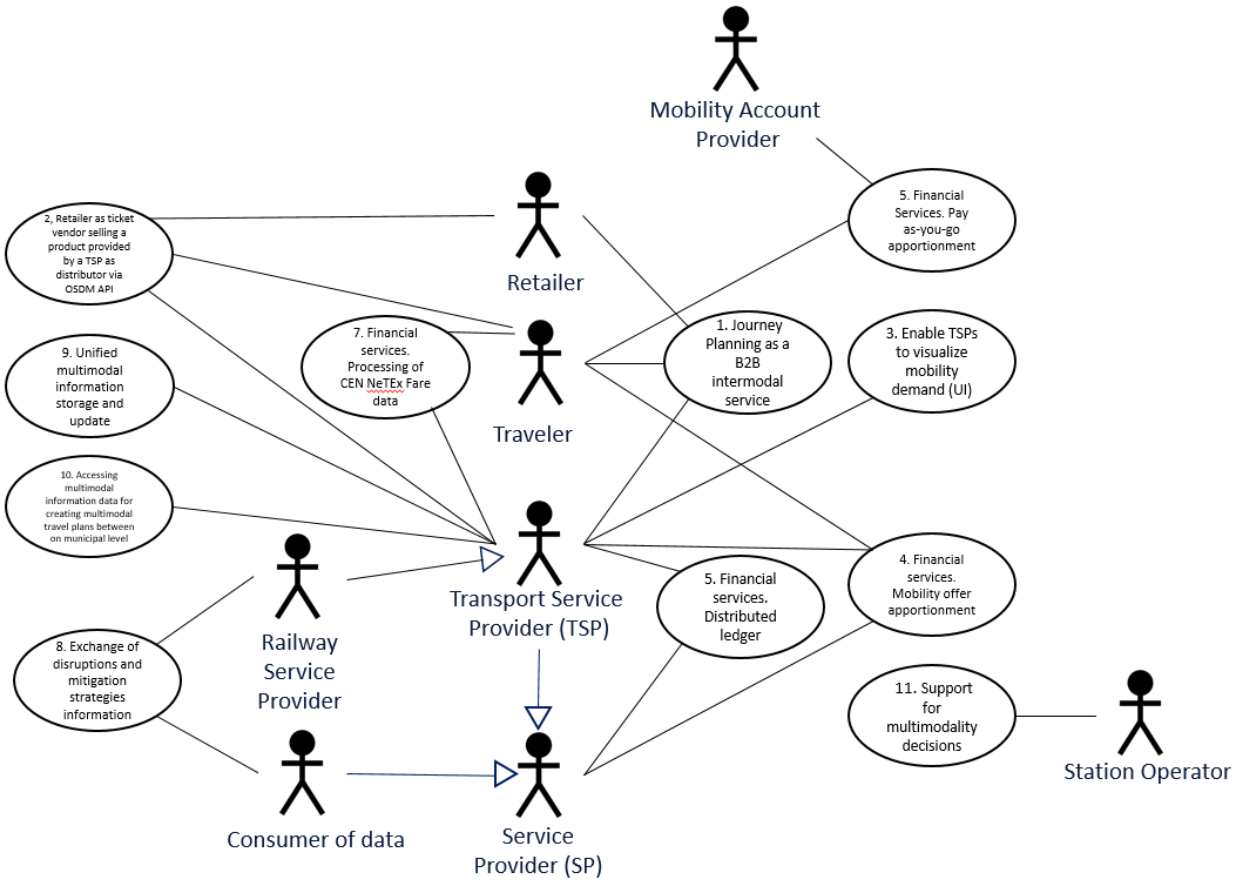

Figure 3: WP20-21 Use Cases diagram

- Services for inclusive rail-based mobility (WP22-23)

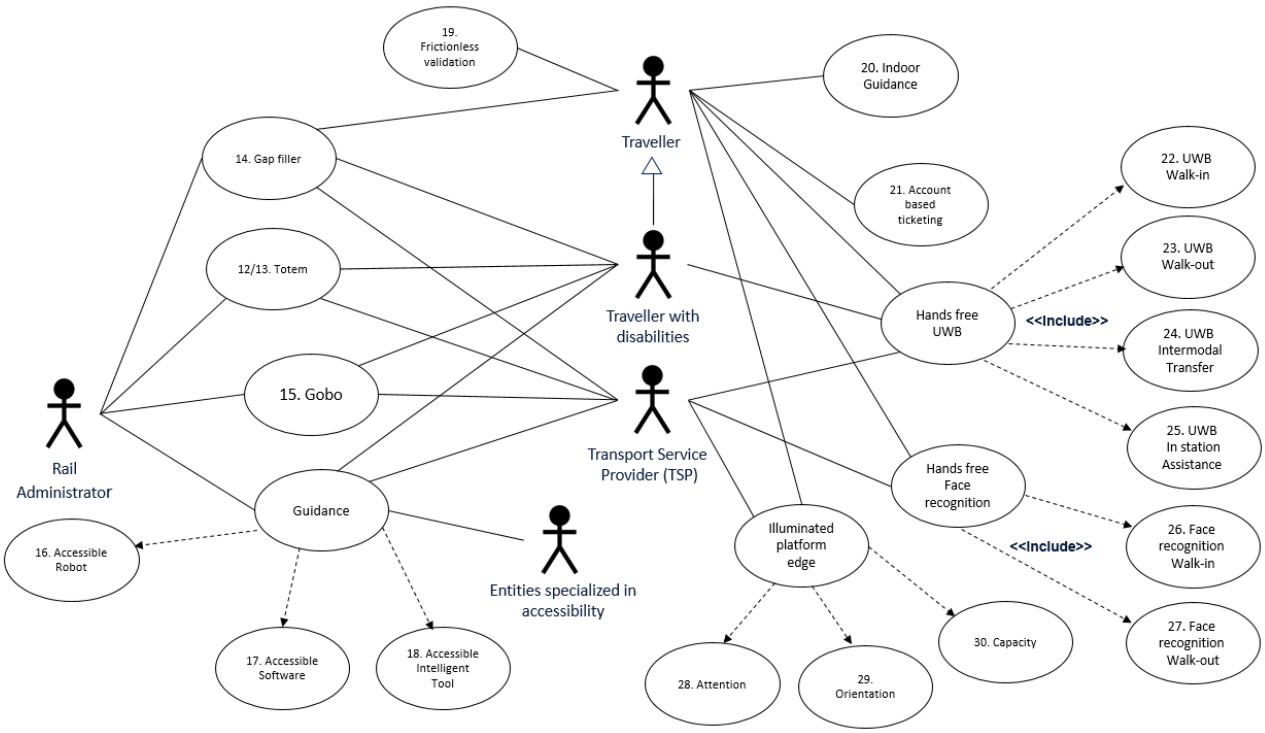

Figure 4: WP22-23 Use Cases diagram

- Anticipate demand leading to improved resource utilisation (WP24-25)

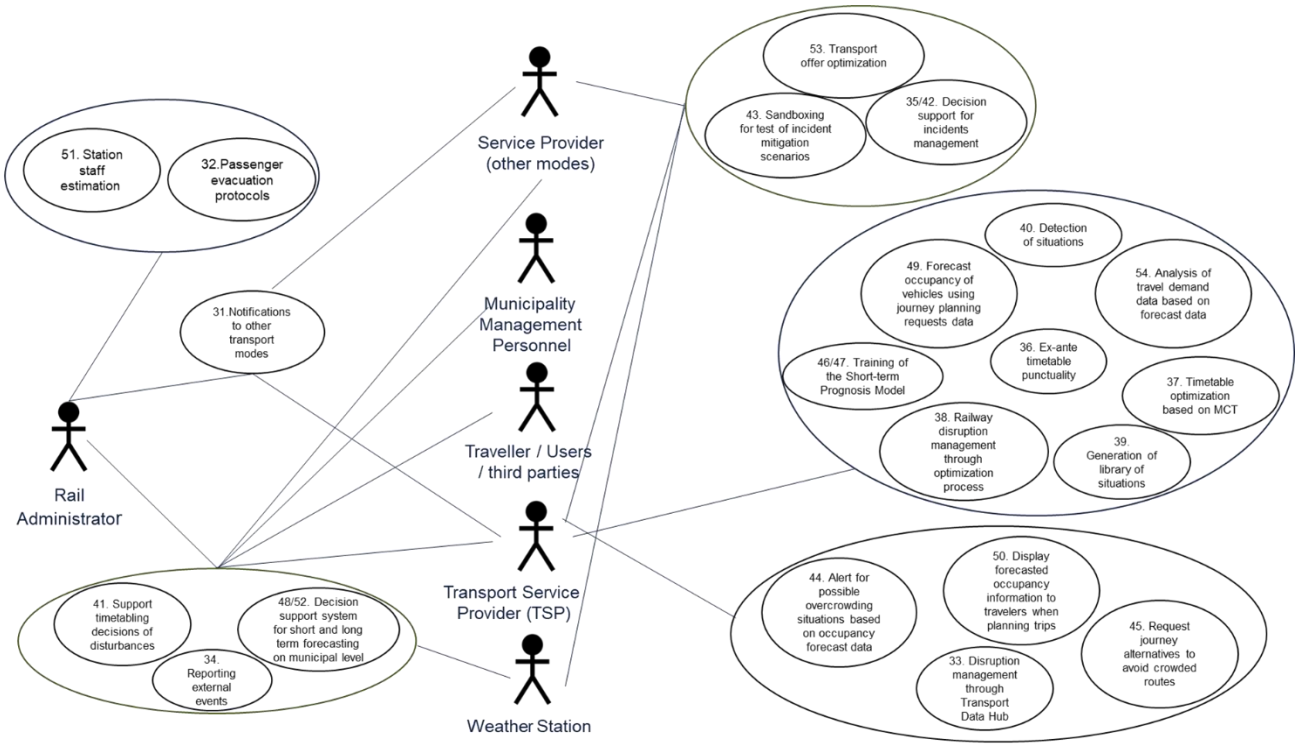

Figure 5: WP24-25 Use Cases diagram

6.2.1 Use Cases & interactions with other FPs

The following table describes the interactions between FP1 WS1.3 use cases and the other FPs.

Use Case Id & Name	FP interaction	Interaction description
UC-FP1-WP19-01 Journey Planning as a B2B intermodal service	FP6	Both projects will develop a multimodal platform to provide journey planning in main line (FP1) and regional line (FP6). The specification of journey planning services should be aligned, and the two platforms will interact through a B2B intermodal interface, using the OJP standard. FP6 will include DRT services on the provided services.
UC-FP1-WP19-09 Unified multimodal information storage and update	FP3	Information storage and updating is realised by a Data Lake system. This system is also being developed in FP3 centralising data from the station asset management. This allows multifaceted integration between all business processes considering station and multimodality.
UC-FP1-WP19-11 Support for multimodality decisions	FP3	Realised decision support systems are oriented for helping station and transport operators. Decision support systems developed in FP1 and FP3 constitute a synergy of effective management.
UC-FP1-WP19-38 Railway disruption management through optimization processes	FP3	Railway disruption management aims at handling both planned and unplanned disruptions. Predicted/prescribed information provided by asset management services (FP3) can be acquired as an input in case of planned maintenance activities.

Table 4: MOTIONAL WS1.3 Use Cases and FPs interaction

7. System Analysis

This section focuses on the description of "what the system must achieve for the users". The system analysis is performed through the identification of capabilities and requirements for each TE.

7.1 System capabilities and requirements

System analysis of MOTIONAL WS1.3 has been finalized through the description of different capabilities and requirements associated to each TE:

- System capabilities: List the specific capabilities that the system must have to meet the Technical Enablers goals.
- High level requirement associated with capabilities: business requirements (specific needs of the organization or stakeholders that the system must meet to be considered a successful solution), are divided into functional (FRQ), which define capability features, and non-functional (NFRQ), which define capability properties.

7.1.1 Technical Enabler 18 - Improve rail integration using B2B intermodal services

- TE18_CA01: Calculate intermodal itineraries.
- TE18_CA02: Calculate intermodal offers.
- TE18_CA03: Orchestrate booking.
- TE18_CA04: Provide access to statistics portal.
- TE18_CA05: Provide historic of multimodal demand data visualisation.
- TE18_CA06: Provide forecasts of multimodal demand data visualisation.
- TE18_CA07: Multimodal Fare Revenue Processing.
- TE18_CA08: Exchange disruption information between different platforms.
- TE18_CA09: Integrated travel and complete travel plan.
- TE18_CA10: Alternative choice of travel.
- TE18_CA11: Determination of travel time.

Capability id	Requirement id	Requirement description
TE18_CA01	TE18_CA01_FRQ01	The system must be able to calculate intermodal itineraries including scheduled transport modes (e.g., Train, Bus, Metro).
	TE18_CA01_FRQ02	The system must be able to calculate intermodal itineraries including non-scheduled transport modes (e.g., Bike-sharing, Car-Sharing, Taxis).
	TE18_CA01_FRQ03	The system should be able to calculate intermodal itineraries including demand responsive transport (DRT, provided by FP6).
	TE18_CA01_FRQ04	The system must be able to calculate intermodal itineraries including individual transport modes (walk, own-bike, own-car).
	TE18_CA01_NFRQ01	The system should calculate a limited number of solutions (best by category: price, time, sustainability, convenience).
	TE18_CA01_NFRQ02	The system should be able to handle a large volume of requests (100 requests/min) and responses in real-time (average of 10 sec response) from Retailer apps.

	TE18_CA01_NFRQ03	The system should be highly available and reliable.
	TE18_CA01_NFRQ04	The system should be secure and protect user data.
	TE18_CA01_NFRQ05	The system should be scalable to support increasing numbers of users and TSPs.
	TE18_CA01_NFRQ06	The system should be compliant with relevant standards used by the industry.
TE18_CA02	TE18_CA02_FRQ01	The system must be able to get trip offers from a distributers OSDM services.
	TE18_CA02_FRQ02	The system must be able to combine intermodal offers from different distributors.
	TE18_CA02_FRQ03	Thes system should be able to provide offers based on an itinerary or optionally create the trip itinerary and offer.
	TE18_CA02_FRQ04	The system should be able to pre-book a trip offer.
	TE18_CA02_NFRQ01	The system should be able to handle a large volume of requests (100 requests/min) and responses in real-time (average of 10 sec response) from Retailer apps.
	TE18_CA02_NFRQ02	The system should be highly available and reliable.
TE18_CA03	TE18_CA03_FRQ01	The system should be able to pre-book a trip offer.
	TE18_CA03_FRQ02	The system must be able to book a trip offer, providing a fulfilment document.
	TE18_CA03_NFRQ01	The system should be secure and protect user data.
	TE18_CA03_NFRQ02	The system should be compliant with relevant industry interfaces (OSDM).
TE18_CA04	TE18_CA04_FRQ01	The system must provide TSPs with access to the statistics portal, displaying demand forecast data related to trip requests and related statistics.
	TE18_CA04_FRQ02	The system should provide individual access per TSP to the portal, data of each TSP should be shared with other TSPs.
	TE18_CA04_FRQ03	The system may allow users to be configured with access and rights to certain aspects of the Statistics UI and/or data.
	TE18_CA04_NFRQ01	The system should be secure and protect user data.
TE18_CA05	TE18_CA05_FRQ01	The system should provide historic multimodal demand data visualization, including information on transport modes, modal split, occupancy for selected time windows, and transport lines.
	TE18_CA05_FRQ02	The system may provide accurate and reliable data on passenger count information.
	TE18_CA05_FRQ03	The system must provide information on the number of itinerary requests to each provider.
	TE18_CA05_FRQ04	The system may provide utilization patterns, including the frequency of requests on different segments/lines.
	TE18_CA05_NFRQ01	The system should have a user-friendly interface for data visualization and analysis.
TE18_CA06	TE18_CA06_FRQ01	The system should provide a visualization of forecasts in a dashboard, some visualizations can be map-based, or just statistics charts representing multimodal demand data.
	TE18_CA06_FRQ02	The system should be able to display forecasts for different

		time horizons, such as daily, weekly, or monthly.
	TE18_CA06_FRQ03	The system should be able to provide forecasts for different modes of transportation, (e.g. rail, buses or other modes).
	TE18_CA06_NFRQ01	The system should have a user-friendly interface for data visualization and analysis.
TE18_CA07	TE18_CA07_FRQ01	The System should provide fare revenue apportionment processing across multiple mobility modes including train and allow the configuration of business participants.
	TE18_CA07_FRQ02	The System should apportion pre-paid fare associated with multimodal mobility offers forwarded by retailers /distributors.
	TE18_CA07_FRQ03	The System should apportion the fare collected in pay-as-you-go mode within the context of multimodal journeys where the travel cost is charged on a mobility account owned by the Traveler.
	TE18_CA07_FRQ04	The System should allow the configuration of business rules supporting revenue apportionment.
	TE18_CA07_FRQ05	The System should include auditing capabilities.
	TE18_CA07_FRQ06	The System shall offer to TSPs an access to financial processing results including the attributed revenue.
	TE18_CA07_FRQ07	The System should generate settlement records and make them available to a distributed ledger an instantiation of which should be provided.
	TE18_CA07_NFRQ01	The System should be compatible with the deployment on public cloud.
	TE18_CA07_NFRQ02	The System should process the financial flows in near real time and make outputs available at the portal.
	TE18_CA07_NFRQ03	The System should include an operation web portal
TE18_CA08	TE18_CA08_FRQ01	The system must be able to send disruption information to other platforms via SIRI SX standard.
	TE18_CA08_NFRQ01	The system must be able of ensure that the information sent is in a consistent format and ready to be received by platforms or directly by travellers.
TE18_CA09	TE18_CA09_FRQ01	The system must provide users up-to-the-minute travel recommendations, including route suggestions and estimated travel times, based on the combination of available modes of transportation.
	TE18_CA09_NFRQ01	The system must integrate data from various municipal transportation sources.
	TE18_CA09_NFRQ02	The system updates data from various municipal transportation sources once a day.
	TE18_CA09_NFRQ03	The system should be available for user on different devices (should be responsive).
TE18_CA10	TE18_CA10_FRQ01	The system should allow users to simultaneously consider various variants of travel plan.
	TE18_CA10_NFRQ01	Alternative variants of travel plan should take into account various municipal modes of transportation.
TE18_CA11	TE18_CA11_FRQ01	The system must provide accurate information regarding travel time.
	TE18_CA11_NFRQ01	Travel time should be counted based on timetables.

Table 5: Requirements of TE18 capabilities

7.1.2 Technical Enabler 19 - Develop standardized interfaces

- TE19_CA01: Standardized interface for Distribution of itineraries.
- TE19_CA02: Standardized interface for Distribution of tickets.
- TE19_CA03: Standardized interface for Fare Transactions.
- TE19_CA04: Standardized interface for disruption messages.
- TE19_CA05: Collect timetables and other relevant datasets.
- TE19_CA06: Allow other transportation providers to update their timetables.
- TE19_CA07: Use of comprehensive dataset.

Capability ID	Requirement ID	Requirement description
TE19_CA01	TE19_CA01_FRQ01	The API Interface to provide itineraries to other platforms must be compatible with the OJP standard.
	TE19_CA01_FRQ02	The Interface to request itineraries to other platforms must be compatible with the OJP standard.
	TE19_CA01_FRQ03	The system must be able to calculate intermodal itineraries with transportation offers provided outside of his transportation domain.
	TE19_CA01_FRQ04	The interface with other platforms should include itineraries with DRT offers.
	TE19_CA01_NFRQ01	The system should be able to handle a large volume of requests (100 requests/min) and responses in real-time (average of 10 sec response) from other platforms.
TE19_CA02	TE19_CA02_FRQ01	The system must be able to distribute tickets between platforms from other TSPs.
	TE19_CA02_FRQ02	The system must allow the users to buy tickets from other systems.
	TE19_CA02_NFRQ01	The system should offer an API that other platforms can integrate with and enable seamless ticket exchange by having the ability to send and receive data.
	TE19_CA02_NFRQ02	The system should facilitate real-time ticket exchange. The response time should not exceed 5 seconds for 95% of the requests.
	TE19_CA02_NFRQ03	The system must follow OSDM specification interface.
TE19_CA03	TE19_CA03_NFRQ01	The System should be able to process CEN NeTEx part 3, Public transport fares exchange format Sales transactions as an external input for multimodal fare revenue processing. NeTEX is not used for distribution.
TE19_CA04	TE19_CA04_FRQ01	The system must provide disruption messages by using a standardized interface (SIRI SX).
	TE19_CA04_NFRQ01	The disruption message should include the involved assets and/or vehicles, the time of disruption occurrence and advices/suggestions for travellers (if any).
	TE19_CA04_NFRQ02	The disruption messages may also include the reasoning for the disruption.
TE19_CA05	TE19_CA05_FRQ01	The system must be capable of collecting timetables datasets from rail, metro, bus and taxi services and will enable

		collection of data in CEN/TS 16614 (NeTEx).
	TE19_CA05_NFRQ01	The system should be able to handle a volume of information without degrading its performance.
TE19_CA06	TE19_CA06_FRQ01	The system must allow timetables to be updated by other providers via the WWW/API interface using standardized data formats.
	TE19_CA06_NFRQ01	The system must be easy to use and intuitive.
TE19_CA07	TE19_CA07_FRQ01	The system must be capable of using comprehensive dataset that includes historical rail ridership data, weather conditions, special events, holidays, and other relevant factors.
	TE19_CA07_FRQ02	The system should generate detailed reports about data set state and timeliness.
	TE19_CA07_NFRQ01	The system must have the ability to update datasets in real time.

Table 6: Requirements of TE19 capabilities

7.1.3 Technical Enabler 20 - Travel assistance across modes

- TE20_CA01: Indoor guidance.
- TE20_CA02: Seamless validation and ticketing.

Capability ID	Requirement ID	Requirement description
TE20_CA01	TE20_CA01_FRQ01	The system should provide accurate indoor maps of stations to facilitate navigation for passengers.
	TE20_CA01_FRQ02	The system should facilitate the guidance for PRM and travellers with disabilities.
	TE20_CA01_FRQ03	The system must provide accessible information related to breakdowns in the station, accessible routes and other types of useful information.
	TE20_CA01_FRQ04	The system must provide guidance in platforms.
	TE20_CA01_NFRQ01	The system should offer precise indoor mapping to ensure reliable navigation guidance.
	TE20_CA01_NFRQ02	The system should offer easily accessible, practical and adaptable information for different needs.
	TE20_CA01_NFRQ03	The system should offer easily accessible, practical and adaptable information for persons with some disabilities in platforms.
TE20_CA02	TE20_CA02_FRQ01	The system must allow the passengers to validate their tickets in a contactless way and therefore saving time.
	TE20_CA02_FRQ02	The system should be compatible across different transportation modes.
	TE20_CA02_FRQ03	The system should allow passengers to travel without buying tickets before travelling.
	TE20_CA02_FRQ04	The system should be able to calculate the final fare for the passenger.
	TE20_CA02_NFRQ01	The system should offer fast, efficient and scalable validation processes to prevent bottlenecks.
	TE20_CA02_NFRQ02	The system should be able to associate the fare per journey to

		the account of the user.

Table 7: Requirements of TE20 capabilities

7.1.4 Technical Enabler 21 - Hands-free solutions & smart information

- TE21_CA01: Hands Free Interaction.
- TE21_CA02: Automatic Access.
- TE21_CA03: Mobile Application.

Capability id	Requirement id	Requirement description
TE21_CA01	TE21_CA01_FRQ01	The system should offer to the traveller a hands-free interaction experience within mobility hubs. This interaction should be enabled by dedicated sensors.
	TE21_CA01_FRQ02	The system should enable real time data transfer between traveller, sensors, processing units and devices located in mobility hubs.
	TE21_CA01_NFRQ01	The system should include UWB (ultra-wideband) positioning technology and come with associated devices (anchors and tags).
	TE21_CA01_NFRQ02	The system should not consume excessive energy, therefore it should include BLE (Bluetooth Low Energy).
	TE21_CA01_NFRQ03	The system should include facial recognition as interaction mechanism with barriers/gates.
	TE21_CA01_NFRQ04	The system should be easily deployable in existing multimodal hubs and especially require limited civil work.
TE21_CA02	TE21_CA02_FRQ01	The system should allow Hands-free transfers at multimodal hubs.
	TE21_CA02_FRQ02	The system shall allow the automatic opening of access gates without explicit gesture or interaction.
	TE21_CA02_FRQ03	The system should allow the verification of passenger rights at transfer time.
	TE21_CA02_FRQ04	The system should allow the management of dedicated transfer lanes for registered travelers.
	TE21_CA02_FRQ05	The system should manage passenger in door positioning in real time.
	TE21_CA02_NFRQ01	The system should include guidance mechanisms including sounds and lights.
TE21_CA03	TE21_CA03_FRQ01	The mobile application should display the ticket and the validation of it.
	TE21_CA03_FRQ02	The mobile application should be able to locate the traveller geographically.
	TE21_CA03_FRQ03	The mobile application should provide soft real-time updates on the users location inside station.
	TE21_CA03_FRQ04	The mobile application should display the path to reach a specific destination inside a station.
	TE21_CA03_NFRQ01	The mobile application must be intuitive, allowing users to

		easily navigate and explore different itineraries.
	TE21_CA03_NFRQ02	The mobile application must allow users to tailor itineraries.

Table 8: Requirements of TE21 capabilities

7.1.5 Technical Enabler 22 - Platform based guidance

- TE22_CA01: Accessible platforms information system.
- TE22_CA02: Physical system for user experience.
- TE22_CA03: Signalling system for user experience.
- TE22_CA04: Customer information system for traveller guidance.

Capability ID	Requirement ID	Requirement description
TE22_CA01	TE22_CA01_FRQ01	The system must be able to use geolocated information.
	TE22_CA01_NFRQ01	The system must use a standardized and easily understandable language or signage.
	TE22_CA01_NFRQ02	The system must comply with current standards and should be able to adapt to new ones that could emerge.
	TE22_CA01_NFRQ03	The system should be able to connect with different devices.
	TE22_CA01_NFRQ04	The system should be scalable to support increasing numbers of users with requests and responses in soft real-time with a cadence of 60 seconds.
TE22_CA02	TE22_CA02_FRQ01	The system will include physical elements in order to increase the safety of the travellers.
	TE22_CA02_NFRQ01	The system must improve the connection between platform and rolling stock.
TE22_CA03	TE22_CA03_FRQ01	In station displays should be able to show tailored transfer information upon the detection of a given passenger.
	TE22_CA03_NFRQ01	The system must show important information by gobos at certain places for the traveller.
TE22_CA04	TE22_CA04_FRQ01	The system must be able to display relevant data using different display patterns.
	TE22_CA04_FRQ02	The system should be integrated in the platform surface for a hight visibility and attention.
	TE22_CA04_FRQ03	The system must be supplied with incoming train information data.
	TE22_CA04_FRQ04	The system must be able to process the incoming train information data (open data interface).
	TE22_CA04_NFRQ01	The system must use intuitively understandable display patterns.
	TE22_CA04_NFRQ02	The system must process and display the data quickly.
	TE22_CA04_NFRQ03	The system must have high availability and durability.

Table 9: Requirements of TE22 capabilities

7.1.6 Technical Enabler 23 - Short term demand forecast

- TE23_CA01: Data-Driven modelling.
- TE23_CA02: Predictive model for short-term rail demand.

- TE23_CA03: Effective user interface/dashboard to optimize transport operation.
- TE23_CA04: Forecast vehicles occupancy.
- TE23_CA05: Calculate Overcrowding Situations based on Occupancy Forecast Data.

Capability id	Requirement id	Requirement description
TE23_CA01	TE23_CA01_FRQ01	The system must be capable of collecting scheduled and soft real-time transportation datasets with a cadence of 60 seconds from transport service providers (TSP) and rail administrators.
	TE23_CA01_FRQ02	The system should be capable of collecting scheduled and soft real-time transportation datasets from Service Providers (SP) of other transport modes with a cadence of 60 seconds.
	TE23_CA01_FRQ03	The system should be capable of collecting relevant information of weather forecast and scheduled special events.
	TE23_CA01_NFRQ01	The system must be able of ensure that the input data is in a consistent format and ready for analysis. The model must be data-driven and created in such a way that errors, inconsistencies, and inaccuracies in the input datasets must be identified and corrected. The datasets must be cleaned to remove duplicates, handle missing values, and correct errors.
TE23_CA02	TE23_CA02_FRQ01	The system must be capable of extracting valuable insights, patterns, and knowledge from large datasets.
	TE23_CA02_FRQ02	The model must be able to predict short-term demand offering a forecast that can be periodically updated.
	TE23_CA02_FRQ03	The predictive model must achieve 80% precision in the forecast at 1 hour.
	TE23_CA02_FRQ04	The system should be capable of displaying the model evaluation metrics, demonstrating the precision achieved. Assess the short-term predictive model performance using the testing dataset.
	TE23_CA02_NFRQ01	The system should be able to handle a large volume of information without degrading its performance.
	TE23_CA02_NFRQ02	The system must ensure security and safeguard both the input and output datasets of the model. It should guarantee that these datasets are handled and stored in compliance with privacy and regulatory standards.
TE23_CA03	TE23_CA03_FRQ01	The system must be able of translate complex data into useful information, and display graphics visualizations and descriptive statistics to help to understand the relationships between different input variables and their impact on transport demand.
	TE23_CA03_FRQ02	Dashboards must be intuitive and self-explanatory, allowing operators/users to interact with them easily, providing ways to filter the data presented.
	TE23_CA03_NFRQ01	Dashboards must deliver the information/warnings in a timely manner to optimize the operation of the transportation network and support informed decision-making.

TE23_CA04	TE23_CA04_FRQ01	The system must be able to gather data relevant for occupancy forecast: • Journey planning requests • Vehicle occupancy sensor data (optional)
	TE23_CA04_FRQ02	The system must be able to process the data and update the occupancy model considering historic data.
	TE23_CA04_FRQ03	The system must be able to inform the MaaS platform (TE18) about the new occupancy model.
	TE23_CA04_FRQ04	The system must be able to present route occupancy levels to the traveller.
	TE23_CA04_NFRQ01	The system must be able process the collected data in reasonable time.
	TE23_CA04_NFRQ02	The system should keep the occupancy model as updated as possible.
TE23_CA05	TE23_CA05_FRQ01	The system must be able to calculate occupancy forecast updates.
	TE23_CA05_FRQ02	The system must be able to compare the occupancy forecast with configured thresholds, triggering events.
	TE23_CA05_NFRQ01	The occupancy forecast updated should be executed regularly.

Table 10: Requirements of TE23 capabilities

7.1.7 Technical Enabler 24 - Long-term demand forecast

- TE24_CA01: Data-Driven modelling.
- TE24_CA02: Predictive model for long-term rail demand.
- TE24_CA03: Effective user interface/dashboard to optimize transport operation.
- TE24_CA04: Provide analysis of demand data.

Capability id	Requirement id	Requirement description
TE24_CA01	TE24_CA01_FRQ01	The system must be capable of collecting scheduled and soft real-time transportation datasets from transport service providers (TSP) and rail administrators with a cadence of 60 seconds.
	TE24_CA01_FRQ02	The system should be capable of collecting scheduled and soft real-time transportation datasets from Service Providers (SP) of other transport modes with a cadence of 60 seconds.
	TE24_CA01_FRQ03	The system should be capable of collecting relevant information of weather forecast and scheduled special events.
	TE24_CA01_NFRQ01	The system must be able of ensure that the input data is in a consistent format and ready for analysis. The model must be data-driven and created in such a way that errors, inconsistencies, and inaccuracies in the input datasets must be identified and corrected. The datasets must be cleaned to remove duplicates, handle missing values, and correct errors.
TE24_CA02	TE24_CA02_FRQ01	The system must be capable of extracting valuable insights, patterns, and knowledge from large datasets.
	TE24_CA02_FRQ02	The model must be able to predict long-term demand offering a forecast that can be periodically updated.
	TE24_CA02_FRQ03	The predictive model must achieve 65% precision in the

		average forecast 1 week in advance.
	TE24_CA02_FRQ04	The system should be capable of displaying the model evaluation metrics, demonstrating the precision achieved. Assess the long-term predictive model performance using the testing dataset.
	TE24_CA02_NFRQ01	The system should be able to handle a large volume of information without degrading its performance.
	TE24_CA02_NFRQ02	The system must ensure security and safeguard both the input and output datasets of the model. It should guarantee that these datasets are handled and stored in compliance with privacy and regulatory standards.
TE24_CA03	TE24_CA03_FRQ01	The system must be able of translate complex data into useful information, and display graphics visualizations and descriptive statistics to help to understand the relationships between different input variables and their impact on transport demand.
	TE24_CA03_FRQ02	Dashboards must be intuitive and self-explanatory, allowing operators/users to interact with them easily.
	TE24_CA03_NFRQ01	Dashboards must deliver the information/warnings in a timely manner to optimize the operation of the transportation network and support informed decision-making.
TE24_CA04	TE24_CA04_FRQ01	The system must be able to collect occupancy data to be analysed.
	TE24_CA04_FRQ02	The system must be able to present a visualization of the traveller's demand analysis.
	TE24_CA04_FRQ03	The system should be able to detect patterns and trends.
	TE24_CA04_NFRQ01	The system should present the data in an intuitive way to be analysed.

Table 11: Requirements of TE24 capabilities

7.1.8 Technical Enabler 25 - Integrate demand forecast into digital twin

- TE25_CA01: Simulate macroscopic passenger flows.
- TE25_CA02: Simulate microscopic passenger flows.
- TE25_CA03: Test incident mitigation scenarios.

Capability ID	Requirement ID	Requirement description
TE25_CA01	TE25_CA01_FRQ01	The system must simulate macroscopic flows of passengers across the different transport systems according to passenger long term demand and planned offer.
	TE25_CA01_FRQ02	The system must provide the OCC Operator with passenger KPIs that are useful for analysing the impacts and contributing to the optimisation of the offer.
	TE25_CA01_FRQ03	The system must retrieve information about planned offer (i.e. vehicle timetables) in a GTFS format, from TSPs.
TE25_CA02	TE25_CA02_FRQ01	The system must simulate microscopic flows of passengers across the different transport systems according to passenger

		short term demand and current offer forecast.
	TE25_CA02_FRQ02	The system must include passenger exchange time models.
	TE25_CA02_FRQ03	The system must include crowd flow models.
	TE25_CA02_FRQ04	The system must include passenger behaviour models in case of incident.
	TE25_CA02_FRQ05	The system must provide the OCC Operator with passenger KPIs modelling exchange time and crowd flow.
	TE25_CA02_FRQ06	The system must retrieve information about the movements of vehicles throughout the day, including past, present, and future schedules, from TSPs.
	TE25_CA02_FRQ07	The system must retrieve incident information from TSPs.
	TE25_CA02_FRQ08	The system may acquire data relating to weather conditions recorded by weather stations.
TE25_CA03	TE25_CA03_FRQ01	The system must provide the OCC Operator with a digital twin acting as a sandbox where he can simulate different scenarios and assess the impact of potential changes or improvements.
	TE25_CA03_FRQ02	The system must provide the OCC Operator with passenger KPIs (modelling exchange time and crowd flow) taking into account assessed scenarios.

Table 12: Requirements of TE25 capabilities

7.1.9 Technical Enabler 26 - Optimize rail capacity to better match the demand

- TE26_CA01: Enhance multi-modal connections.
- TE26_CA02: Reinforce railway network timetable stability.
- TE26_CA03: Support timetabling decisions.

Capability id	Requirement id	Requirement description
TE26_CA01	TE26_CA01_FRQ01	The system should show the multimodal routes.
	TE26_CA01_FRQ02	The system should provide optimal connection times to allow multimodal journeys.
	TE26_CA01_NFRQ01	The system should handle a large volume of connections without degrading its performance.
TE26_CA02	TE26_CA02_FRQ01	The Railway Timetable Database must acquire current timetable, historical punctuality data and optimized timetable.
	TE26_CA02_FRQ02	The system must be able to evaluate ex-ante timetable punctuality.
	TE26_CA02_FRQ03	The system must be able to optimize a given timetable on the basis of MCT.
	TE26_CA02_FRQ04	The system should have a dashboard to allow the TSP to visualize optimization results.
	TE26_CA02_NFRQ01	The railway infrastructure constraints must be met during the optimization phase.
	TE26_CA02_NFRQ02	The system must be highly reliable in order to ensure accurate punctuality performance estimates.
	TE26_CA02_NFRQ03	The Railway Timetable Database must be easily available,

		accessible and it should enable scalable data management.
	TE26_CA02_NFRQ04	The HMI should be intuitive and user-friendly to enhance decision-making.
TE26_CA03	TE26_CA03_FRQ01	The system should be able to support timetabling decisions with visualisation of present disturbances in the municipality.
	TE26_CA03_FRQ02	The system should be able to estimate severity of present disturbances in the municipality.
	TE26_CA03_NFRQ01	The system database on which system operates should be accessible (for data inclusion) through well documented robust API

Table 13: Requirements of TE26 capabilities

7.1.10 Technical Enabler 27 - Manage/inform disruption across modes

- TE27_CA01: Broadcast disruption events (TSPs).
- TE27_CA02: Support operators to face disruption.
- TE27_CA03: Exchange and report disturbances between disparate operators of multimodal transport.
- TE27_CA04: Generate information about possibility of disturbances.
- TE27_CA05: Calculate impact on trips based on high occupancy levels.
- TE27_CA06: Overcrowded alerts distributions to impacted travellers.
- TE27_CA07: Provide alternative routes to avoid overcrowded route.

Capability id	Requirement id	Requirement description
TE27_CA01	TE27_CA01_FRQ01	The system should be able to broadcast disruption events to TSPs via a B2B service.
	TE27_CA01_NFRQ01	The system should be highly available and reliable to ensure timely and accurate information to all stakeholders.
	TE27_CA01_NFRQ02	The system should be able to provide soft real-time information, characterized by a maximum latency of 10 seconds between message receipt and display in HMI, to ensure that all stakeholders can make timely decisions.
	TE27_CA01_NFRQ03	The system should be designed to be compliant, when it will become a commercial product, with the standard ISO, "*Ergonomics of human-system interaction - Part 125: Guidance on visual presentation of information*", ISO 9241-125:2017.
TE27_CA02	TE27_CA02_FRQ01	The system should provide the operators a clear understanding of the disruption events.
	TE27_CA02_FRQ02	The system must acquire input data related to passenger flow.
	TE27_CA02_FRQ03	The system must acquire input data related to disruptions.
	TE27_CA02_FRQ04	The system must provide the operators possible solutions to deal with disruption events.
	TE27_CA02_NFRQ01	The system should provide an expiration time for each solution proposed to the operators.
	TE27_CA02_NFRQ02	The dashboard should be intuitive and user-friendly to

		enhance decision-making.
TE27_CA03	TE27_CA03_FRQ01	The system must be able to represent disparate disturbance sources with their geographical location, severity and temporal parameters.
	TE27_CA03_FRQ02	The system should validate reported disturbances.
	TE27_CA03_NFRQ01	The system should be highly available and reliable to ensure timely and accurate information to all stakeholders.
TE27_CA04	TE27_CA04_FRQ01	The system should generate information of probability for disturbances of departures and arrivals.
	TE27_CA04_NFRQ01	The system must be capable of using comprehensive dataset that includes historical rail ridership data, weather conditions, special events, holidays, and other relevant factors for disturbances predictions of departures and arrivals.
	TE27_CA04_NFRQ02	The functionality will be available by 90% of system operating time.
TE27_CA05	TE27_CA05_FRQ01	The system must be able to receive occupancy forecast alerts.
	TE27_CA05_FRQ02	The system must be able to calculate the planned trips that are impacted by an overcrowding alert.
	TE27_CA05_NFRQ01	The system should be able to calculate the impacted trips in a short amount of time.
TE27_CA06	TE27_CA06_FRQ01	The system must be able to distribute alert messages to the traveller through a digital channel.
	TE27_CA06_FRQ02	The system must be able to target the travellers impacted by the alert.
	TE27_CA06_NFRQ01	The system should be able to distribute large volumes of alerts.
TE27_CA07	TE27_CA07_FRQ01	The system must be able to provide the traveller with the option to request alternative routes when receiving an overcrowd alert.
	TE27_CA07_FRQ02	The system must request alternative routes to the MaaS platform (TE18).
	TE27_CA07_NFRQ01	The system should be able display the alternative option in an intuitive way.

Table 14: Requirements of TE27 capabilities

8. Logical Architecture

This section focuses on the description of **"**How the system will work to meet expectations"**.** Logical analysis has been performed through the design of Logical Architecture diagrams (divided by development WPs), the description of components and functions (and links with requirements), the presentation of sequence diagrams and the reference to interfaces and standards.

8.1 High Level Architecture

Due to the large number of components and functions on each development WP, it was decided to create several architectures divided by clusters of functionalities.

- WP20 – Development: Integrate Rail with other transport modes.
    - Rail Disruption management information exchange.

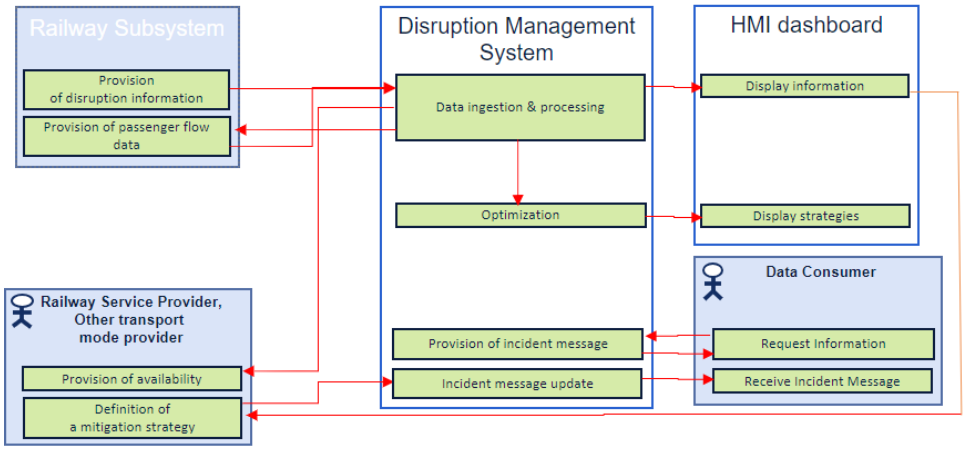

Figure 6: Logical Architecture for Rail Disruption Management information exchange

Rail disruption management is encompassing the actors Rail Service Provider, other transport mode provider, and the Data Consumer. The involved components are the Disruption Management System and the HMI dashboard. Furthermore, Railway Subsystems participate as external components. The Disruption Management System is used by the Railway Subsystem for provisioning disruption information and passenger flow data. The Railway Service Provider uses the Disruption Management System to provision availability and to define mitigation strategies while the Railway Service Provider inspects the HMI dashboard for information from the Disruption Management system. The Data Consumer uses the Disruption Management System to request incident information and incident information updates.

- Journey Planning and Booking.

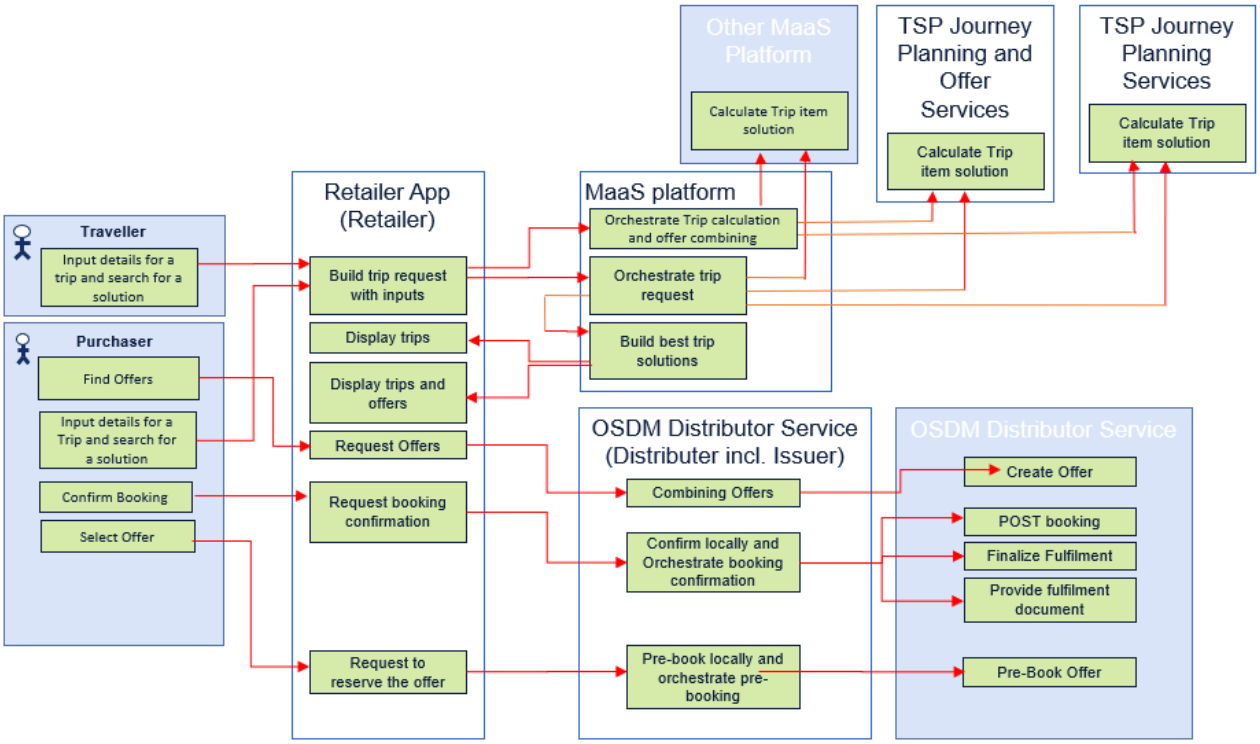

Figure 7: Logical Architecture for Journey Planning and Booking

Travellers can plan Journeys while Purchasers can find offers and book them via the Retailer App. The Retailer App uses the MaaS Platform to request Trip solutions for the Journey Planning requests. The MaaS Platform uses other MaaS Platforms, Journey Planning Services, and Journey Planning and Offer Services for this task, aggregates the results and provides them to the Retailer App again. For booking offers, the Purchaser requests offers and provides additional information to the Retailer App which forwards the request to the OSDM Distributor Service. The OSDM Distributor Service (playing the Distributer and Issuer role) applies necessary booking steps locally while also requesting other OSDM Distributor Services from other parties involved in the offer to apply them as well.

- Visualization of mobility demand.

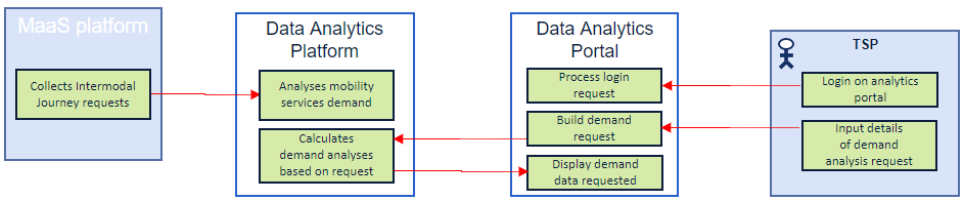

Figure 8: Logical Architecture for the visualisation of mobility demand

Transport Service Providers (TSP) use the Data Analytics Portal to access and request details of demands. The Data Analytics Portal provides authentication and authorization functionality for the TSP as well as the user interface to the Data Analytics Platform. The Data Analytics Platform receives the Journey Planning requests from the MaaS Platform and analyses them to calculate the demand based on the request from the Data Analytics Portal.

- Financial Services.

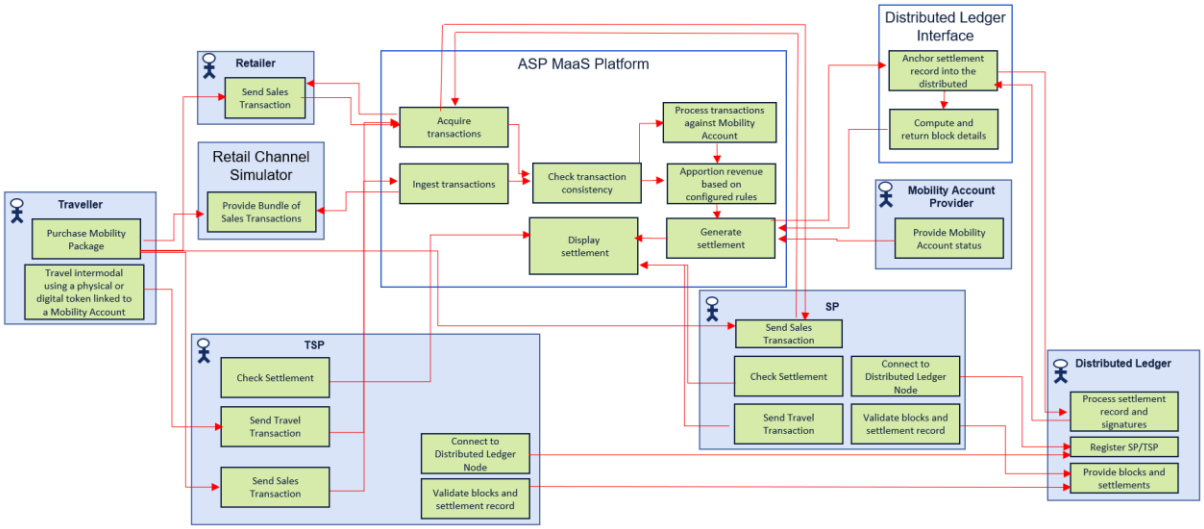

Figure 9: Logical Architecture for Financial Services

Financial Services involve sales transactions from Retailers, Travellers via Retail Channel Simulators, TSP, or Service Providers (SP). Travellers may also use the TSP for physical and digital tokens linked to a Mobile Account. In the heart of the financial services is the ASP MaaS Platform which provides functions to the Retailer, Retail Channel Simulator, TSP, SP, and Mobility Account Provider to process, acquire, check, and display transactions. Additionally, it provides functionalities to generate and display settlements and to apportion revenues. While generating settlements, the ASP MaaS Platform uses the Distributed Ledger Interface which translates communicates with the Distributed Ledger. The Mobility Account Provider provides account status to the ASP MaaS Platform. The TSP and SP connect to the Distributed Ledger to validate blocks and settlement records. They also check settlements at the ASP MaaS Platform.

- Unified Multimodal Information.

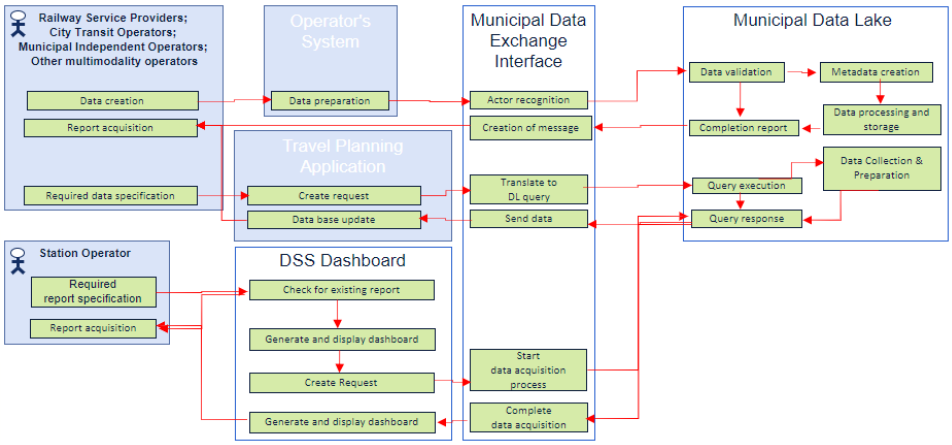

Figure 10: Logical Architecture for Unified Multimodal Information

The Municipal Data Exchange Interface provides functions to the Railway Service Providers, City Transit Operators, Municipal Independent Operators, and other multimodality operators to access

and use the Municipal data uniformly via the operators System or the Travel Planning Application. Station Operators access the DSS Dashboard to request reports according to the unified multimodal information via the Municipal Data Exchange Interface from the Municipal Data Lake. The Municipal Data Lake collects, validates, and prepares data, creates Metadata and enables queries on the data to create reports.

- WP22 – Development: Services for inclusive rail-based mobility.
    - Assistance and improvement of the user experience.

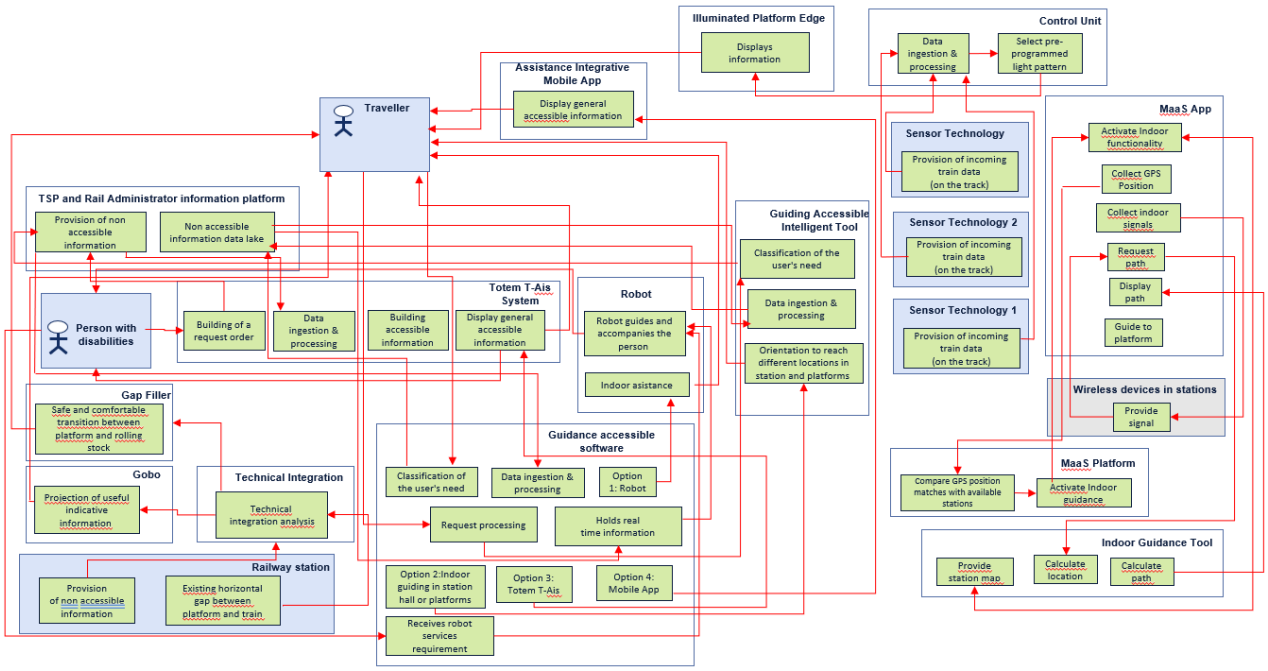

Figure 11: Logical Architecture for Assistance and improvement of the user experience

The enhancement and optimisation of user experience encompass various components aimed at improving the travel experience for individuals, whether they have disabilities or not. This process starts with the search and provision of an itinerary through the MaaS App, in collaboration with the MaaS Platform and the Indoor Guidance Tool, extending all the way until the traveller reaches a station.

Within the station premises, travellers are provided with comprehensive assistance, facilitated by systems like the Totem T-Ais System or a guiding Robot, which directs them through the station. These systems work in conjunction with other tools such as the Guiding Accessible Intelligent Tool and Software. Information regarding non-accessible facilities for travellers with disabilities, such as elevators or accessible areas of the station, is available through the Railway station, the TSP, and the Rail Administrator information platform. Other accessibility solutions like Gobo´s projections to indicate the accessible car and Gap Filler between the platform and the train will be implemented.

To further aid travellers, an Assistance Integrative Mobile App is at their disposal, offering guidance throughout the station.

Moreover, travellers are kept informed about the incoming train through information displayed on the platform. Sensors relay data to the Control Unit, responsible for transmitting light patterns to the Illuminated Platform Edge. These patterns convey vital information about the approaching

train, including its passenger capacity, identifying danger zones in the absence of a train on the platform, and indicating the stopping position for the train.

- Ticketing.

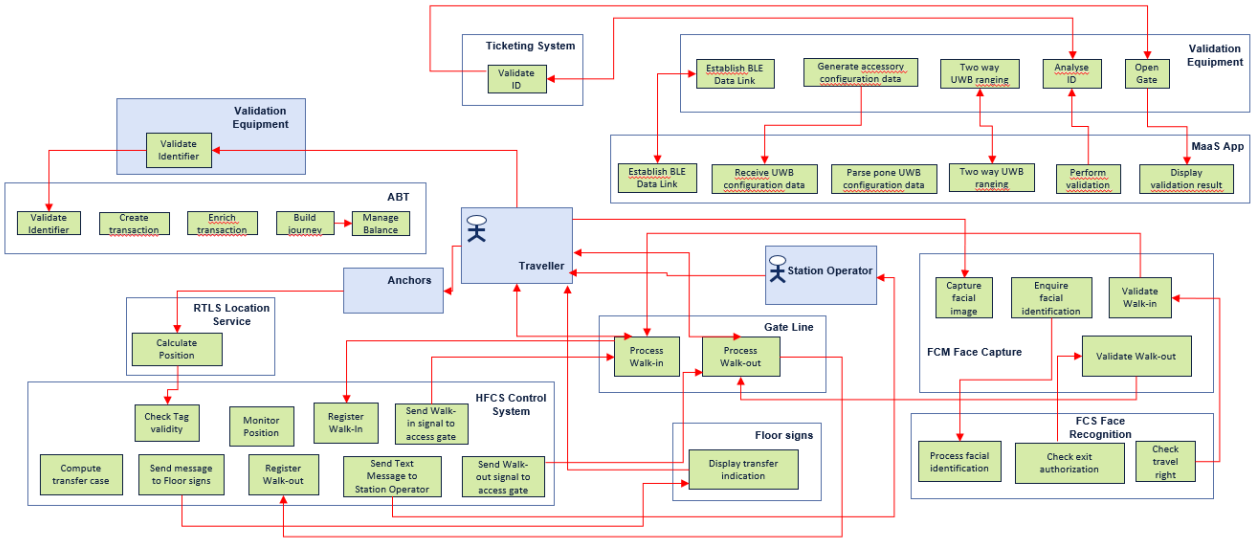

Figure 12: Logical Architecture for Ticketing

Ticketing enhancement can be divided into two main sections. The first section focuses on enabling the seamless entry and exit of travellers at stations or mobility hubs, while the second section concentrates on calculating the fare once the journey concludes.
On one hand, travellers can effortlessly pass through the gates thanks to the station's Validation Equipment. This equipment validates tickets either by receiving a token (UWB Wearable Tag) from the traveller or by communicating with the MaaS App. Utilising Anchors in conjunction with the RTLS Location Service allows precise traveller location within the Gate Line. The HFCS Control System verifies the tag's validity and monitors the traveller's movement toward the Gate Line until they enter the station. This process involves illuminating Floor Signs with appropriate messages to guide the traveller and communicating with the Station Operator. Additionally, registered passengers can access restricted areas of a mobility hub through facial recognition. In such cases, FCS Face Capture communicates with FCS Face Recognition to capture and validate the facial image for authorisation.
Furthermore, if the MaaS App communicates with the validation equipment, via BLE and UWB the traveller's location is determined before reaching the gate. Subsequently, the ticket ID is shared with the Ticketing System for validation, and the gates open as the traveller approaches.
On the other hand, when a traveller completes their journey, the validation equipment verifies the identifier, initiating the Account-Based Ticketing (ABT) process. This process calculates the final fare of the trip in a ticketless manner.

- WP24 – Development: Anticipate demand leading to improved resource utilisation.
  - Notice & Notification.

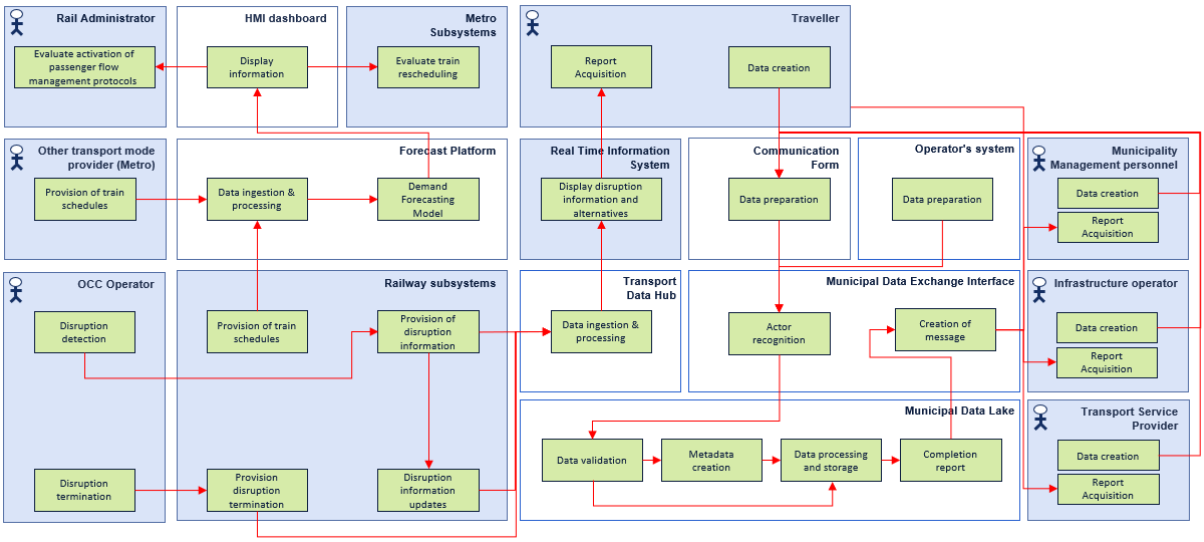

Figure 13: Logical Architecture for Notice & Notification

Railway Subsystems and other transport providers feed a Forecast Platform with their service schedules. The Forecast Platform then processes it and generates a Demand Forecast Model whose outputs are displayed in the HMI dashboard and from there, warnings are generated for the Rail Administrator and Metro Subsystems to help them evaluate train rescheduling and activate passenger flow management protocols.
OCC Operators provide information about detected disruptions in the services to the Railway Subsystems, which serve as conduits, channelling the incident data to the Transport Data Hub that transmit these incident updates to the Traveller through various Real-Time Information Systems.
The Transport Service Provider, the Infrastructure Operator, the Municipality Management Personnel or a Traveller may provide information about disturbances by filling a communication form which creates data in appropriate format. Municipal data exchange interface provides a connection layer which recognizes the actor and generates appropriate query. Municipal data lake then validates the data, stores it, and generates a report back to the user. Certain disruptions may have organizational effect, requiring an integration with Operator's Systems.

- Rail Capacity Optimization.

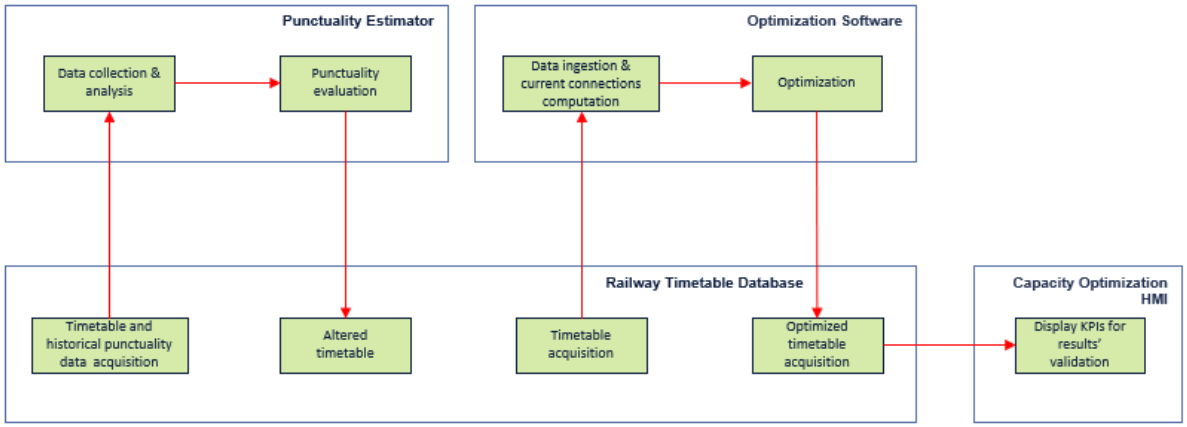

Figure 14: Logical Architecture for Rail Capacity Optimization

Rail capacity optimization it's a data driven approach that aims to maximize the performance of railway operation. Railway Timetable Database feeds the punctuality estimator and optimization software with the timetable and historical punctuality data in the first case, and only the timetable in the second. The Punctuality Estimator component performs the data collection and analysis for later undertake the punctuality evaluation that feeds the Railway Timetable Database with the altered timetable. On the other hand, the Optimization Software conducts the data ingestion and current connections computation, and then the optimization which feeds the Railway Timetable Database and finally the Capacity Optimization HMI component displays KPIs of the optimized timetable for results' validation.

- Disruption management.

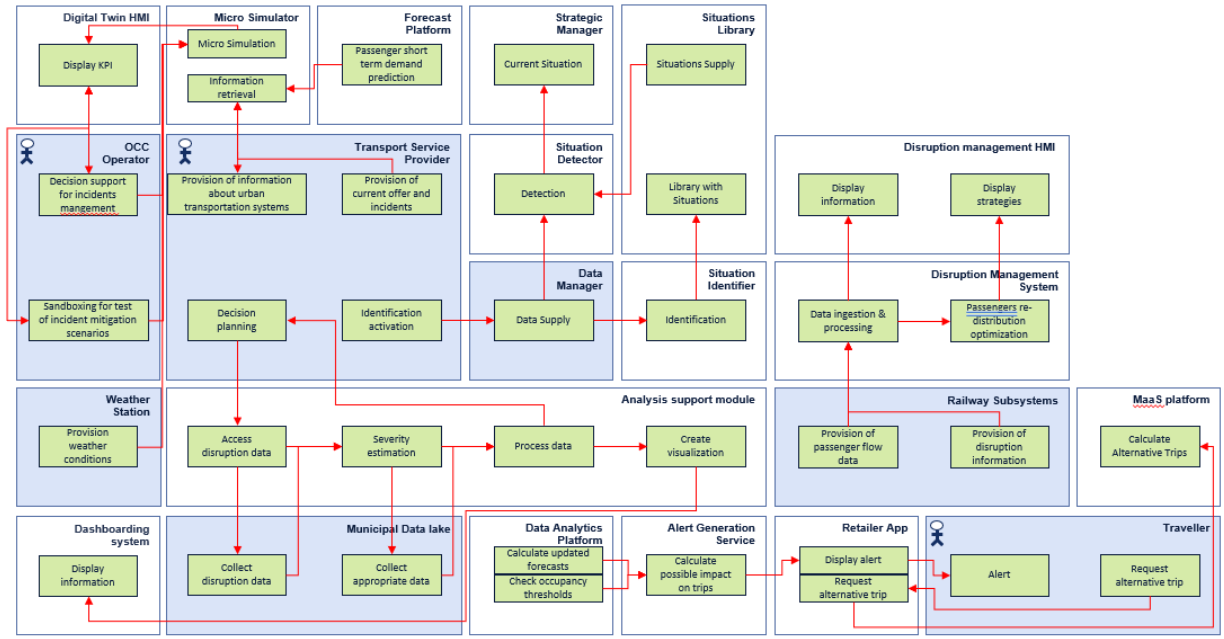

Figure 15: Logical Architecture for Disruption Management

Railway disruption management is a systematic approach to efficiently addressing and mitigating disruptions within the railway network. In these cases, the components: Transport Service Provider, OCC Operator, Traveller, Municipal Data Lake, Railway Subsystem, Data Manager or Weather Station supplies with useful input information, that can be for instance: data about urban transport systems disruption, current offer and incidents, passenger flow data, weather conditions, railway disruption information, to the components developed in the Motional Project. On one hand, the Railway Subsystems provides with passenger flow data and disruption information to the Disruption Management System which conducts the data ingestion and processing and displays the information in the Disruption Management HMI, later on this data feeds the optimization algorithms that ultimately show the multimodal mitigation strategies on the Disruption Management HMI.

On the other hand, the Data Manager supplies with theoretical/realistic timetables to the Situation Identifier which identifies the situation and later adds it to the Situations Library component. After that, both Data Manager and Situation Library feed the Situation Detector which undertakes the detection and finally informs the predicted data to the Strategic Manager.

In another case, the Transport Service Provider planning decision is supported by the Analysis Support Module which interacts with the Municipal Data Lake, that collects disruption and

weather data, in order to get the disruption information and with the TSP to obtain the planning data. The Analysis Support Module after process the information creates a visualization which is show on the Dashboarding System.
In another sequence the Micro Simulator, that feeds on the TSP, Weather Station and Forecast platform (TE23) components in order to get the information about current offer and incidents in the urban transportation systems, the weather conditions and the passenger short-term demand respectively, carries out a micro simulation process that obtain as a result the passenger flows. Then, that result provides information to the Digital twin HMI component which displays KPIs with two objectives, the first one to inform the decision making for incidents management of the OCC Operator and the second one for test of incident mitigation scenarios in a sandbox.
Finally, there is another sequence where the Data Analytics calculates the updated forecasts and checks occupancy thresholds, after sends an alert forecast to the Alert Generation Service component. That component calculates possible impact on trips and sends overcrowded route alert to the Retailer app which informs to the Traveller. In response the Traveller asks for an alternative trip to the Retailer app which, in the end, requests for intermodal trips avoiding overcrowded trips to the MaaS Platform component in order to improve the journey planning.

- Short Term Forecast.

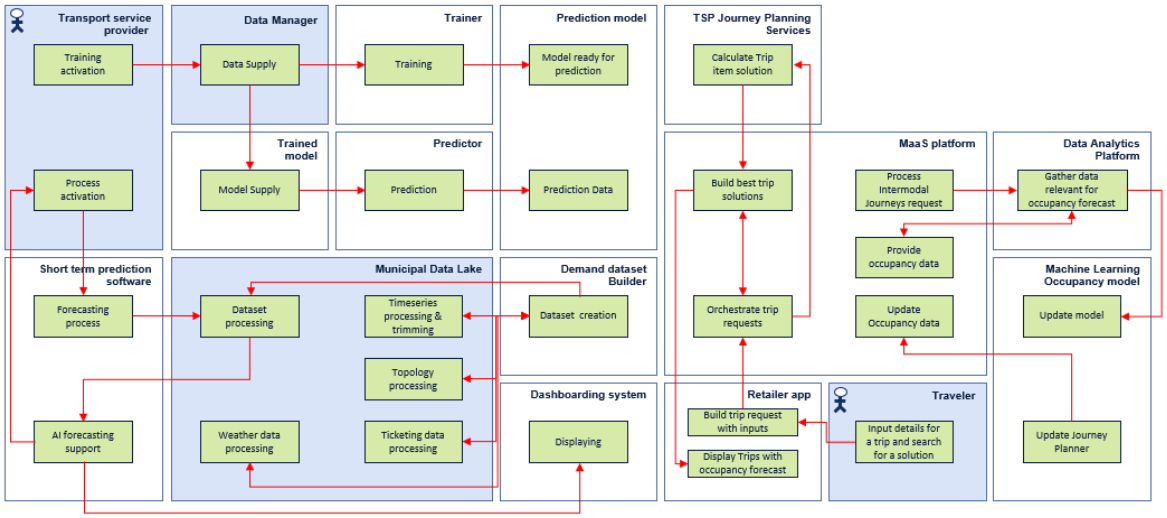

Figure 16: Logical Architecture for Short Term Forecast

The Transport Service Provider activates the training so that the Data Manager provides the available historical data that is processed by the Trainer, which by means of deep learning techniques generates a trained Prediction Model. This Trained Model is then fed with data just received in real time from the Data Manager to perform a short-term prediction and generate prediction data.
The Transport Service Provider activates a request for flow forecasting to the short-term prediction software, which connects to the Municipal Data Lake to gather a current time dataset with data from train operators as well as other sources of information, e.g., weather stations. The Demand dataset Builder is also connected to the Municipal Data Lake and builds the dataset to be used in the prediction module, taking into account interpolations over time and geographical markers. This dataset is fed to the short-term prediction software, which by means of AI forecasting techniques generates decision support information that is displayed using the

Dashboarding system.

The MaaS Platform continuously forwards the Journey Planning requests to the Data Analytics Platform which may also retrieve occupancy data from the MaaS Platform for occupancy forecasting. This gathered data is forwarded to the Machine Learning Occupancy Model which updates itself accordingly. After the update, the new model is forwarded to the MaaS Platform which then updates the occupancy data. This allows the MaaS Platform to receive requests for trips from Travellers through the Retailer app and orchestrate and build the best trip solutions for each request across itself and integrated TSP Journey Planning Services. Once obtained, the solutions are displayed back on the Retailer app.

- Long Term Forecast.

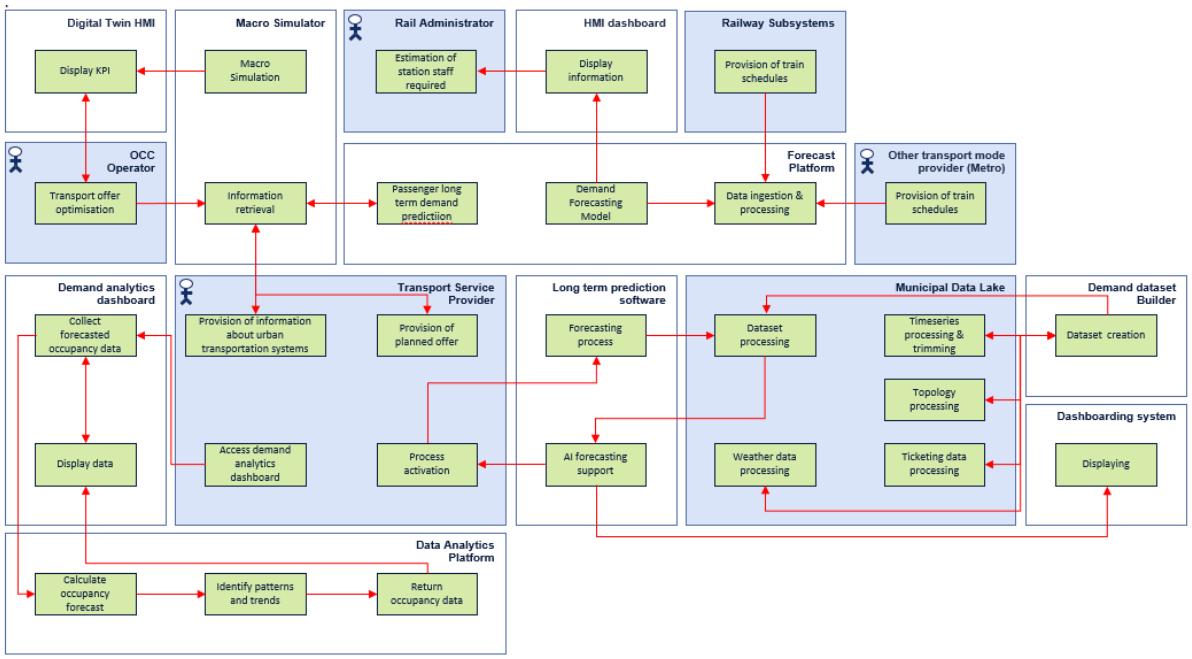

Figure 17: Logical Architecture for Long Term Forecast

Railway Subsystems and other transport providers feed a Forecast Platform with their service schedules. The Forecast Platform then processes it and generates a long term demand forecast model whose outputs are displayed in the HMI dashboard and from there, warnings are generated that help the administrator estimate the required staff.

The Transport Service Provider activates a request for flow forecasting to the long term prediction software, which connects to the Municipal Data Lake to gather a current time dataset with data from train operators as well as other sources of information, e.g., weather stations. The Demand dataset Builder is also connected to the Municipal Data Lake and builds the dataset to be used in the prediction module, taking into account interpolations over time and geographical markers. This dataset is fed to the long-term prediction software, which by means of AI forecasting techniques generates decision support information that is displayed using the Dashboarding system.

The OCC Operator may start a transport offer optimisation process retrieving information from the Digital twin HMI that receives passenger flows information and KPIs from a macro simulation performed by a Macro simulator, which in turn receives information from the Transport Service

Provider (urban transportation systems and planned offer) and from a Forecast Platform (long term demand prediction). The KPIs resulting from the simulation help the OCC operator to optimise the offer.
The Data Analyst of a TSP can access the Demand Analytics Dashboard to inspect the Demand data. The Demand Analytics Dashboard requests the intermodal Journey from the data Analytics Platform which calculates occupancy forecasts, identifies patterns and trends and ultimately returns the occupancy data to the Demand Analytics Dashboard which displays the result to the Data Analyst.

8.2 Components description

This section includes a description of all components that will be developed in MOTIONAL project WS1.3. Each component is responsible for one or more functions. Components and functions are linked with non-functional and functional requirements respectively, introduced in chapter 7. Components and functions are referred to specific enablers (based on the use cases in which they are present): requirements must belong to those enablers (even less but not more).

- ABT (Account Manager + Fare Manager + Transaction Manager)

Component Name	*Component Description*	*NFRQ ID*
ABT (TE20-21)	Fare collection system that calculates the fares that each user needs to pay for based on their journeys. It is divided in three subcomponents: transaction manager, fare manager and account manager.	- TE20_CA02_NFRQ02
Function Name	***Function Description***	***FRQ ID***
Validate Identifier (TE20-21)	The function that identifies the user based on the ID.	- TE20_CA02_FRQ04 - TE21_CA02_FRQ03
Create transaction (TE20-21)	The function that creates the transaction on the Log of the ABT.	- TE20_CA02_FRQ04
Enrich transaction (TE20-21)	The function that provides information from the ABT database to enrich the transaction created	- TE20_CA02_FRQ04
Build journey (TE20-21)	The function that builds the journey of the user based on the different	- TE20_CA02_FRQ04
Manage Balance (TE20-21)	The function that calculates the fare that needs to be paid by the user and associated with their previous transactions.	- TE20_CA02_FRQ04

Table 15: ABT component

- Alert Generation Service

Component Name	*Component Description*	*NFRQ ID*

Alert Generation Service (TE27)	The Alert Generation Service receives forecasts from the Data Analytics Platform and generates alerts for potential future incidents to the Retailer App.	- TE27_CA06_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Calculate possible impact on trips (TE27)	Analysing the forecasted information from the Data Analytics Platform, the Alert Generation Service determines the likelihood of a future incident and informs the Traveller about it by pushing an alert to the Retailer App.	- TE27_CA06_FRQ01 - TE27_CA06_FRQ02

Table 16: Alert Generation Service component

- Analysis Support Module

Component Name	***Component Description***	***NFRQ ID***
Analysis Support Module (TE26-27)	This software operates as a responsive tool, activated upon request by transport service provider planners. Leveraging disturbance data, it furnishes detailed and accurate severity estimates, which serve as invaluable aids in the meticulous preparation of timetables. This data-driven approach ensures that planners can optimize scheduling to account for disruptions, resulting in more efficient and reliable transport services.	- TE26_CA04_NFRQ01 - TE27_CA04_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Access disruption data (TE26-27)	It is a vital component of our analysis support module. It gathers pertinent data from the data lake, focusing on municipal disturbances, enabling informed decision-making.	- TE27_CA03_FRQ01 - TE27_CA03_FRQ02
Severity estimation (TE26-27)	It is a crucial component within our analysis support module. It gauges the severity of disturbances, providing valuable insights for informed decision-making in transport service provider planning activities.	- TE26_CA03_FRQ02 - TE27_CA04_FRQ01
Process data (TE26-27)	It is an essential function within our analysis support module. It handles the processing of weather data, aiding decision support for transport service provider planning activities.	- TE27_CA04_FRQ01
Create visualization (TE26-27)	is a vital function in our analysis support module. It generates compelling visual representations, empowering decision support for transport service provider planning activities with insightful data visualizations.	- TE26_CA03_FRQ01 - TE27_CA03_FRQ01 - TE27_CA03_FRQ02

Table 17: Analysis Support Module component

- ASP MaaS Platform

Component Name	Component Description	NFRQ ID
ASP MaaS Platform (TE18-19)	The ASP (Apportionment and Settlement Platform) MaaS platform is a central processing system housed in the cloud and delivering accounting services across mobility modes. It ingests transactions resulting from sales and travels and generates settlements between participants. The ASP offers a flexible configuration of the apportionment rules. The ASP includes the required services for managing a Mobility Account and processing revenue apportionment in pay-as-you-go mode. The ASP platform is interfaced with a Distributed Ledger.	- TE18_CA07_NFRQ01 - TE18_CA07_NFRQ02 - TE18_CA07_NFRQ03
Function Name	**Function Description**	**FRQ ID**
Ingest transactions (TE18)	This is the implementation of an acquiring processing for fare transactions including sales (bundles of transactions resulting from multi-modal distributions) and travels (pay-as-you-go). This is essentially the providing of an API allowing retail and TSP channels to post transactions. The acquiring process includes the storage of received data and basic checks (check of duplication, acknowledgment)	- TE18_CA07_FRQ01 - TE18_CA07_FRQ02 - TE18_CA07_FRQ03 - TE18_CA07_FRQ05
Check transaction consistency (TE18)	Validation rules are run on received transactions. The rules are based on ASP settings and include structural checks and value-based checks	- TE18_CA07_FRQ01 - TE18_CA07_FRQ02 - TE18_CA07_FRQ03 - TE18_CA07_FRQ05
Apportion revenue based on configured rules (TE18)	Revenue apportionment consists in the repartition of the collected revenue across business participants. This is accrual accounting in that sense that there is no management of the effective fund received, the repartition being based on the delivered service. The apportionment is done per transaction on the basis of rules configured at the ASP and defining the logic- (e.g. fees, percentages). The logic is applicable to pre-paid and post-paid offers (pay-as-you-go).	- TE18_CA07_FRQ01 - TE18_CA07_FRQ02 - TE18_CA07_FRQ03 - TE18_CA07_FRQ04
Generate settlement (TE18)	At the end of a configured period (settlement period), the apportionment records generated at transaction level are aggregated into settlements that reflect the fund transfers to be executed between business participants (typically transfer from distributor to TSP)	- TE18_CA07_FRQ07
Display settlement (TE18)	Once generated, settlements are displayed on request to the TSPs. This is achieved through the	- TE18_CA07_FRQ06

	ASP web portal	
Process transactions against Mobility Account (TE18)	Travel transactions in pay-as-you-go mode are processed against the associated Mobility Account. The token identifier in the travel transaction is used to retrieve the Mobility Account. Travel is then charged against the account based on rules configured at the ASP. Mobility accounts are updated. Information is available to the TSP at the ASP portal	- TE18_CA07_FRQ03
Acquire transactions (TE19)	Acquire transactions is a derivation of the transaction ingestion function including the adaptation of transactions from external sources. Here the adaptation is done on CEN NeTEx part 3 Sales Transactions.	- TE19_CA03_NFRQ01

Table 18: ASP MaaS Platform component

- Assistance Integrative Mobile App

Component Name	*Component Description*	*NFRQ ID*
Assistance Integrative Mobile App (TE20-22)	The Mobile app would integrate different elements in the mobile phone and from there user should be able to access different elements (robot, guidance, assistance, information, etc.).	- TE20_CA01_NFRQ01 - TE20_CA01_NFRQ02 - TE20_CA01_NFRQ03 - TE22_CA01_NFRQ01 - TE22_CA01_NFRQ03 - TE22_CA01_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Display general accessible information (TE20-22)	The system should provide clear information or attendance requested by the user. It should be in an accessible format for people with different disabilities (not the same way to communicate to people with visual problems as to people in wheelchair).	- TE20_CA01_FRQ01 - TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE22_CA01_FRQ01

Table 19: Assistance Integrative Mobile App component

- Capacity Optimization HMI

Component Name	*Component Description*	*NFRQ ID*
Capacity Optimization HMI (TE26)	The component is designed to display all information related to the optimization results produced by the Optimization Software component. This HMI component can be used by the railway service provider to visualize KPIs and optimized timetables, allowing a comparison with the initially planned scenario.	- TE26_CA02_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Display KPIs for	This function allows to visualize the KPIs and	- TE26_CA01_FRQ01

results' validation (TE26)	optimized timetables as well as a comparison with planned ones.	- TE26_CA02_FRQ04

Table 20: Capacity Optimization HMI component

- Communication form

Component Name	*Component Description*	*NFRQ ID*
Communication form (TE27)	The "Communication form" component plays a pivotal role in the municipal transport ecosystem, facilitating the seamless reporting of disturbance information by various actors. Its primary responsibility lies in accessing the relevant API, enabling disparate entities to relay crucial data that can impact transport services. This component streamlines the communication process, ensuring that valuable disruption information is efficiently captured and disseminated, thereby enhancing the overall efficiency and responsiveness of the municipal transport system.	- TE27_CA04_NFRQ02
Function Name	***Function Description***	***FRQ ID***
Data preparation (TE27)	This function is a cornerstone of communication. It collects data from the actor, readying it for seamless integration with ETL/API processes, facilitating efficient data flow and communication.	- TE27_CA04_FRQ01

Table 21: Communication form component

- Control Unit [Supervision software]

Component Name	*Component Description*	*NFRQ ID*
Control Unit [Supervision software] (TE22)	The control unit for the illuminated platform describes a server rack with different IT-components that are necessary for the data processing, control and data sending. Integrated main components are the data server, internet router and lighting control software. Remote access via cloud and a control terminal is also available.	- TE22_CA04_NFRQ02 - TE22_CA04_NFRQ03
Function Name	***Function Description***	***FRQ ID***
Data ingestion & processing (TE22)	This function describes the data reception from several external sensors (incoming train data like arrival times, train lengths and capacity), the data processing and data provision.	- TE22_CA04_FRQ03 - TE22_CA04_FRQ04
Select pre-programmed light pattern	After the incoming train data has been processed, the software forwards the pre-programmed display patterns to the illuminated platform edge	- TE22_CA04_FRQ01

(TE22)	in real time.	

Table 22: Control Unit component

- Dashboarding system

Component Name	*Component Description*	*NFRQ ID*
Dashboarding system (TE23-24-26-27)	The "Dashboarding system" serves as a unifying interface across disparate systems, presenting critical information related to multimodality and demand analysis processes. It offers a consolidated view of key data points and insights, aiding decision-makers in efficiently monitoring and optimizing transport services. This component enhances coordination, providing a comprehensive visual representation of essential information, ultimately contributing to improved planning and management in the realm of multimodality and demand analysis.	- TE23_CA03_NFRQ01 - TE24_CA03_NFRQ01 - TE24_CA04_NFRQ01 - TE27_CA03_NFRQ01 - TE27_CA04_NFRQ02
Function Name	***Function Description***	***FRQ ID***
Display information (TE23-24-26-27)	It is a pivotal function within our Dashboarding system, ensuring the smooth and efficient operation of relevant dashboards. It presents critical data, enhancing user experience and facilitating informed decision-making.	- TE23_CA02_FRQ04 - TE23_CA03_FRQ02 - TE24_CA02_FRQ04 - TE24_CA03_FRQ01 - TE24_CA03_FRQ02 - TE26_CA03_FRQ01 - TE27_CA03_FRQ01

Table 23: Dashboarding system component

- Data Analytics Platform

Component Name	*Component Description*	*NFRQ ID*
Data Analytics Platform (TE18-23-24-27)	The Data Analytics Platform repeatedly processes input like journey planning requests or other information sources if available to create occupancy forecasts.	- TE23_CA04_NFRQ01 - TE27_CA05_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Calculate updated forecasts (TE27)	According to incoming Journey Planning requests the Data Analytics Platform repeatedly calculates occupancy forecasts.	- TE27_CA05_FRQ01 - TE27_CA05_FRQ02
Check occupancy thresholds (TE27)	After the Data Platform determines the occupancy forecast, it checks whether the forecast meets a given threshold which when met triggers an alert towards the Alert Generation Service.	- TE27_CA05_FRQ01 - TE27_CA05_FRQ02
Identify patterns and trends (TE24)	While analysing the historic information it receives, the Data Analytics Platform also identifies potential trends and shifts in the	- TE24_CA04_FRQ03

	mobility of travellers in the service area of the MaaS Platform.	
Return occupancy data (TE24)	When requested to provide the insights it gathered, the Data Analytics Platform returns the calculated occupancy data.	- TE24_CA04_FRQ01
Gather data relevant for occupancy forecast (TE23)	As input for the forecast calculation, the Data Analytics Platform receives the Journey Planning requests from the MaaS Platform and optionally may request additional information from the MaaS Platform, such as counted passenger information from the vehicles, which contributes to higher quality forecasts. This occupancy data is then forwarded to the Machine Learning Occupancy Model.	- TE23_CA04_FRQ01
Calculates demand analyses based on request (TE18)	According to the processed historic journey planning results, the Data Analytics Platform provides a demand analysis to the Data Analytics Portal.	- TE18_CA05_FRQ03 - TE18_CA05_FRQ04 - TE18_CA06_FRQ03
Analyses mobility services demand (TE18)	Journey requests to the MaaS Platform are forwarded to this function of the Data Analytics Platform to analyse the demand as the ground data for the demand analysis calculation.	- TE18_CA05_FRQ01

Table 24: Data Analytics Platform component

- Data Analytics Portal

Component Name	*Component Description*	*NFRQ ID*
Data Analytics Portal (TE18)	The Data Analytics Portal is the frontend component of the Data Analytics Platform and provides a User Interface to the information.	- TE18_CA04_NFRQ01 - TE18_CA05_NFRQ01 - TE18_CA06_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Process login request (TE18)	check authenticity and authorization of the representative of the TSP.	- TE18_CA04_FRQ01 - TE18_CA04_FRQ02 - TE18_CA04_FRQ03
Build demand request (TE18)	Request the Data Analytics Platform to provide the analysed demand.	- TE18_CA05_FRQ01
Display demand data request (TE18)	Display the results provided by the Data Analytics Platform.	- TE18_CA05_FRQ02 - TE18_CA05_FRQ03 - TE18_CA05_FRQ04 - TE18_CA06_FRQ01 - TE18_CA06_FRQ02 - TE18_CA06_FRQ03

Table 25: Data Analytics Portal component

- Demand analytics dashboard

Component Name	Component Description	NFRQ ID
Demand analytics dashboard (TE24)	The Demand analytics dashboard gathers forecasted information from the Data Analytics Platform and provides it in various graphical forms to the Data Analyst.	- TE24_CA04_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Collect forecasted occupancy data (TE24)	The Demand Analytics Dashboard retrieves the forecasted occupancy data from the Data Analytics Platform.	- TE24_CA04_FRQ01
Display data (TE24)	After the Demand Analytics Dashboard retrieved the occupancy data, it processes and displays the insight for the Data Analyst.	- TE24_CA04_FRQ02

Table 26: Demand analytics dashboard component

- Demand dataset Builder

	Component Description	NFRQ ID
Demand dataset builder (TE23-24)	A component which, communicating mainly with the data lake, is able to create a dataset for training and testing predictive models.	- TE23_CA01_NFRQ01 - TE23_CA02_NFRQ02 - TE24_CA01_NFRQ01 - TE24_CA02_NFRQ02
Function Name	**Function Description**	**FRQ ID**
Dataset creation (TE23-24)	The system processes the data and updates the occupancy model considering historic data.	- TE23_CA04_FRQ02

Table 27: Demand dataset Builder component

- Digital twin HMI

Component Name	Component Description	NFRQ ID
Digital twin HMI (TE25)	This component is a Human-Machine Interface (HMI) of a Digital Twin of a multimodal transport network. This HMI integrates both traffic simulation and demand forecast to optimise various elements of the transport network, such as offer, passenger occupancy, connection time, and other service-related factors.	
Function Name	**Function Description**	**FRQ ID**
Display KPI (TE25)	The function provides the OCC Operator with passenger KPIs that are useful for analysing the impacts and contributing to the optimisation of the offer, modelling exchange time and crowd flow.	- TE25_CA01_FRQ02 - TE25_CA02_FRQ05 - TE25_CA03_FRQ02

Table 28: Digital twin HMI component

- Disruption Management HMI

Component Name	*Component Description*	*NFRQ ID*
Disruption Management HMI (TE18-19-27)	The component is designed to display all information related to disruption events. This HMI component can be used by TSP to visualize in real-time occurring disruptions and, possibly, some alternative options (if provided by the optimization system) to be implemented in order to reduce the impact on travellers' journey.	- TE27_CA01_NFRQ01 - TE27_CA01_NFRQ02 - TE27_CA01_NFRQ03 - TE27_CA02_NFRQ02
Function Name	***Function Description***	***FRQ ID***
Display information (TE18-19-27)	This function allows to visualize the information related to the occurred disruption (e.g., start time, involved assets, affected vehicles) in the operator dashboard.	- TE27_CA01_FRQ01 - TE27_CA02_FRQ01
Display strategies (TE18-19-27)	This function is responsible for showing the mitigation strategies (if any) suggested to the TSP. These strategies aim at managing the disrupted situation by proposing different alternative transport services in order to let travellers complete their own journey.	- TE27_CA02_FRQ04

Table 29: Disruption Management HMI component

- Disruption Management System

Component Name	*Component Description*	*NFRQ ID*
Disruption Management System (TE18-19-27)	This component includes functions related to dataset manipulation and optimization. It acquires disruption information and aims at finding alternative mitigation strategies (if needed) to be proposed to the service provider. Strategies are provided to enable travellers to conclude their journeys. Moreover, the component is responsible for creating and delivering incident messages to be sent to platforms or directly to travellers.	- TE18_CA08_NFRQ01 - TE19_CA04_NFRQ01 - TE19_CA04_NFRQ02 - TE27_CA02_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Provision of incident message (TE18-19-27)	This function aims at creating an incident message which includes information related to the occurred disruption (start date, involved assets and vehicles, etc.). This message is provided to other platforms and/or directly to travellers.	- TE18_CA08_FRQ01 - TE19_CA04_FRQ01
Incident message update (TE18-19-27)	The function allows to update the previously sent incident message (see above function) by adding advice for travellers on how to continue their journey (if any).	- TE18_CA08_FRQ01 - TE19_CA04_FRQ01
Data ingestion & processing (TE18-19-27)	This function is responsible for acquiring all the information needed for optimization. Input data may be raw and need re-processing.	- TE27_CA02_FRQ02 - TE27_CA02_FRQ03

Passenger re-distribution optimization (TE18-19-27)	Optimization function that aims at finding feasible solutions to allow travellers to end their journey if the occurred disruption has a high impact on travellers.	- TE27_CA02_FRQ04

Table 30: Disruption Management System component

- Distributed Ledger Interface

Component Name	*Component Description*	*NFRQ ID*
Distributed Ledger Interface (TE18)	The Distributed Ledger Interface is a central processing component housed in the cloud together with the ASP. It processes settlements records generated by the ASP and makes them available to participants (TSP) through a Distributed Ledger. The Distributed Ledger is a block-chain based infrastructure used for managing, verifying and distributing settlement records. TSPs can have their own computing nodes allowing to check and review settlement records. The Distributed Ledger and Blockchain technology ensure settlement records immutability distribution and validation.	- TE18_CA07_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Anchor settlement record into the distributed (TE18)	Settlement records generated by the ASP are processed and anchored into the Distributed Ledger. A digest signature is generated.	- TE18_CA07_FRQ07
Compute and return block details (TE18)	Following the anchoring, the block and transaction identifiers as provider by the Blockchain as well as the signature are returned.	- TE18_CA07_FRQ07

Table 31: Distributed Ledger Interface component

- DSS dashboard

Component Name	*Component Description*	*NFRQ ID*
DSS dashboard (TE18)	The "DSS dashboard" component is an integral part of decision support systems, streamlining the preparation of report requests and presenting crucial information related to multimodality and demand analysis processes. It offers an intuitive interface for users to generate tailored reports, harnessing data-driven insights to inform decision-making in the realm of transport services. This component enhances efficiency, providing a user-friendly platform for accessing and visualizing pertinent information, ultimately supporting informed choices and optimizing multimodality	- TE18_CA09_NFRQ03 - TE18_CA10_NFRQ01 - TE18_CA11_NFRQ01

	and demand analysis processes.	
Function Name	***Function Description***	***FRQ ID***
Check for existing report (TE18)	It is a vital function within our DSS dashboard, activated upon user report requests. It verifies the existence and currency of relevant reports, ensuring data accuracy and efficiency.	- TE18_CA09_FRQ01
Generate and display dashboard (TE18)	It is a key function within our DSS dashboard, tasked with creating and presenting reports from available data. It empowers users with visually informative insights for informed decision-making.	- TE18_CA10_FRQ01 - TE18_CA11_FRQ01
Create Request (TE18)	It is a vital function within our DSS dashboard, activated when relevant report data is unavailable. It initiates requests to the data lake, ensuring the necessary information is retrieved for comprehensive reporting and informed decision-making.	- TE18_CA11_FRQ01

Table 32: DSS dashboard component

- FCM Face Capture Module

Component Name	***Component Description***	***NFRQ ID***
FCM Face Capture Module (TE21)	Device allowing to capture facial image, calculate signature, communicate with external system to check the validity of the signature and drive local interfaces such as automatic gates. The FCM (Facial Capture Module) comes as a pod installed on the automatic gate cabinet. The capture angle is intended to deliver an optimal User Experience and to ensure privacy. The FCM is connected to the communication network.	- TE21_CA01_NFRQ03 - TE21_CA01_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Capture facial image (TE21)	When a traveller enters the identification area (typically less than one meter from the camera), the capture process starts and an adequate image of the face is registered. Then the face signature is computed by the FCM. The capture process is carried out in real time.	- TE21_CA01_FRQ01
Enquire facial identification (TE21)	The FCM having computed a facial signature sends a request to the FCS in order to verify the face identification. The matching process is carried out at the FCS that returns a confirmation or rejection status. The enquiry is performed in real time.	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02 - TE21_CA02_FRQ03
Validate Walk-in (TE21)	When the FCM is controlling the entry to a closed area in a mobility hub, the purpose of face recognition is to grant access to registered travellers having the adequate rights. Following	- TE21_CA01_FRQ01 - TE21_CA02_FRQ02 - TE21_CA02_FRQ04

	the facial identification enquiry sent to the FCS and the reception of an acknowledgment, the FCM triggers the entry process at the automatic gate.	
Validate Walk-out (TE21)	When the FCM is controlling the exit from a closed area in the mobility hub, the purpose of the face recognition is to allow the passage of registered travellers (e.g., priority lanes) and optionally to make sure they have the adequate travel right. Following the facial identification enquiry sent to the FCS and the reception of an acknowledgment, the FCM triggers the exit process at the automatic gate.	- TE21_CA01_FRQ01 - TE21_CA02_FRQ02 - TE21_CA02_FRQ04

Table 33: Face Capture Module component

- Floor Signs

Component Name	*Component Description*	*NFRQ ID*
Floor Signs (TE21-22)	Led sign placed on the floor and driven by hands free control system. The sign displays contextual information when the passenger is approaching: light and adequate message. Using floor signs reduces the complexity of the installation and ensures a better interactivity (no need for the passenger to stop and read a display). Floor signs are connected to a communication network in order to receive indications from the control systems.	- TE21_CA01_NFRQ04 - TE21_CA02_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Display transfer indication (TE21-22)	Upon trigger of an external driving system, displays transfer indication (light and message) visible by the approaching traveller. Information is removed when the traveller is passed. This second part of the processing is monitored by the external driving system.	- TE21_CA02_FRQ01 - TE22_CA03_FRQ01 - TE22_CA04_FRQ01

Table 34: Floor Signs component

- Forecast platform

Component Name	*Component Description*	*NFRQ ID*
Forecast platform (TE23-24)	This component is a system that uses historical and real-time data to forecast the future demand for rail transportation services. The component ensures that the input data is in a consistent format and ready for analysis. The model is data-	- TE23_CA01_NFRQ01 - TE23_CA02_NFRQ01 - TE23_CA02_NFRQ02 - TE23_CA04_NFRQ02 - TE23_CA05_NFRQ01

	driven and created in such a way that errors, inconsistencies and inaccuracies in the input datasets must be identified and corrected. The component is capable of extracting valuable insights, patterns, and knowledge from large data sets. And finally, this component predicts short- and long-term demand by offering a forecast that can be updated periodically.	- TE24_CA01_NFRQ01 - TE24_CA02_NFRQ01 - TE24_CA02_NFRQ02 - TE24_CA04_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Data ingestion & processing (TE23-24)	This function collects, process and clean the input information: scheduled and real-time transportation datasets, weather forecast and scheduled special events.	- TE23_CA01_FRQ01 - TE23_CA01_FRQ02 - TE23_CA01_FRQ03 - TE24_CA01_FRQ01 - TE24_CA01_FRQ02 - TE24_CA01_FRQ03
Demand Forecasting Model (TE23-24)	This function performs a forecast of the future demand for rail transportation services.	- TE23_CA02_FRQ01 - TE23_CA02_FRQ02 - TE23_CA02_FRQ03 - TE23_CA02_FRQ04 - TE24_CA02_FRQ01 - TE24_CA02_FRQ02 - TE24_CA02_FRQ03 - TE24_CA02_FRQ04

Table 35: Forecast platform component

- FRS Face Recognition Server

Component Name	***Component Description***	***NFRQ ID***
FRS Face Recognition Server (TE21)	The FRS (Face Recognition Server) is a set of cloud services dedicated to the central processing of face recognition. The FRS provides an on-line enrolment service (accessed from a mobile application) allowing the registration of travellers. This enrolment includes the registration of the facial signature as well as the subscription to travel rights. The FRS provides an on-line enquiry service allowing FCMs to verify online face identifiers.	- TE21_CA01_NFRQ03
Function Name	***Function Description***	***FRQ ID***
Process facial identification (TE21)	Upon reception of an enquiry from the FCM, the FRS checks the facial signature against the ones registered in database. The objective is to perform a 1:N matching. One of the objectives is to minimize false negative and false positive identifications. Another challenge is the real time processing. The result consists in the identification	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02

	status (positive, negative) and the traveller reference when positive.	
Check travel right (TE21)	Following a positive facial identification on entry side, a check of the traveller rights is performed using the data recorded at subscription time. When the traveller profile allows the entry, an acknowledgment is sent back to the FCM. Otherwise, access is refused.	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02 - TE21_CA02_FRQ02 - TE21_CA02_FRQ03 - TE21_CA02_FRQ04
Check exit authorization (TE21)	Following a positive facial identification on exit side, the FRS check whether exit is allowed. This check is based on data registered at subscription time typically whether the traveller is allowed to use the face recognition lane. No emergency process (e.g., fire alarm) is included here.	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02 - TE21_CA02_FRQ02 - TE21_CA02_FRQ03 - TE21_CA02_FRQ04

Table 36: Face Recognition Server component

- Gap Filler

Component Name	*Component Description*	*NFRQ ID*
Gap Filler (TE22)	This solution aims to improve travellers' safety during the transition between platforms and rolling stock. It is more critical in platforms with curvature as this makes the gap wider and increases the risks to get trapped in between. The solution consists in Physical element that will minimize the distance between platform and rolling stock by filling the gap between them following the current safety standards.	- TE22_CA01_NFRQ02 - TE22_CA02_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Safe and comfortable transition between platform and rolling stock (TE22)	Reducing the gap between platform and rolling stock and facilitating the transition of travellers between train and platform.	- TE22_CA02_FRQ01

Table 37: Gap Filler component

- Gate Line

Component Name	*Component Description*	*NFRQ ID*
Gate line (TE21)	Automatic gate in a mobility hub used for accessing or leaving closed area, typically train platform. Gates are assembled in gate lines or gate arrays. Main components include cabinets housing processing units, detectors and displays and obstacles controlling the access. Automatic gates are used within the context of hands-free	- TE21_CA01_NFRQ03 - TE21_CA02_NFRQ01

	travel and walk-in and walk-out processing. Technologies used for the interaction with travellers include UWB (Ultra Wide Band) and Face Recognition).	
Function Name	***Function Description***	***FRQ ID***
Process Walk-in (TE21)	Upon reception of a signal granting the access process the entry including obstacle opening and closure, welcome message display and passenger safety management based on local sensors. Following the processing of the entry, a confirmation message is sent to the system having initiated the access.	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02 - TE21_CA02_FRQ02
Process Walk-out (TE21)	Upon reception of a signal confirming the right for a passenger to leave the closed area in the mobility hub, process the exit including obstacle opening and closure, good-bye message display and passenger safety management based on local sensors. A confirmation message is sent to the system having initiated the request. Management of emergency situations (e.g., fire exit is not included here).	- TE21_CA01_FRQ01 - TE21_CA01_FRQ02 - TE21_CA02_FRQ02

Table 38: Gate Line component

- Gobo

Component Name	***Component Description***	***NFRQ ID***
Gobo (TE22)	Element that will project important accessible information in certain places. This solution encompasses lights/projectors that in a very simple way can guide traveller and improve their time management in the multimodal station with a complex environment to get oriented faster and better.	- TE22_CA01_NFRQ01 - TE22_CA03_NFRQ01 - TE22_CA04_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Projection of useful indicative information (TE22)	Provision of useful transport public information for travellers in stations: projection of a wheelchair in the specific areas of the platforms where it is known that will match with accessible rolling stock entrance.	- TE22_CA03_FRQ01 - TE22_CA04_FRQ01 - TE22_CA04_FRQ02 - TE22_CA04_FRQ03

Table 39: Gobo component

- Guiding Accessible Intelligent Tool

Component Name	***Component Description***	***NFRQ ID***
Guiding Accessible Intelligent Tool	This tool is based on informing user in different points of the station about different useful	- TE20_CA01_NFRQ02 - TE20_CA01_NFRQ03

(TE20-22)	elements that can be reached (bathrooms, ticket office, information points, etc.) and also offers the pod tactile routes to increase efficient navigation and decision making indoor of the multimodal station.	- TE22_CA01_NFRQ01 - TE22_CA01_NFRQ02 - TE22_CA01_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Classification of the user´s need (TE20-22)	The system receives requests from the user about information in different points of the station.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ04
Data ingestion & processing (TE20-22)	Data needed is processed and transferred into accessible format.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ04
Orientation to reach different location in station and platforms (TE20-22)	Orientation instructions and supportive equipment (podotactile routes) are provided and can be adequately used.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ04 - TE22_CA02_FRQ01 - TE22_CA04_FRQ01

Table 40: Guiding Accessible Intelligent Tool component

- Guiding Accessible Software

Component Name	***Component Description***	***NFRQ ID***
Guiding Accessible Software (TE20-22)	This software integrates different elements (mobile app, totem T-Ais system, robot and guiding intelligent tool) in the same system, so all these elements are connected to this SW and form part of it. The main goal of this SW is to facilitate traveller, depending on specific needs, to find the solution, that can be: display of useful information (timetables, incidents), location of accessible routes in multimodal station of Málaga, assistance of different accessibility tools depending on the traveller´s needs (robot, podotactile routes, information codes, etc.), etc.	- TE20_CA01_NFRQ01 - TE20_CA01_NFRQ02 - TE20_CA01_NFRQ03 - TE22_CA01_NFRQ02 - TE22_CA01_NFRQ03 - TE22_CA01_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Classification of the user's need (TE20-22)	System recognizes the different user´s needs and requests the relevant non-accessible data to the TSP and Rail Administrator Information Platform. This information will be used and processed to facilitate the information or guidance for PRM and travellers with disabilities in stations and platforms, information related to breakdowns in the station, accessible routes and other types of useful information.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA01_FRQ04
Data ingestion & processing (TE20-22)	The SW system ingest the information from the data cloud of the TSP provider (rail administrator or metro) according to the user needs (timetable, taxis, incidents, etc.).	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA01_FRQ04 - TE22_CA04_FRQ01
Option 1: Robot	Robot would receive a request through the SW	- TE20_CA01_FRQ02

(TE20-22)	system and attend the person with disabilities.	- TE20_CA01_FRQ02
Option 2: Indoor guiding in station hall or platforms (TE20-22)	The indoor guiding system helps the traveler to orientate in the stations and platforms.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ04 - TE22_CA02_FRQ01 - TE22_CA04_FRQ01
Option 3: Totem T-Ais (TE20-22)	The system should provide information of the multimodal station (timetables, incidents, accessible routes, etc.) to facilitate navigation and use of transport services for passengers.	- TE20_CA02_FRQ02 - TE20_CA01_FRQ02 - TE20_CA01_FRQ03
Option 4: Mobile App (TE20-22)	The system should provide accurate indoor maps of stations to facilitate navigation for passengers.	- TE20_CA01_FRQ01 - TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE22_CA01_FRQ01
Holds real time information (TE20-22)	The system related to the robot has as an objective to have different types of information available in real time to exploit it depending on the user's objectives.	- TE20_CA01_FRQ01 - TE20_CA01_FRQ02
Receives robot services requirement (TE20-22)	The robot will be connected to a tool that will allow it to process different service requirements in order to process the information and prepare the sequence of operations in order to carry out the request.	- TE20_CA01_FRQ02
Request processing (TE20-22)	The request will be processed through a system that will receive an input and work on the output, preparing everything necessary to carry out the request received.	- TE20_CA01_FRQ02

Table 41: Guiding Accessible Software component

- HFCS Control System

Component Name	*Component Description*	*NFRQ ID*
HFCS Control System (TE20-21-22)	The HFCS (Hands Free Control System) is a central processing system housed in the cloud and managing the business logic for UWB hands free processing in mobility hubs. It processes the information received from the RTLS and drives customer facing devices and services: automatic gates, signs, messages. The interface to customer facing devices and services is done via heterogeneous communication networks: open internet, mobility hub network devices	- TE20_CA01_NFRQ01 - TE21_CA01_NFRQ04 - TE22_CA01_NFRQ03
Function Name	***Function Description***	***FRQ ID***
Check tag validity (TE21)	On reception of an UWB wearable device identifier from the RTLS, the HFCS checks whether the identifier is valid. This is done prior to any other processing. Identifiers shall be registered at the HFCS. In case of invalid identifier, there is no further processing.	- TE21_CA01_FRQ02 - TE21_CA02_FRQ03

Monitor position (TE21)	The HCFS manages a geographical model of the navigation area in the form of a breakdown into zones. Every time a valid UWB wearable identifier is received from the RTLS, the HFCS works out its position against zones and triggers when require Walk-In, Walk-Out or transfer actions	- TE21_CA01_FRQ02 - TE21_CA02_FRQ05
Send walk-in signal (TE21)	Once the position monitoring function detects the presence of an UWB wearable in the entry side of a valid gate aisle, the HFCS sends a Walk-in signal to the gate	- TE21_CA01_FRQ02 - TE21_CA02_FRQ02 - TE21_CA02_FRQ05
Register walk-in (TE21)	The HFCS registers a Walk-In confirmation sent by the automatic gate.	- TE21_CA01_FRQ02 - TE21_CA02_FRQ02
Send walk-out signal (TE21)	Once the position monitoring functions detects the presence of an UWB wearable in the exit side of a valid gate aisle, the HFCS sends a Walk-Out signal to the gate if the	- TE21_CA01_FRQ02 - TE21_CA02_FRQ02 - TE21_CA02_FRQ05
Register walk-out (TE21)	The HFCS registers a Walk-Out confirmation sent by the automatic gate.	- TE21_CA01_FRQ02 - TE21_CA02_FRQ02
Compute transfer case (TE21-22)	Following the completion of a Walk-Out, the HFCS checks whether the UWB wearable is associated with a transfer indication consistent with current location and time.	- TE21_CA01_FRQ02 - TE21_CA02_FRQ01 - TE22_CA03_FRQ01 - TE22_CA04_FRQ01
Send message to floor signs (TE21-22)	The HFCS sends over the communication network a message to the floor sign. The message contains the indication of colours and light and the text when applicable. Floor sign identifier and message are provided by the 'Compute Transfer case' function. When the UWB wearable leaves the area, the HFCS sends a message removing light and text.	- TE21_CA01_FRQ02 - TE22_CA03_FRQ01 - TE22_CA04_FRQ01
Send text message to Station Operator (TE20-21)	On detection of an UWB wearable entering the detection zone, a check is done on whether the device is associated with a PRM profile. If this is the case, a text message is sent to the station operator staff. This is done over the mobile network, using a mobile number configured at the HFCS.	- TE20_CA01_FRQ02 - TE21_CA01_FRQ02 - TE21_CA02_FRQ05

Table 42: HFCS Control System component

- HMI dashboard

Component Name	*Component Description*	*NFRQ ID*
HMI dashboard (TE23-24)	This component is a graphical user interface designed to facilitate communication with the operator. The component translates complex data	- TE23_CA03_NFRQ01 - TE24_CA03_NFRQ01

	into useful information and displays graphical visualizations and descriptive statistics to help understand the relationships between different input variables and their impact on transportation demand. Dashboards are intuitive and self-explanatory, allowing operators/users to interact with them easily. Dashboards provide information/warnings in a timely manner to optimize transportation network operation and support informed decision making.	
Function Name	***Function Description***	***FRQ ID***
Display information (TE23-24)	This function displays model results (demand KPIs & warnings) and provides a visual representation of critical information to the user.	- TE23_CA03_FRQ01 - TE23_CA03_FRQ02 - TE24_CA03_FRQ01 - TE24_CA03_FRQ02 - TE24_CA04_FRQ02

Table 43: HMI dashboard component

- Illuminated Platform Edge

Component Name	***Component Description***	***NFRQ ID***
Illuminated Platform Edge (TE22)	The Illuminated Platform Edge describes an innovative customer information system for traveller guidance. It consists of connected LED elements which are integrated into the platform surface and can display information in real-time about the incoming train using different light patterns (e.g., via colours, dynamics etc.). It increases safety, orientation and capacity on the platforms.	- TE22_CA04_NFRQ01 - TE22_CA04_NFRQ03
Function Name	***Function Description***	***FRQ ID***
Displays information (TE22)	By using different light patterns the Illuminated Platform Edge display various information on the platform surface like train arriving and departure, the stopping position and capacity of the train compartments.	- TE22_CA02_FRQ01 - TE22_CA04_FRQ01 - TE22_CA04_FRQ02

Table 44: Illuminated Platform Edge component

- Indoor Guidance Tool

Component Name	***Component Description***	***NFRQ ID***
Indoor Guidance Tool (TE20-21)	Tool that focuses on travellers with disabilities that assists them on the guidance inside the stations by providing maps and indoor paths in order to guide them through a station to the objective platform.	- TE20_CA01_NFRQ01 - TE20_CA01_NFRQ03

Function Name	Function Description	FRQ ID
Provide station map (TE20-21)	Process through which the indoor guidance tool provides the map of the station where the traveller is at the moment that the traveller is located in a station that requires guidance through it.	- TE20_CA01_FRQ02
Calculate location (TE20-21)	The function that calculates the location of the user through different wireless signals collected by receiving different signals intensities via Bluetooth in the different wireless devices located in the station.	- TE20_CA01_FRQ02
Calculate path (TE20-21)	Function that calculates the indoor path through which the traveller will be able to be guided through the station in order to get to the objective platform.	- TE20_CA01_FRQ04

Table 45: Indoor Guidance Tool component

- Long term prediction software

Component Name	Component Description	NFRQ ID
Long term prediction software (TE24)	This component is a system that uses historical and real-time data to forecast the future long-term demand for rail transportation services.	- TE24_CA01_NFRQ01 - TE24_CA02_NFRQ01 - TE24_CA02_NFRQ02 - TE24_CA04_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Forecasting process (TE24)	The system learns long-term prediction from historical data. Model quality analysis carried out with a test set.	- TE24_CA02_FRQ01 - TE24_CA02_FRQ02 - TE24_CA02_FRQ04
AI forecasting support (TE24)	The system should be able to detect patterns and trends.	- TE24_CA02_FRQ03

Table 46: Long term prediction software component

- MaaS App

Component Name	Component Description	NFRQ ID
MaaS App (TE20-21)	It is an application that allows users to organise trips, book and buy tickets. Within the project, ticketing and guidance functionalities will be developed.	- TE20_CA01_NFRQ01 - TE20_CA02_NFRQ01 - TE21_CA01_NFRQ01 - TE21_CA01_NFRQ02 - TE21_CA03_NFRQ01 - TE21_CA03_NFRQ02
Function Name	**Function Description**	**FRQ ID**
Establish BLE Data Link	Process through which the user app creates a secure and low-power Bluetooth connection with	- TE20_CA02_FRQ01 - TE21_CA02_FRQ01

(TE20-21)	the validator device. By establishing this connection with the validator, the UWB of the traveller's phone will be activated and ready to establish connection through UWB with the validator.	
Receive UWB configuration data (TE20-21)	Process through which the validator sends to the traveller the necessary information to establish the connection with it.	- TE21_CA01_FRQ02
Parse pone UWB configuration data (TE20-21)	Process through which the mobile phone analyses and interprets the parameters send by the validator.	- TE21_CA01_FRQ02
Two-way UWB ranging (TE20-21)	Process through which the user app and the validator start connecting with each other.	- TE21_CA01_FRQ02
Perform validation (TE20-21)	Process through which the user app sends the token to the validator equipment in order to validate it.	- TE20_CA02_FRQ01 - TE20_CA02_FRQ02
Display validation result (TE20-21)	Once the ticket ID is validated, a function to display a validation message is shown to the user.	- TE20_CA02_FRQ01 - TE21_CA03_FRQ01
Collect GPS Position (TE20-21)	Function to collect the GPS position of the traveller during the journey.	- TE21_CA03_FRQ02 - TE21_CA03_FRQ03
Activate Indoor functionality (TE20-21)	Process through which the app activates the indoor functionality when the traveller is in a station.	- TE20_CA01_FRQ01
Guide to platform (TE20-21)	Function that provides guidance in the station.	- TE20_CA01_FRQ02
Collect indoor signals (TE20-21)	Function to collect the different wireless signals within the station in order to locate the user in the station.	- TE20_CA01_FRQ01
Request path (TE20-21)	Function that requests the path to the Indoor Guidance tool based on the itinerary provided the by MaaS platform and the location of the user in the station	- TE20_CA01_FRQ02
Display path (TE20-21)	Function that displays the path to reach the specific destination in the station.	- TE20_CA01_FRQ02 - TE21_CA03_FRQ04

Table 47: MaaS App component

- MaaS platform

Component Name	*Component Description*	*NFRQ ID*
MaaS platform (TE18-19-20-21-23-24-27)	The MaaS Platform orchestrates the services of multiple connected TSP or other MaaS platforms.	- TE18_CA01_NFRQ01 - TE18_CA01_NFRQ02 - TE18_CA01_NFRQ03 - TE18_CA01_NFRQ04 - TE18_CA01_NFRQ05 - TE18_CA01_NFRQ06 - TE19_CA01_NFRQ01
Function Name	***Function Description***	***FRQ ID***

Orchestrate trip requests (TE18-19-23)	Upon receiving a Journey Planning request, the MaaS platform identifies the relevant TSP Journey Planning Services and orchestrate to these external services and receives the results. Optionally, this orchestration may include calls toward other MaaS platforms as well.	- TE18_CA01_FRQ01 - TE18_CA01_FRQ02 - TE18_CA01_FRQ03 - TE18_CA01_FRQ04 - TE19_CA01_FRQ01 - TE19_CA01_FRQ02 - TE19_CA01_FRQ03 - TE19_CA01_FRQ04
Build best trip solutions (TE18-19-23)	When the MaaS platform received the results from the TSP Journey Planning service and MaaS platforms, it analyses and builds the best overall trip solutions. The results are provided to the Retailer App.	- TE18_CA01_FRQ01 - TE18_CA01_FRQ02 - TE18_CA01_FRQ03 - TE18_CA01_FRQ04
Orchestrate Trip calculation and offer combining (TE18-19)	Alternatively to the pure Journey Planning request from "Orchestrate trip request", this function is in some instances capable of combining the journey planning with the offer building. The MaaS platform not only requests trip solutions from the TSP Journey Planning and Offer Services or other MaaS Platforms, but trips and applicable offers.	- TE18_CA01_FRQ01 - TE18_CA01_FRQ02 - TE18_CA01_FRQ03 - TE18_CA01_FRQ04 - TE18_CA02_FRQ01 - TE18_CA02_FRQ02 - TE18_CA02_FRQ03
Collect intermodal Journey requests (TE18-23-24)	The MaaS Platform forwards the Journey Requests to the Data Analytics platform.	- TE23_CA04_FRQ01
Calculate Alternative Trips (TE23-24-27)	In the event of incidents, such as over crowdedness, Travellers may use the Retailer App to request alternative trips. In this case, the Retailer App requests the MaaS platform to provide alternative trips avoiding highly occupied vehicles for instances.	- TE27_CA07_FRQ02
Process Intermodal Journeys request (TE23)	Whenever the MaaS platform receives a Journey Planning request, this request is also forwarded via this function to the Data Analytics Platform as input for the occupancy forecasting.	- TE23_CA04_FRQ01
Provide occupancy data (TE23)	In addition to the journey planning requests, a MaaS platforms may offer additional occupancy data, such as counting data for the vehicles. This data is provided via this function to the Data Analytics Platform.	- TE23_CA04_FRQ01
Update Occupancy data (TE23)	Whenever the Machine Learning Occupancy Model updates its forecasted model for occupancy, this information is provided to the MaaS platform through this function which incorporates the information into the Journey Planning. This way, the occupancy information is provided as a result of the Journey Planning to the Retailer App.	- TE23_CA05_FRQ01
Compare GPS position matches with available stations (TE20-21)	This function is in charge of checking the GPS position with the GPS position of the available indoor map stations. If the GPS is close to the station of the itinerary and the system has the indoor map, it requests the activation of the	- TE20_CA01_FRQ02

	indoor guidance.	
Activate indoor guidance (TE20-21)	This function is in charge of activating the indoor guidance that provides the paths at the stations. This guidance takes into account the location of the user inside the station.	- TE20_CA01_FRQ02

Table 48: MaaS platform component

- Machine Learning Occupancy model

Component Name	*Component Description*	*NFRQ ID*
Machine Learning Occupancy model (TE23)	The Machine Learning Occupancy Model is used to calculate and regularly update the occupancy forecasts used by other components, such as the MaaS platform or the Data Analytics Platform.	- TE23_CA04_NFRQ02
Function Name	***Function Description***	***FRQ ID***
Update model (TE23)	The Machine Learning Occupancy Model receives input data from the Data Analytics Platform and recalculates the occupancy forecast model regularly.	- TE23_CA04_FRQ02
Update Journey planner (TE23)	When the Machine Learning Occupancy Model recalculated its occupancy forecast it provides this new model to the MaaS Platform which incorporates it into its journey planning.	-TE23_CA04_FRQ03

Table 49: Machine Learning Occupancy model component

- Macro Simulator

Component Name	*Component Description*	*NFRQ ID*
Macro Simulator (TE25)	This component is a macro simulator that uses passenger long-term demand and planned offer to analyse impacts and contribute to the optimisation of the offer at a macro level. The simulation includes the integration of the results of the long-term demand forecast into the Digital Twin, focusing on the urban transport offer and demand.	
Function Name	***Function Description***	***FRQ ID***
Information retrieval (TE25)	This function retrieves information about planned offers, specifically vehicle timetables.	- TE25_CA01_FRQ03
Macro simulation (TE25)	This function is responsible for simulating the overall movement of passengers across various transportation systems, taking into account long-term passenger demand and planned transportation services.	- TE25_CA01_FRQ01

Table 50: Macro Simulator component

- Micro Simulator

Component Name	Component Description	NFRQ ID
Micro Simulator (TE25)	This component is a micro simulator that uses passenger short-term demand and current offer forecast to simulate the flow of passengers across different transport systems. The micro simulation includes passenger exchange time models, crowd flow models, and passenger behaviour models in case of incidents. The main purpose of this simulator is to provide short-term flow prediction, enable operators to perform corrective actions, and manage incidents on the network.	
Function Name	**Function Description**	**FRQ ID**
Information retrieval (TE25)	This function collects information about vehicle movements, including past, present, and future schedules, as well as incident information and data related to weather conditions.	- TE25_CA02_FRQ06 - TE25_CA02_FRQ07 - TE25_CA02_FRQ08
Micro simulation (TE25)	This function simulates microscopic flows of passengers across different transport systems, considering short-term passenger demand and current offer forecasts. It includes passenger exchange time models, crowd flow models, and passenger behaviour models in case of incidents	- TE25_CA02_FRQ01 - TE25_CA02_FRQ02 - TE25_CA02_FRQ03 - TE25_CA02_FRQ04
Micro simulation with a mitigation scenario (TE25)	This function offers the OCC Operator a digital twin that acts as a sandbox, enabling the simulation of various scenarios and the assessment of potential changes or improvements' impact.	- TE25_CA03_FRQ01

Table 51: Micro Simulator component

- Municipal Data Exchange Interface

Component Name	Component Description	NFRQ ID
Municipal Data Exchange Interface (TE18-19-27)	The ETL/API component serves as the linchpin in connecting disparate decision support systems at the municipal level with a centralized Data Lake. It combines the Extract, Transform, Load (ETL) processes to harmonize data from diverse sources, ensuring consistency and compatibility. Simultaneously, standard APIs establish secure, efficient connections for seamless data exchange, facilitating real-time access and enabling data-driven decision-making. This integration enhances operational efficiency, fosters collaboration, and empowers municipalities with cohesive insights from their decision support systems.	- TE19_CA05_NFRQ01 - TE19_CA06_NFRQ01 - TE19_CA07_NFRQ01

Function Name	Function Description	FRQ ID
Actor recognition (TE18-19-27)	It serves a critical role by identifying system users, enabling the creation of bespoke data upload queries that align with their permissions, enhancing both security and user efficiency.	- TE19_CA05_FRQ01 - TE19_CA06_FRQ01
Creation of message (TE18-19-27)	This function is integral to user experience, promptly informing users about the success or failure of data uploads, along with any essential error details.	- TE19_CA05_FRQ01 - TE19_CA07_FRQ01
Translate to DL querry (TE18-19)	It is a pivotal function that ensures seamless interaction with the data lake. It transforms requests into data lake queries adhering to best practices and structural integrity.	- TE19_CA06_FRQ01 - TE19_CA07_FRQ01 - TE19_CA07_FRQ02
Send data (TE18-19)	It is a critical function bridging the data lake and the actor's system. It converts retrieved data into a compatible format, facilitating seamless integration and utilization.	- TE19_CA05_FRQ01 - TE19_CA07_FRQ01
Start data acquisition process (TE18)	This function takes charge of data collection. It initiates data gathering to create a new report when an up-to-date version is absent, ensuring current and accurate information.	- TE18_CA11_FRQ01
Complete data acquisition (TE18)	It is a pivotal ETL function. It transforms collected data into a decision support system dashboard-friendly format, enabling informed, data-driven decisions.	- TE18_CA11_FRQ01

Table 52: Municipal Data Exchange Interface component

- Municipal Data Lake

Component Name	Component Description	NFRQ ID
Municipal Data Lake (TE18-19-23-24-26-27)	The "Data lake" is the cornerstone of comprehensive data management in our municipal ecosystem, consolidating a wealth of information concerning multimodal transport, demand analysis, and disruption management. Serving as the single point of truth, it unifies data from diverse sources, ensuring a central repository of reliable, up-to-date information. This invaluable resource facilitates data-driven decision-making, enhancing efficiency and responsiveness across the municipality's transport infrastructure, ultimately promoting seamless and effective multimodal transportation services.	- TE18_CA09_NFRQ01 - TE18_CA09_NFRQ02 - TE19_CA05_NFRQ01 - TE19_CA06_NFRQ01 - TE19_CA07_NFRQ01 - TE23_CA01_NFRQ01 - TE23_CA02_NFRQ01 - TE23_CA04_NFRQ01 - TE24_CA02_NFRQ01 - TE26_CA03_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Data Collection & Preparation (TE18-19)	Function plays a vital role within our data lake, meticulously gathering and formatting data for seamless transmission to the ETL/API in the	- TE19_CA05_FRQ01 - TE19_CA06_FRQ01 - TE19_CA07_FRQ01

	required, standardized format. This function ensures efficient data flow for further processing and analysis.	
Data validation (TE18-19-27)	is a crucial function within our data lake's data uploading pipeline. It meticulously checks data integrity, ensuring it meets quality standards and maintains consistency throughout the system.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Metadata creation (TE18-19-27)	is an essential component of our data lake's data uploading pipeline. It furnishes vital metadata, enriching the data lake with contextual information crucial for effective data management and retrieval.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Data processing and storage (TE18-19-27)	is a pivotal step in our data lake's data uploading pipeline. This function expertly transforms validated data, enriching it with metadata, and prepares it to adhere to data lake standards. It ensures efficient, standardized storage for streamlined accessibility and analysis.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Completion report (TE18-19-27)	Function serves as a concluding function within our data lake's data uploading pipeline. It provides a critical success or failure message, reflecting the validation result, ensuring data integrity and reliability throughout the process.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Query execution (TE18-19)	is a pivotal function within our data lake, responsible for executing pertinent queries, providing users with access to the precise data they need for informed decision-making and analysis.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Query response (TE18-19)	is a critical component within our data lake, generating tailored responses to be returned to the ETL/API. It provides the requested data, facilitating informed decision-making and data integration processes.	- TE19_CA07_FRQ01 - TE19_CA07_FRQ02 - TE19_CA06_FRQ01 - TE19_CA05_FRQ01
Collect disruption data (TE26-27)	is an integral function within data lake, offering specialized and optimized queries for accessing precise information regarding disturbances in the municipality. It streamlines data retrieval, enhancing decision-making and enabling efficient disturbance management.	- TE27_CA03_FRQ01 - TE27_CA03_FRQ02
Collect weather data (TE26-27)	is an integral function within data lake, offering specialized and optimized queries for accessing precise information regarding weather in the municipality. It streamlines data retrieval, enhancing decision-making and enabling efficient disturbance management.	- TE27_CA03_FRQ01
Timeseries processing & trimming (TE23-24)	In order to analyse the time series, an appropriate formal model will be built. The function analyses data in series, separating it and eliminating random fluctuations or errors data registration. A sudden change in values can	- TE23_CA01_FRQ01 - TE23_CA01_FRQ02 - TE24_CA01_FRQ01 - TE24_CA01_FRQ02

	also be detected.	
Topology processing (TE23-24)	Topology processing is used to obtain the internal data consolidated model for all data types (passenger traffic, weather etc.) In addition, topology processing can be used to retain information about neighbouring stations for inflow and outflow analysis.	- TE23_CA02_FRQ01 - TE23_CA04_FRQ01 - TE24_CA02_FRQ01 - TE24_CA04_FRQ01
Ticketing data processing (TE23-24)	Processing data on ticket sales for specific railway connections (lines) in order to determine the starting and ending points of travel routes and passenger traffic at stations.	- TE23_CA02_FRQ01
Weather data processing (TE23-24)	Analysis of weather data to determine its impact on passenger traffic. Finding data from weather stations closest to railways and stations	- TE23_CA01_FRQ03 - TE24_CA01_FRQ03
Dataset processing (TE23-24)	Preparing a dataset for the needs of current prediction	- TE23_CA02_FRQ03 - TE23_CA04_FRQ02 - TE23_CA04_FRQ03 - TE23_CA05_FRQ01 - TE23_CA05_FRQ02 - TE24_CA02_FRQ02

Table 53: Municipal Data Lake component

- Optimization software

Component Name	*Component Description*	*NFRQ ID*
Optimization software (TE26)	This software collects the current timetable data to be processed by means of a mixed integer linear programming model. After implementing the optimization algorithms, it returns as an output translation times to alter the initial timetable and generate an optimized one.	- TE26_CA01_NFRQ01 - TE26_CA02_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Data ingestion & current connections computation (TE26)	After collecting the timetable data from the database, it processes and analyses the data to calculate the current connection times and number of connections.	- TE26_CA01_FRQ02 - TE26_CA02_FRQ03
Optimization (TE26)	It implements complex mathematical algorithms to determine the translation times that return optimal connection times, therefore generate an optimized timetable.	- TE26_CA01_FRQ02 - TE26_CA02_FRQ03

Table 54: Optimization software component

- OSDM Distributor Service

Component Name	*Component Description*	*NFRQ ID*
OSDM Distributor Service	The OSDM Distributor Service in this case is combining the distributor and the carrier service	- TE18_CA02_NFRQ01 - TE18_CA02_NFRQ02

(TE18-19)	in OSDM terms and facilitates distributed booking. The roles "Distributor" and "Carrier" can be separated, but for the FP1 demonstrators the same service is combine both roles.	- TE18_CA03_NFRQ01 - TE18_CA03_NFRQ02 - TE19_CA02_NFRQ01 - TE19_CA02_NFRQ02 - TE19_CA02_NFRQ03
Function Name	***Function Description***	***FRQ ID***
Create Offer (TE18-19)	After receiving an offer request from another OSDM Distributor Service, the OSDM Distributor Service creates an offer according to the given Journey Details and Passenger Information.	- TE18_CA02_FRQ01
Pre-Book Offer (TE18-19)	Prebook an offer previously obtained via the create offer function. Result is a prebooked booking.	- TE18_CA02_FRQ04 - TE18_CA03_FRQ01
Confirm locally and Orchestrate booking confirmation (TE18-19)	Upon receiving the request to confirm a booking the OSDM Distributor service does it locally for the offers the came from itself and orchestrates the booking confirmation requests toward other OSDM Distributor Services.	- TE18_CA03_FRQ01
Pre-book locally and orchestrate pre-booking (TE18-19)	Upon receiving the request to reserve an offer, the OSDM Distributor Service does it locally for the offers that came from itself and orchestrates the pre-booking requests toward other OSDM Distributor Services.	- TE18_CA03_FRQ01
Combining Offers (TE18-19)	Upon receiving a request for Offers according to Journey Details and Passenger Information, the OSDM Distributor Service creates an offer locally and orchestrates the offer requests toward other OSDM Distributor Services.	- TE18_CA02_FRQ02
POST booking (TE18-19)	When requested by another OSDM Distributor Service with a POST booking request, the OSDM Distributor Service confirms a prebooked booking.	- TE18_CA03_FRQ01
Finalize fulfilment (TE18-19)	During the process of booking confirmation, the OSDM Distributor Service may finalize the fulfilments (tickets). Even before it is ultimately created, the OSDM Distributor Service responds with the confirmed booking.	- TE18_CA03_FRQ02 - TE19_CA02_FRQ01 - TE19_CA02_FRQ02
Provide fulfilment document (TE18-19)	After the successful booking confirmation which also optionally lead to the finalisation of the fulfilment, the OSDM Distributor Service may provide the fulfilment document (ticket) at a later stage.	- TE18_CA03_FRQ02

Table 55: OSDM Distributor Service component

- Prediction Model

Component Name	***Component Description***	***NFRQ ID***
Prediction Model (TE23)	The Prediction Model is a deep recurrent neural network that allows the prediction of short-term	- TE23_CA02_NFRQ01

	future demand based on the latest data received. The Model must be trained with historical data. For prediction, since it is a recurrent model, it uses recent data acquired during a certain time interval. The data used for prediction includes the demand data itself and other variables that may influence them such as the calendar, weather, events, etc.	
Function Name	***Function Description***	***FRQ ID***
Prediction Data (TE23)	After training the model by using historical data, it receives the demand data and the rest of the variables from the last periods during a specific time interval and obtains the demand for the following period.	- TE23_CA02_FRQ01
Model ready for prediction (TE23)	The model, once trained from historical data, is ready to make predictions. The model can be continually updated when it receives new data.	- TE23_CA02_FRQ01

Table 56: Prediction Model component

- Predictor

Component Name	***Component Description***	***NFRQ ID***
Predictor (TE23)	The Predictor is responsible for receiving the information from the last time interval divided into periods, adapting it to the recurring structure and, using the Trained Model, predicting the demand for the next period. The Predictor makes the prediction every time the data corresponding to the last available period is received and makes use of the data from several periods prior to this until the time interval considered in the model is completed.	- TE23_CA02_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Prediction (TE23)	It receives data from the considered time interval divided into periods up to the last available period, adapts it to the recurring data structure and predicts the demand for the next period.	- TE23_CA02_FRQ02

Table 57: Predictor component

- Punctuality Estimator

Component Name	***Component Description***	***NFRQ ID***
Punctuality Estimator (TE26)	This system contains a model built by means of a programming language which collects timetable and punctuality data and, after processing them, gives as an output punctuality indicator to be referred to alter the initial timetable.	- TE26_CA02_NFRQ02

Function Name	Function Description	FRQ ID
Data collection & analysis (TE26)	After collecting the timetable and historical punctuality data from the database, it processes and analyses the data to estimate ex-ante punctuality.	- TE26_CA02_FRQ02
Punctuality evaluation (TE26)	After implementing prediction models and statistical methods, it returns the punctuality evaluation.	- TE26_CA02_FRQ02

Table 58: Punctuality Estimator component

- Railway Timetable Database

Component Name	Component Description	NFRQ ID
Railway Timetable Database (TE26)	This component is a railway timetable repository that collects train schedule and historical punctuality data. It employs tables to organize information, ensuring data integrity and facilitating queries.	- TE26_CA02_NFRQ03
Function Name	**Function Description**	**FRQ ID**
Timetable and historical punctuality data acquisition (TE26)	It acquires timetable and historical punctuality data and reorganizes it to facilitate processing by the estimator.	- TE26_CA02_FRQ01
Timetable acquisition (TE26)	It acquires timetable data in GTFS format and reorganizes it to facilitate processing by the optimization software.	- TE26_CA02_FRQ01
Timetable alteration (TE26)	On the basis of the punctuality evaluation provided by the estimator, an altered timetable is proposed and stored in the database.	- TE26_CA02_FRQ01
Optimized timetable acquisition (TE26)	It acquires optimized timetable data in GTFS format and reorganizes it to facilitate post-processing and results' validation.	- TE26_CA02_FRQ01

Table 59: Railway Timetable Database component

- Retailer app

Component Name	Component Description	NFRQ ID
Retailer app (TE18-19-23-24-27)	The Retailer App is the Traveller and Purchaser facing component to interact with the MaaS Platform, OSDM Distributor Services or the Alert Communication Service. The Retailer App for Journey Planning, Incident Management, and the Occupancy Use Cases will be a different App from the App to support the booking Use Cases.	- TE27_CA07_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Build trip request	Create a Journey Planning request from the input	N/A

with inputs (TE18-19)	from the Traveller or the Purchaser.	
Display trips (TE18-19)	Display the results of the Journey Planning request.	N/A
Display trips and offers (TE18-19)	Display the results of the journey planning including the offer building via the MaaS Platform.	N/A
Request Offers (TE18-19)	As a step after the journey planning, the Retailer App enables the Traveller to request offers for a given trip while adding Passenger information.	N/A
Display Trips with occupancy forecast (TE23)	When the results of the Journey Planning request contains occupancy forecast information, it is displayed with the trips as well.	- TE23_CA04_FRQ04
Request to reserve the offer (TE18-19)	When the Purchaser selects an offer, the Retailer App requests the OSDM Distributor Service to reserve the offer (pre-booking).	N/A
Display Alert (TE23-24-27)	Upon receiving an Alert from the Alert Generation Service, the Retailer App displays the alert to the Traveller.	N/A
Request alternative trip (TE23-24-27)	The Traveller is capable of requesting Journeys that avoid high occupancy.	- TE27_CA07_FRQ01
Request booking confirmation (TE18-19)	When the Purchaser confirms the booking of the previously selected and reserved offer via the Retailer App, the Retailer App requests the booking from the Offer from the OSDM Distributor Service of the system.	N/A

Table 60: Retailer app component

- Robot

Component Name	*Component Description*	*NFRQ ID*
Robot (TE20-22)	The Robot would help persons with disabilities to reach, for example, the correct gates and/or to transport their luggage in the station hall (indoor navigating). The internal robot's system includes indoor mapping of the stations' hall to ensure reliable navigation guidance.	- TE20_CA01_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Indoor assistance (TE20-22)	Persons with disabilities can book a robot to help them to get oriented and reach, for example, correct gates, bathrooms, etc. It can also help them to transport luggage.	- TE20_CA01_FRQ02

Table 61: Robot component

- RTLS Location Service

Component Name	Component Description	NFRQ ID
RTLS Location Service (TE20-21)	The RTLS (Real Time Location Service) is a cloud service dedicated to the identification and positioning of UWB wearables. The RTLS uses the information transmitted UWB Anchors installed in the station that receives the wireless signal from the wearables. The RTLS publishes the computed positions. This is done during a navigation phase where the passenger moves in a positioning area covers by the Anchors. Anchors in the station are connected to a communication network infrastructure that allows the forwarding of the signals to the RTLS cloud service.	- TE21_CA01_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Calculate position (TE20-21)	For UWB wearables detected in the area covered by the Anchors, the RTLS calculates and updates the position using UWB TDoA (Time Difference of Arrival) technique. Positions and wearable identifiers are published to HFCS (Hands Free Control System).	- TE21_CA01_FRQ02 - TE21_CA02_FRQ05

Table 62: RTLS Location Service component

- Short term prediction Software

	Component Description	NFRQ ID
Short term prediction Software (TE23)	This component is a system that uses historical and real-time data to forecast the future short-term demand for rail transportation services.	- TE23_CA01_NFRQ01 - TE23_CA02_NFRQ01 - TE23_CA02_NFRQ02 - TE23_CA04_NFRQ02 - TE23_CA05_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Forecasting process (TE23)	The system learns short-term prediction from historical data. Model quality analysis carried out with a test set.	- TE23_CA02_FRQ01 - TE23_CA02_FRQ04
AI forecasting support (TE23)	Artificial intelligence-based forecasting tools predict passenger traffic with high accuracy.	- TE23_CA02_FRQ02 - TE23_CA02_FRQ03

Table 63: Short term prediction software component

- Situation Detector

Component Name	Component Description	NFRQ ID
Situation Detector (TE26-27)	The Situation Detector receives information on all the variables that define the behavior of the multimodal	- TE27_CA04_NFRQ01

	mobility network and compares them with the situations stored in the Situation Library to determine if it matches any of those previously defined. If they match, the current situation is identified with one of the stored situations. If it does not match, the situation is considered new.	
Function Name	***Function Description***	***FRQ ID***
Detection (TE26-27)	The Situation Detector uses the information of the variables that define the mobility situation and compares them with the variables that define the situations stored in the Situation Library to determine if it matches any of them. If the Situation Detector identifies the situation as one of those stored in the Situation Library, it declares it as an active situation and informs the rest of the system components, otherwise it declares as new.	- TE27_CA04_FRQ01

Table 64: Situation Detector component

- Situation Identifier

Component Name	***Component Description***	***NFRQ ID***
Situation Identifier (TE26-27)	The Situation Identifier generates the Situation Library. To do this, it analyses the available historical information with the variables that define the behavior of multimodal mobility and, using unsupervised learning algorithms, generates a set of situations to store in the Situations Library. Each situation is characterized by the centroids corresponding to each of the variables that define the situation.	- TE27_CA04_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Identification (TE26-27)	The Situation Identifier analyses historical data and, using a K-Means type unsupervised learning algorithm, identifies the set of situations that have occurred during the analysed interval and determines the centroids that characterize each of the situations.	- TE27_CA04_FRQ01

Table 65: Situation Identifier component

- Situations Library

Component Name	***Component Description***	***NFRQ ID***
Situations Library (TE26-27)	The Situation Library stores the situations that have been identified from the previously analysed historical data. Each situation has an associated identifier, a description (Optional) and data on the centroids of	- TE27_CA03_NFRQ01

	the variables that characterize it. The situation library is implemented on a database that also stores the historical data that defines the state of mobility. These data are expanded as new data is received.	
Function Name	***Function Description***	***FRQ ID***
Library with Situations (TE26-27)	The Situation Library manages the data that characterizes the situations. To do this, it is supported by a database that allows the functions of storage, consultation and modification of data, both of the situations themselves and of historical data.	- TE27_CA03_FRQ01
Situations Supply (TE26-27)	Once a situation has been identified and its execution activated, the information is provided to the Situation Detector.	- TE27_CA03_FRQ01

Table 66: Situations Library component

- Strategic Manager

Component Name	***Component Description***	***NFRQ ID***
Strategic Manager (TE26-27)	The Strategic Manager oversees identifying the situations that occur in multimodal mobility and activating strategies that carry out the most appropriate management of mobility, adapting to the needs of each of the situations. It is made up of components for the identification of situations from historical data (Situation Identifier), management of situations (Situation Library), identification of the current situation with one of the Situation Library (Situation Detector) and activation of the strategy associated with the situation detected.	- TE27_CA01_NFRQ01
Function Name	***Function Description***	***FRQ ID***
Current Situation (TE26-27)	Once a situation has been identified in the Situation Library, the Strategic Manager activates the strategy associated with that situation and disseminates it to the multimodal mobility management systems so that they execute the strategy cooperatively.	- TE27_CA01_FRQ01

Table 67: Strategic Manager component

- Technical integration

Component Name	***Component Description***	***NFRQ ID***
Technical integration (TE22)	This is the process that will help to define the best technical solution to integrate equipment in the installations. This might include: gauge analysis, technical analysis of different solutions, that must comply with current standards and should be able to adapt to new ones that could emerge.	- TE22_CA01_NFRQ02 - TE22_CA04_NFRQ01

Function Name	Function Description	FRQ ID
Technical integration analysis (TE22)	Technical integration will also encompass better safety conditions for the travellers. The technical integration will also define requirements in order to display relevant data using different display patterns.	- TE22_CA02_FRQ01 - TE22_CA04_FRQ01

Table 68: Technical integration component

- Ticketing System

Component Name	Component Description	NFRQ ID
Ticketing System (TE20-21)	Component that checks the background and validity of all the information transmitted.	- TE20_CA02_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Validate ID (TE20-21)	Process through which the Back-Office checks and validates the ID information received from the validator.	- TE20_CA02_FRQ01

Table 69: Ticketing System component

- Totem T-Ais System

Component Name	Component Description	NFRQ ID
Totem T-Ais System (TE20)	It is a specific spot for people with hearing impairment, PRM, motor disability, cognitive impairment, language misunderstanding and some visual impairments and for people with no disabilities, where they can access information in the adequate format depending on the traveller.	- TE20_CA01_NFRQ02
Function Name	**Function Description**	**FRQ ID**
Building of a request order (TE20)	Totem facilitates the creation of a request of non-accessible information to the TSP and Rail Administrator Information Platform by travellers	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA02_FRQ02
Data ingestion & processing (TE20)	Totem receives non-accessible data from TSP and Rail Administrator Information Platform and process it according to the request.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA02_FRQ02
Building accessible information (TE20)	Totem transforms the non-accessible information in accessible following the specific request.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA02_FRQ02
Display general accessible information (TE20)	Totem displays the requested, received, processed and built data in an accessible personalized format.	- TE20_CA01_FRQ02 - TE20_CA01_FRQ03 - TE20_CA02_FRQ02

Table 70: Totem T-Ais System component

- Trained Model

Component Name	Component Description	NFRQ ID
Trained Model (TE23)	The Trained Model is the deep and recurrent neural network that allows the prediction of short-term demand (Next period). The model has as input the demand and the variables that influence it corresponding to a time interval divided into several periods. The Model must be initially trained from historical data, which allows establishing the relationship between the input data and the prediction results. It is possible to expand the training of the model as new historical data becomes available.	- TE23_CA04_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Model Supply (TE23)	The model allows us to relate the input variables: Demand and variables that influence it (Current and previous periods) with the result of the prediction (Future demand).	- TE23_CA04_FRQ02

Table 71: Trained Model component

- Trainer

Component Name	Component Description	NFRQ ID
Trainer (TE23)	The Trainer is responsible for processing the historical data, adapting it to the data structure required by the Prediction Model and carrying out the training process to determine the parameters that establish the relationship between the input variables and the prediction result. The Trainer must perform the initial training of the prediction model and also perform a continuous training process as new historical data is received.	- TE23_CA02_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Training (TE23)	The initial training consists of processing the available historical data to generate a model that allows the prediction of short-term demand. To carry out the training, the historical data is adapted to the structure of the recurrent prediction model. After that a continuous update allows the model to adapt to the evolution of the demand behaviour and continuously learning.	- TE23_CA02_FRQ01

Table 72: Trainer component

- Transport Data Hub

Component Name	Component Description	NFRQ ID
Transport Data Hub (TE27)	Hub that keeps the users of the transport systems informed in real time of incidents and other relevant information regarding the trips that are going to be done.	- TE27_CA01_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Data ingestion & processing (TE27)	Process through which the hub receives and process all the disruption information from the railway subsystems. They can be disruption information or updates, or terminations of disruptions.	- TE27_CA02_FRQ01

Table 73: Transport Data Hub component

- TSP and Rail Administrator information Platform

Component Name	Component Description	NFRQ ID
TSP and Rail Administrator Information Platform (TE20-22)	The information contained in the ADIF's platform is a source for different information, guiding or attending systems depending on different needs.	- TE20_CA01_NFRQ02
Function Name	**Function Description**	**FRQ ID**
Provision of non-accessible information (TE20-22)	The platform (data systems of ADIF and Metro de Málaga) provides data needed for different requests for different systems (timetables, incidents, etc.) to the system that processes it. This information is "non accessible" as it is not accessible by everyone, especially by personas with disabilities.	- TE20_CA01_FRQ03
Non accessible information data lake (TE20-22)	The information that is contained in the systems of ADIF and Metro de Málaga needed for different requests for different systems (timetables, incidents, etc.). This information is "non accessible" as it is not accessible by everyone, especially by personas with disabilities.	- TE20_CA01_FRQ03

Table 74: TSP and Rail Administrator information Platform component

- TSP Journey Planning Services

Component Name	Component Description	NFRQ ID
TSP Journey Planning Services (TE18-19)	The TSP Journey Planning Service provides the capability to provide trips to Journey Planning requests.	N/A
Function Name	**Function Description**	**FRQ ID**
Calculate Trip item solution	Provide trips as the result to a Journey Planning request.	N/A

(TE18-19)	

Table 75: TSP Journey Planning Services component

- TSP Journey Planning and Offer Services

Component Name	*Component Description*	*NFRQ ID*
TSP Journey Planning and Offer Services (TE18-19)	The TSP Journey Planning and Offer Service provides the capability to provide trips with potential offers to Journey Planning requests.	N/A
Function Name	***Function Description***	***FRQ ID***
Calculate Trip item solution (TE18-19)	Provide trips and potential offers as the result to a Journey Planning request.	N/A

Table 76: TSP Journey Planning and Offer Services component

- Validation Equipment

Component Name	*Component Description*	*NFRQ ID*
Validation Equipment (TE20-21)	An equipment that allows the user to validate a ticket purchased before the trip, via wireless signals, and allowing a frictionless passage into the stations without having any physical interaction.	- TE20_CA02_NFRQ01 - TE21_CA01_NFRQ01 - TE21_CA01_NFRQ02 - TE21_CA01_NFRQ04
Function Name	***Function Description***	***FRQ ID***
Establish BLE data link (TE20-21)	Process through which the validator device creates a secure and low-power Bluetooth connection with the user app. By establishing this connection with the user app, the UWB of the traveller's phone will be activated and ready to establish connection through UWB with the validator.	- TE20_CA02_FRQ01 - TE21_CA02_FRQ01
Generate accessory configuration data (TE20-21)	Process through which the validator generates the necessary information to be send to the user app and make possible the connection between both.	- TE21_CA01_FRQ01
Two way UWB ranging (TE20-21)	Process through which the validator starts connecting with the user application.	- TE21_CA01_FRQ01
Analyse ID (TE20-21)	Process through which the validator analyses the ID information of the ticket send by the user app.	- TE20_CA02_FRQ02 - TE21_CA01_FRQ02
Open Gate (TE20-21)	Once the ID information is validated, process through which the validator opens the gate, and the traveller can access the station.	- TE20_CA02_FRQ03

Table 77: Validation Equipment component

- Wireless devices in stations

Component Name	Component Description	NFRQ ID
Wireless devices in stations (TE20-21)	Components that are located at specific spots of a station to support the location of users within the station using different signals intensity that are received from the users via Bluetooth.	- TE20_CA01_NFRQ01
Function Name	**Function Description**	**FRQ ID**
Provide signal (TE20-21)	Process through which the devices send to the user app the different signal that they collect from the physical position of the traveller.	- TE20_CA01_FRQ02

Table 78: Wireless devices in stations component

8.3 Sequence diagrams (per use case)

Sequence diagrams define the exchanges/interactions between components. Each use case is described through a sequence diagram. Actors and components are represented by stick figures and rectangles (blue if they are not developed in the MOTIONAL project but are needed for input/output exchange, white if they are developed in the project), respectively. Functions performed by a component are represented by a green rectangle, while actions and exchanges are indicated by arrows.

8.3.1 WP20-21

- [UC-FP1-WP19-01] Journey Planning as a B2B intermodal service

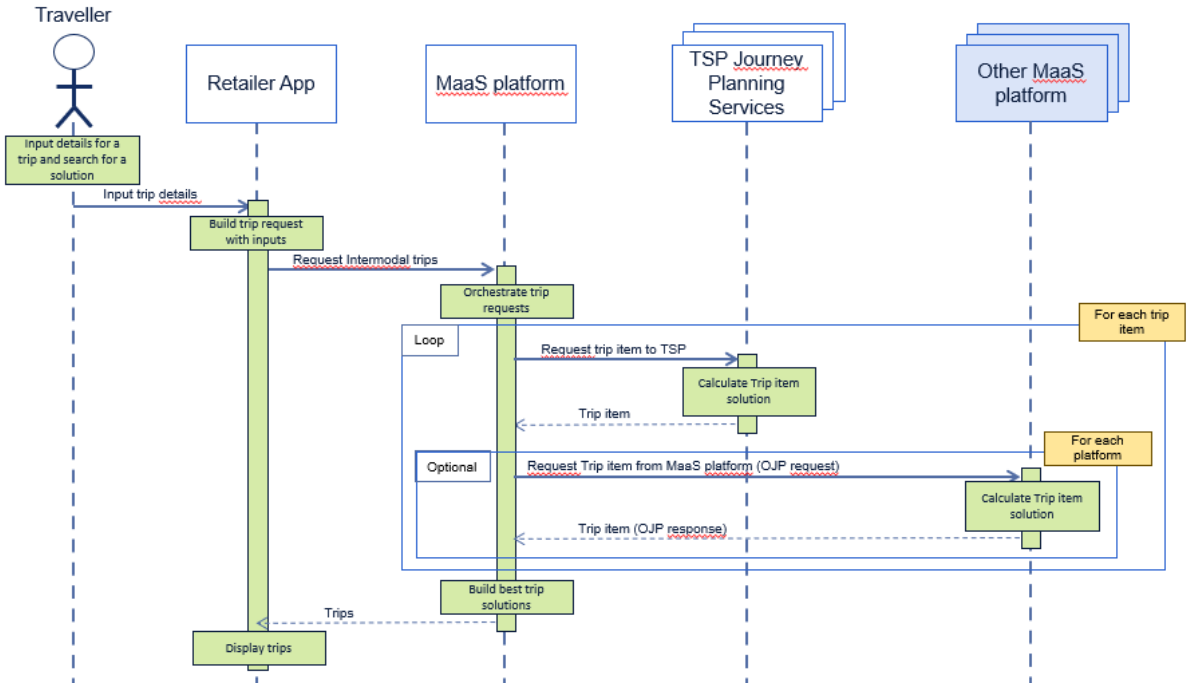

Figure 18: UC-FP1-WP19-01 sequence diagram

The Journey Planning across multiple Journey Planning Services and MaaS Platforms is initiated by the Traveller via the Retailer App which forwards this request to the MaaS Platform of the system.

The MaaS Platform orchestrates the trip requests across the integrated TSP Journey Planning Services and other MaaS Platforms by generating individual Trip Requests to these Services, aggregating the results to complete trip solutions. In the end, the MaaS Platform responds to the Retailer App with potential Trips.

- [UC-FP1-WP19-02] Retailer as ticket vendor selling a product provided by a TSP as distributor via OSDM API (1a/3 Offer Building)

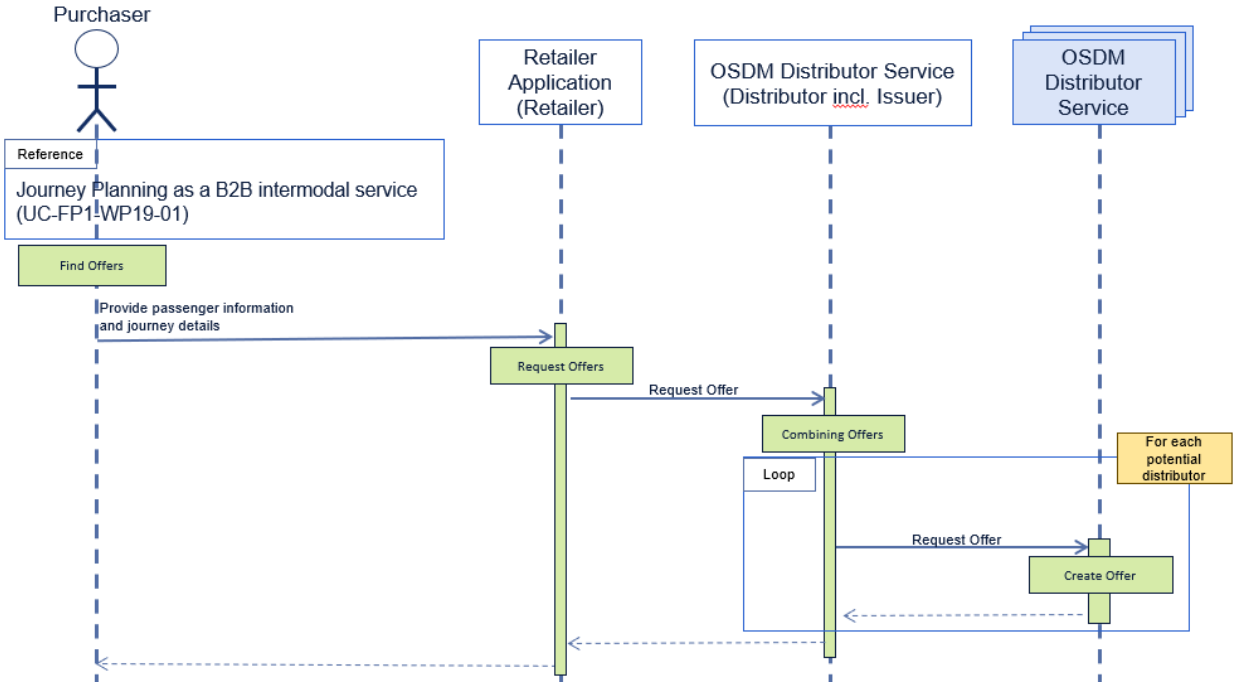

Figure 19: UC-FP1-WP19-02 (1a/3) sequence diagram

In this version of building an offer, the Purchaser chooses a previously calculated trip, and requests offers for it via the Retailer App which forwards this request to its connected OSDM Distributor Service (combining the Distributor and Issuer roles). This OSDM Distributer Service is responsible to orchestrate the offer building across other OSDM Distributor including itself which are capable of contributing offers to the trip. The combined offers are the provided to the Retailer App which presents them to the Purchaser.

The following figure illustrates the same sequence but with separated distributor and issuer components where the issuer provides offers or requests them via the distributor from external distributor services and the distributor requests and combines offers from the external distributor services.

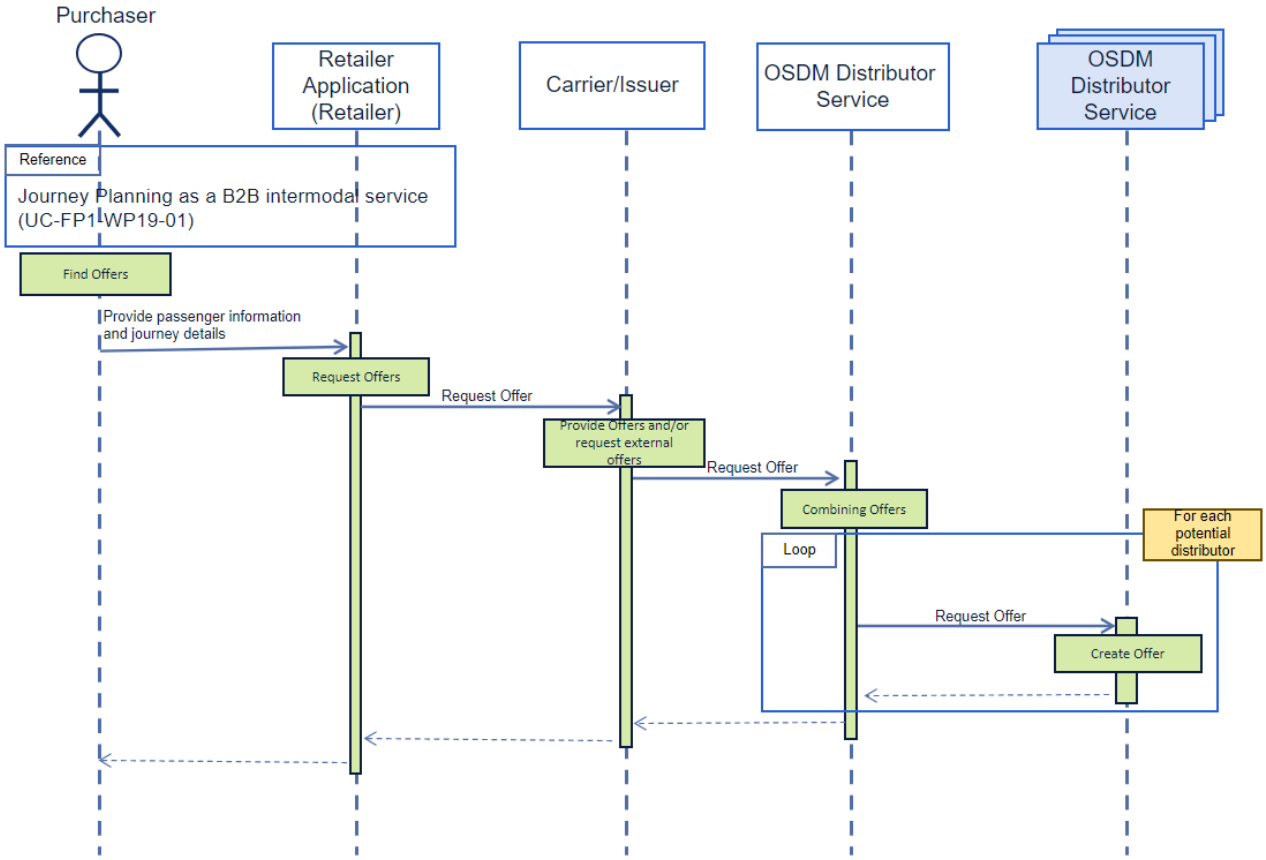

Figure 20: UC-FP1-WP19-02 (1a/3) sequence diagram with separated distributor and issuer

- [UC-FP1-WP19-02] Combined Journey Planning and Offer Building as part of the OSDM workflow (1b/3 Offer Building)

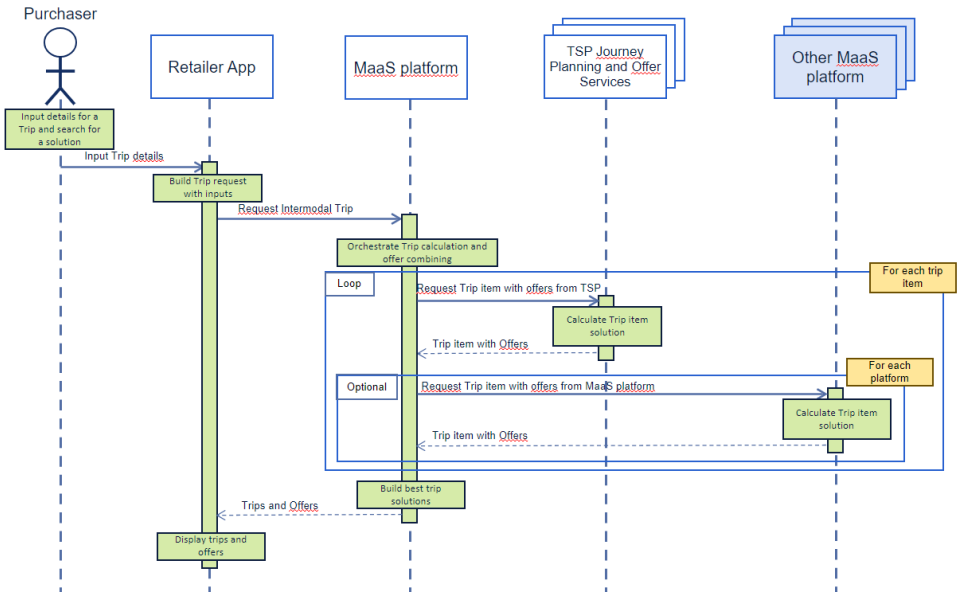

Figure 21: UC-FP1-WP19-02 (1b/3) sequence diagram

In this alternative version of building offers, the Journey Planning and Offer building is done

simultaneously. The Purchaser initiates the process via the Retailer App which forwards the request to the MaaS Platform. The MaaS Platform orchestrates the trip calculation and offer building across integrated TSP Journey Planning and Offer services and other MaaS Platforms which both provide not only their partial trip solutions but also potential offers for them in one response. The MaaS Platform aggregates the results and responds with them to the Retailer app which displays it to the Purchaser.

- [UC-FP1-WP19-02] Retailer as ticket vendor selling a product provided by a TSP as distributor via OSDM API (2/3 Offer Selection)

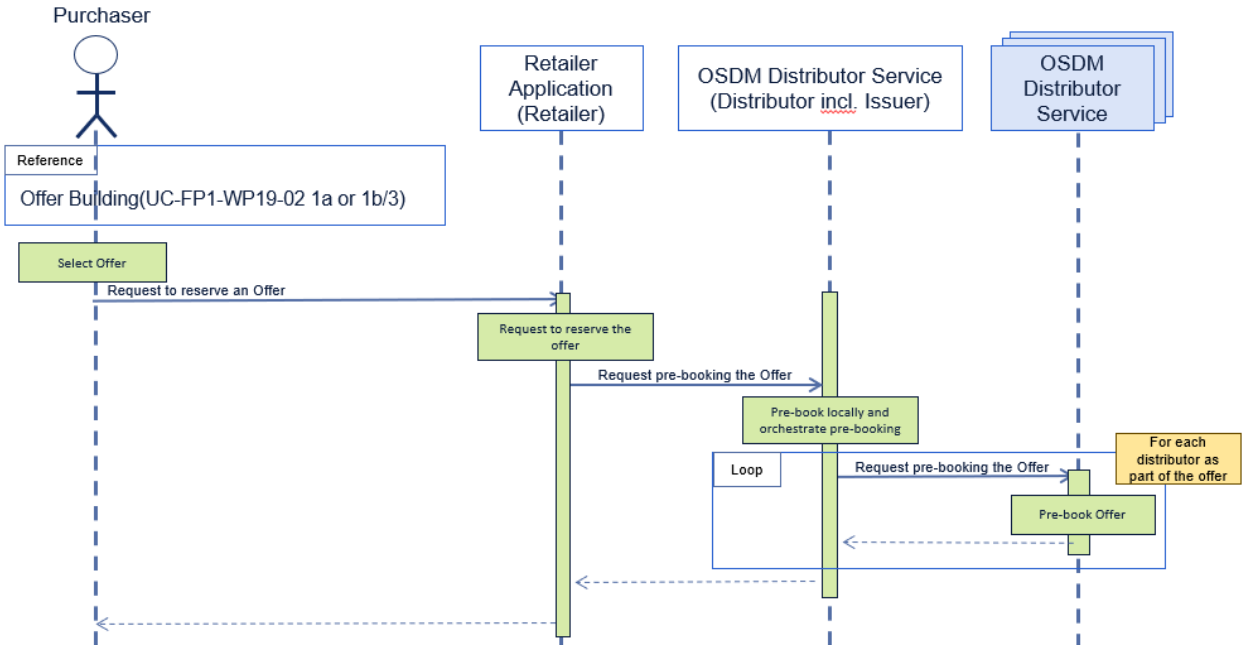

Figure 22: UC-FP1-WP19-02 (2/3) sequence diagram

After the Purchaser received the offers, the Purchaser selects one to be reserved via the Retailer App which forwards the request to its connected OSDM Distributor Service (combining the Distributor and Issuer roles). This OSDM Distributor Service pre-books its parts of the Offer locally and orchestrates the pre-booking to the other involved OSDM Distributer Services as well.

The following figure illustrates the same sequence but with separated distributor and issuer components where the issuer processes the pre-booking locally and requests the pre-booking via the distributor from external distributor services and the distributor orchestrating the pre-booking across multiple external distributor services.

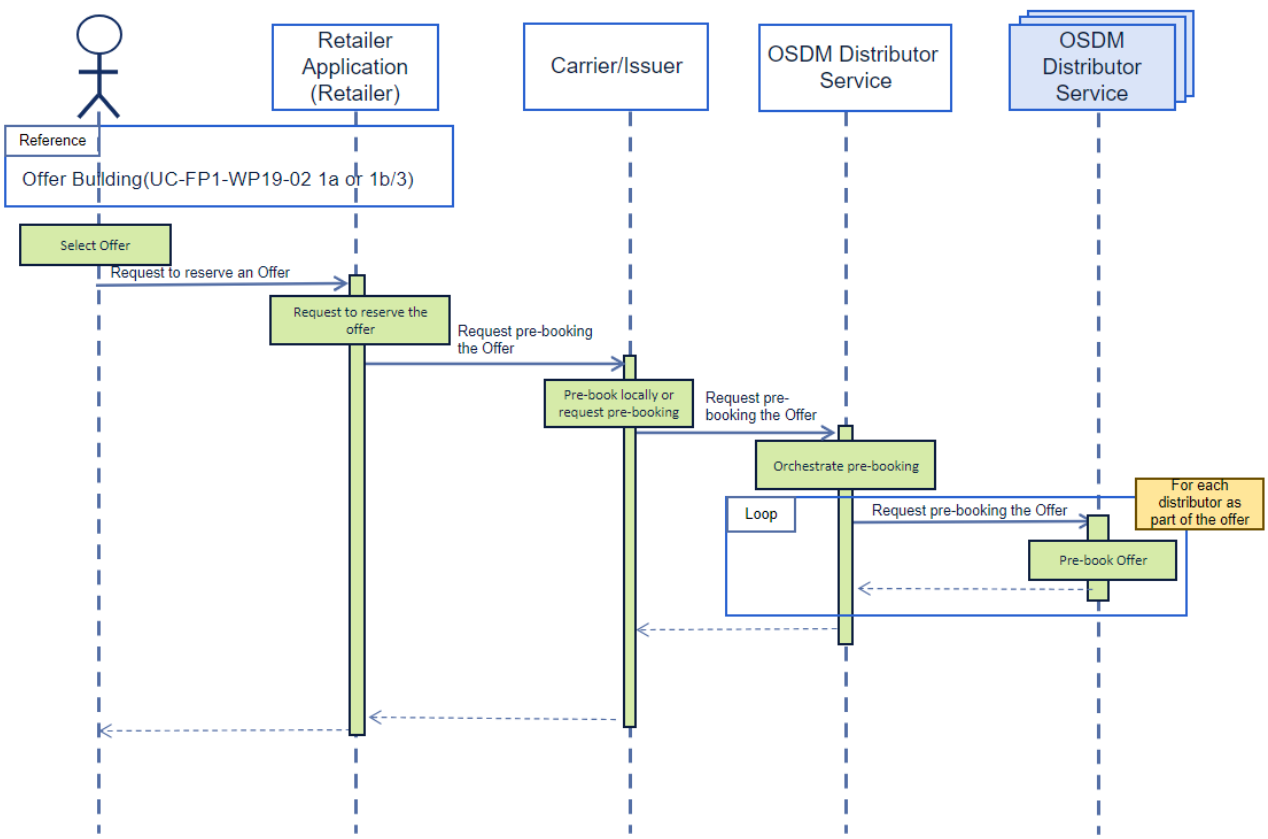

Figure 23: UC-FP1-WP19-02 (2/3) sequence diagram with separated issuer and distributor

- [UC-FP1-WP19-02] Retailer as ticket vendor selling a product provided by a TSP as distributor via OSDM API (3/3 Offer Booking)

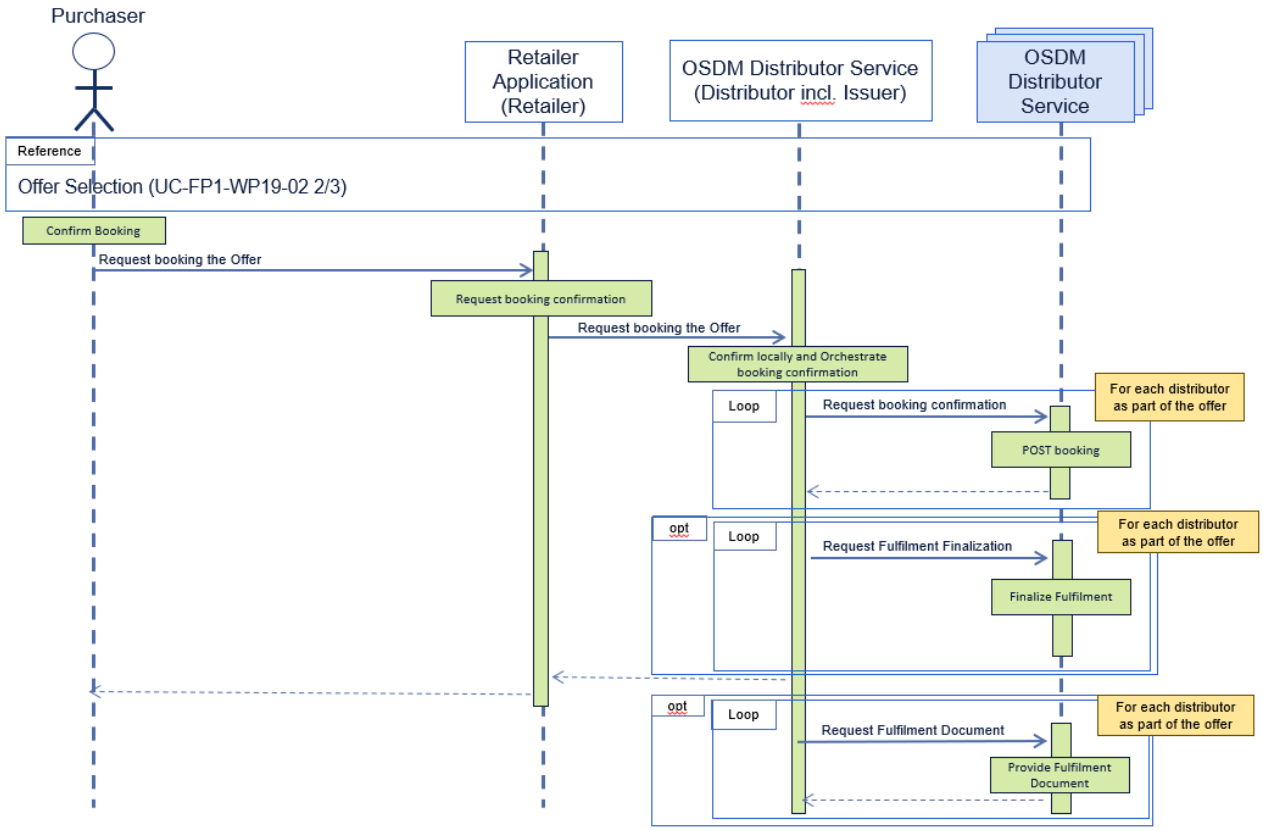

Figure 24: UC-FP1-WP19-02 (3/3) sequence diagram

After the offer was successfully pre-booked, the Purchaser can confirm the booking via the Retailer App which forwards the request to its connected OSDM Distributor Service (combining the Distributor and Issuer roles). This OSDM Distributor Service confirms the booking locally and also orchestrates the booking to other OSDM Distributor Services by first requesting the booking confirmation and then optionally also requesting the fulfilment finalisation. This fulfilment finalisation may be done asynchronously and the OSDM Distributor Service may already respond positively to the Retailer App about the successful booking of the offer. At a later point in time, the OSDM Distributor Service may retrieve the now finalised fulfilment document.

The following figure illustrates the same sequence but with separated distributor and issuer components where the issuer processes the booking locally and requests the booking via the distributor from external distributor services. The distributor confirms the local booking and orchestrates the booking across multiple external distributor services while also optionally automatically request the fulfilment finalisation and requesting the fulfilment document.

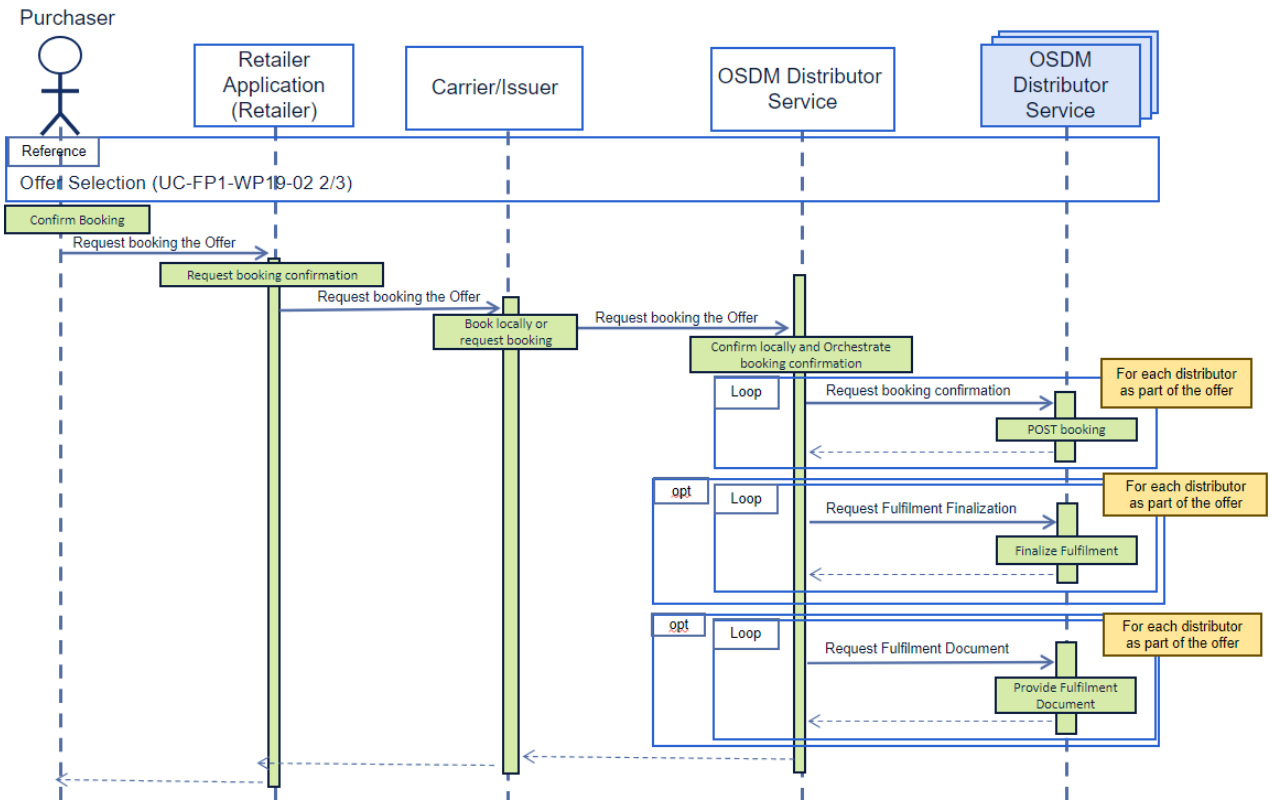

Figure 25: UC-FP1-WP19-02 (3/3) sequence diagram with separated issuer and distributor

- [UC-FP1-WP19-03] Enable TSPs to visualise mobility demand (UI)

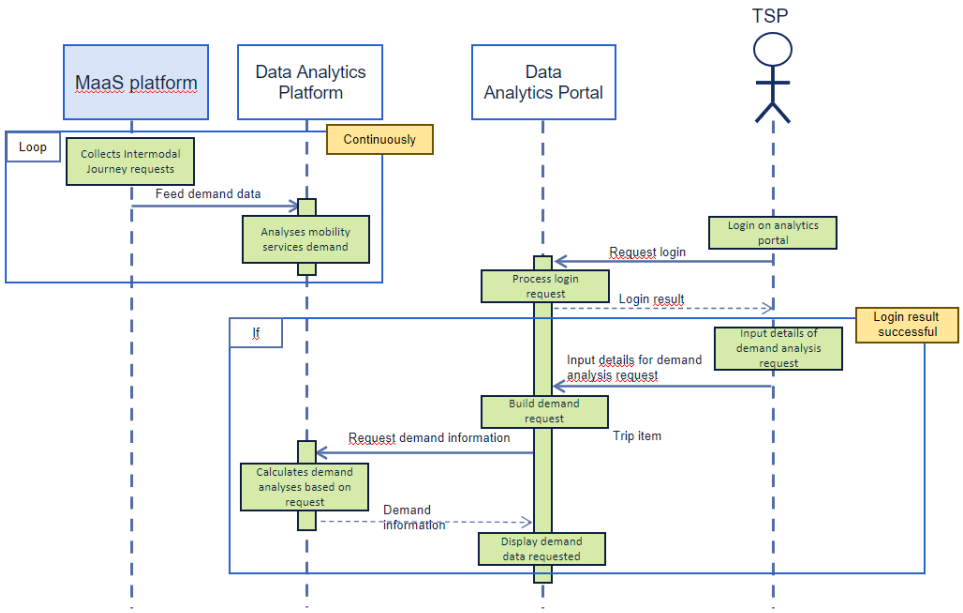

Figure 26: UC-FP1-WP19-03 sequence diagram

The Data Analytics Platform is continuously fed with the Journey Planning requests from the MaaS Platform to analyse the mobility service demand. In parallel to this data processing, a TSP representative can log in to the Data Analytics Portal which authenticates and authorises the log

in request. After a successful login, the TSP representative may request a detailed demand analysis via the Data Analytics Portal which builds the appropriate request to the Data Analytics Platform. The result from the Data Analytics Platform is then displayed via the Data Analytics Portal to the TSP representative.

- [UC-FP1-WP19-04] Financial Services. Mobility Offer apportionment

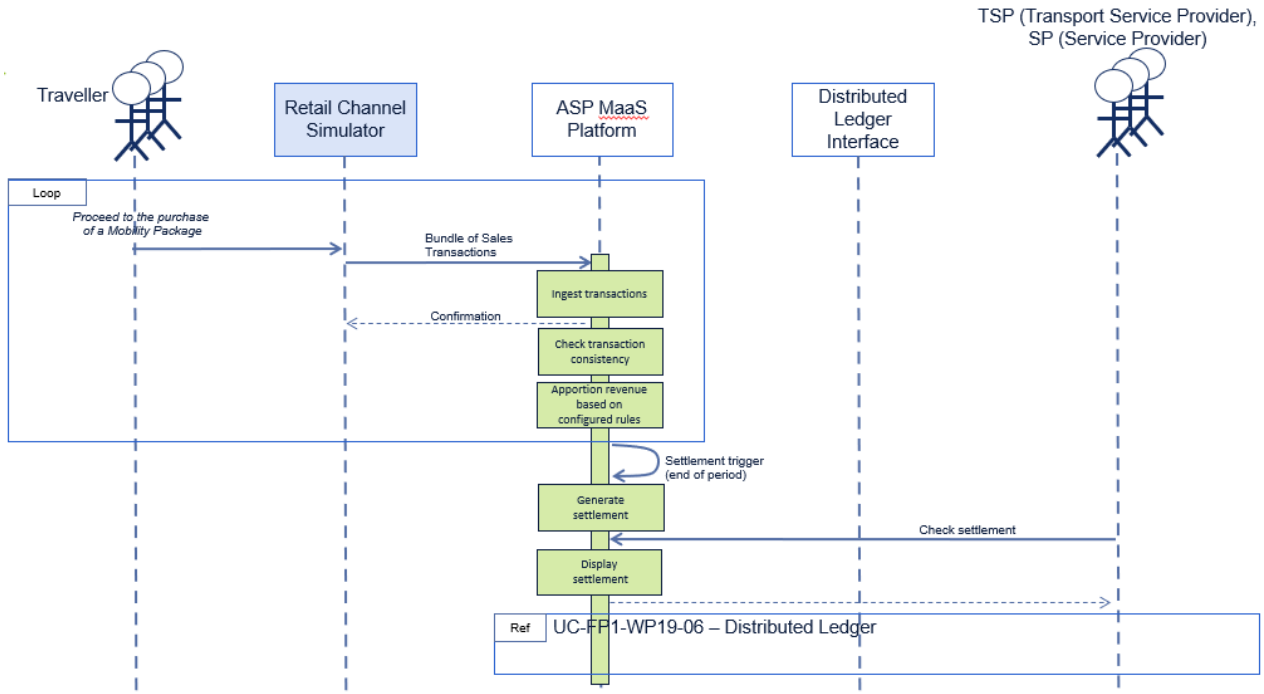

Figure 27: UC-FP1-WP19-04 sequence diagram

This sequence diagram shows the processing of Mobility Packages sales transactions by the ASP MaaS platform, the objective being to distribute and settle the revenue between business participants. On the left, travellers are purchasing offers. Here a Retail Channel Simulator is used for simulating the purchase and creating the orders. Payment is processed there but this is at the Retail Channel and excluded from the sequence. Sales transactions are sent to the ASP MaaS Platform that ingests and checks the transactions. The revenue associated with the package is apportioned. This first sequence is repeated for multiple purchases (refer to the loop frame). Then at a given point of time (end of period that could be end of day), the ASP triggers the settlement process that aggregates fund transfers between participants. The settlement is available at the ASP portal and can be checked by participants (TSP, SP on right hand side). The publishing of settlement records to the Distributed Ledger is a dedicated sequence.

- [UC-FP1-WP19-05] Financial Services. Pay as-you-go apportionment

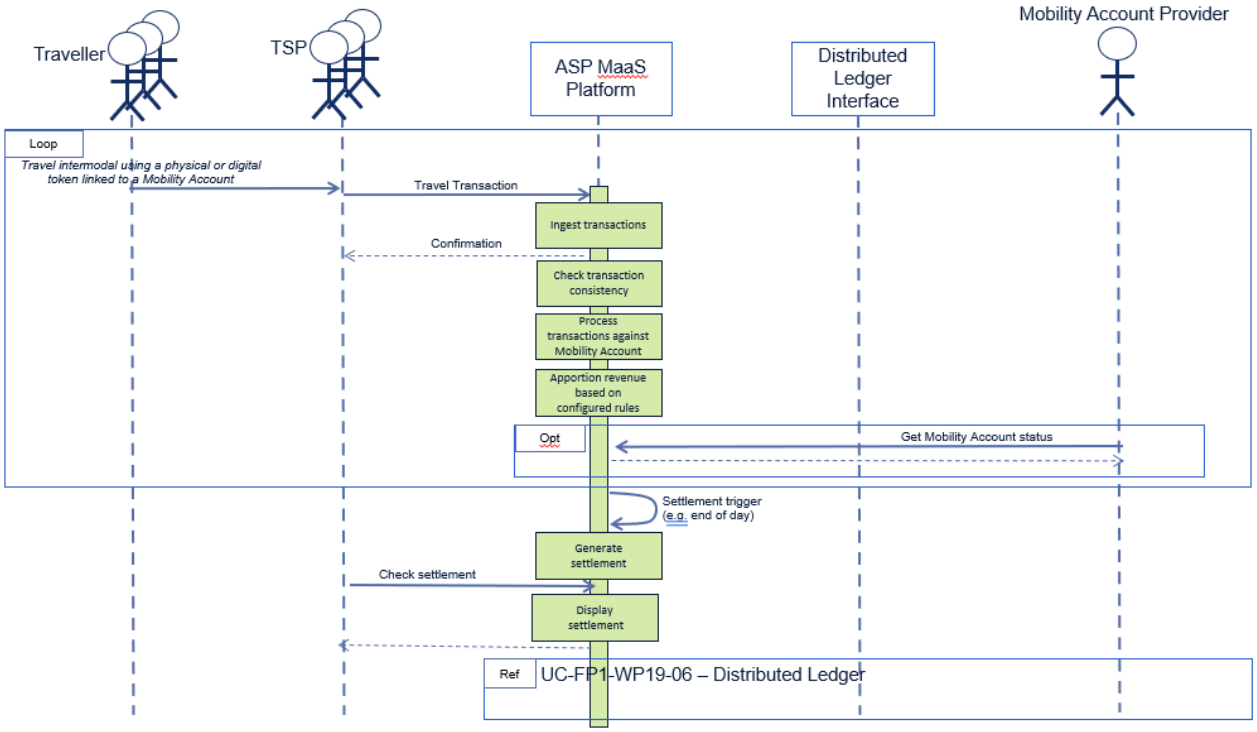

Figure 28: UC-FP1-WP19-05 sequence diagram

This sequence diagram shows the processing of travel transactions by the ASP platform, the objective being to charge intermodal travels on a Mobility Account and to apportion the revenue between business participants. On the left-hand side, Travelers do intermodal travels, validating with a physical or digital token. The acceptance infrastructure is managed by the TSP and outside of the implementation. The TSP acceptance solutions send travel transactions to the ASP. Then the ASP ingests and checks transactions. Transactions are processed against the Mobility Account managed at the ASP. Then the revenue is apportioned. This is typically a transfer from the Mobility Account to the TSP having provided the service. At this stage, the Mobility Account Provider, on the right-hand side can monitor the changes on the Mobility Account using the ASP portal. This sequence is carried out multiple time (refer to the loop frame). Then at a given point of time (end of period that could be end of day), the ASP triggers the settlement process that aggregates fund transfers between participants. The settlement is available at the ASP portal and can be checked by participants (TSP, SP). The publishing of settlement records to the Distributed Ledger is a dedicated sequence.

- [UC-FP1-WP19-06] Financial Services. Distributed Ledger

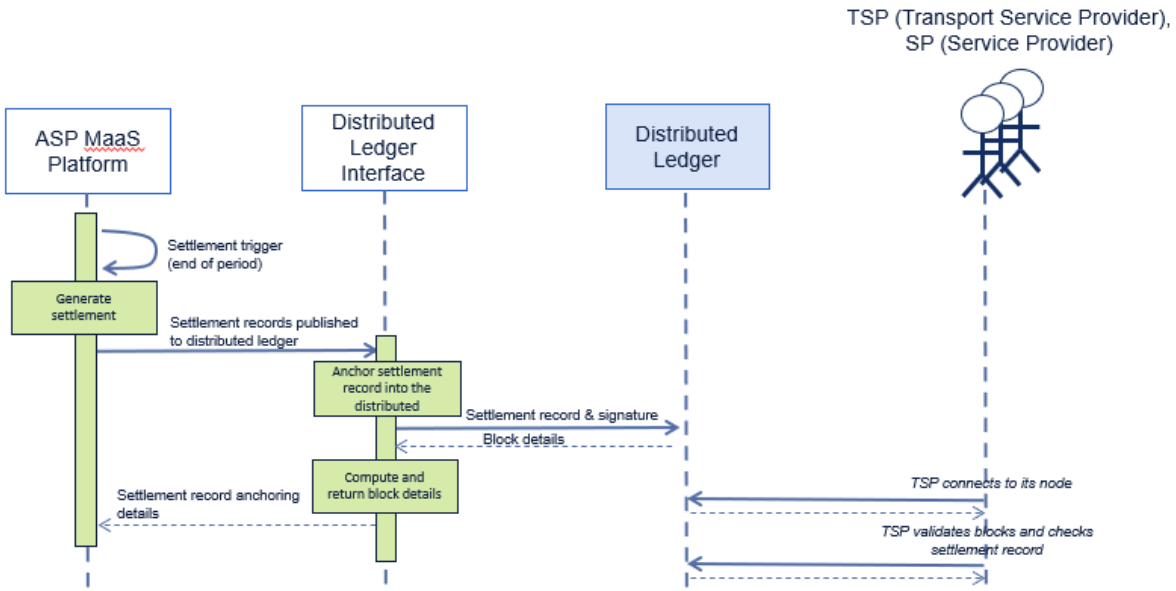

Figure 29: UC-FP1-WP19-06 sequence diagram

This sequence diagram shows the anchoring of settlement records generated by the ASP MaaS Platform into a Distributed Ledger. On the left-hand side, the ASP generates the settlements on a periodic trigger. This is fund transfers between participants and associated details. The Distributed Ledger is a block-chain based infrastructure used for managing, verifying and distributing settlement records. TSPs can have their own computing nodes allowing to check and to review settlement records. The Distributed Ledger Interface receives the settlement records and anchors them into the Distributed Ledger. Following the anchoring, the block and transaction identifiers as provided by the Blockchain as well as the signature are returned. Information is sent back to the ASP. On the right-hand side, a TSP having a computing node can check and review the settlement records.

- [UC-FP1-WP19-07] Financial Services. Processing of CEN NeTEx Fare data

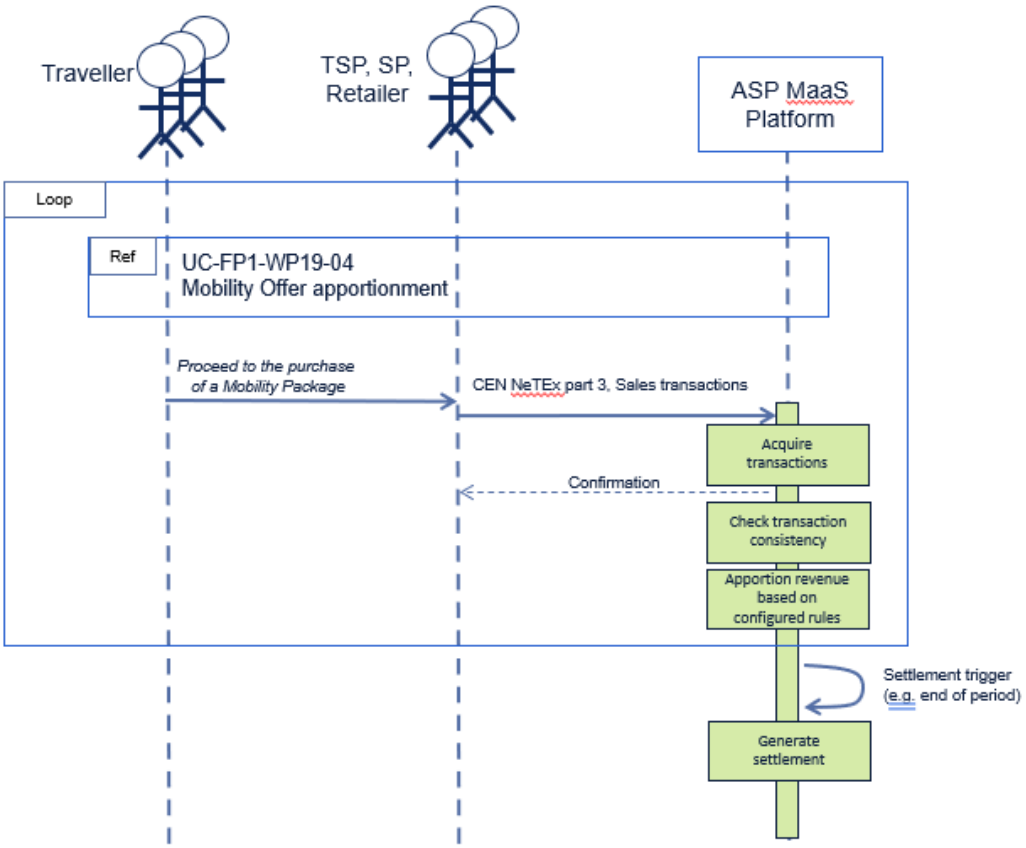

Figure 30: UC-FP1-WP19-07 sequence diagram

This sequence diagram shows the acquiring of standard sales transactions (NeTEx part 3 Sales model) by the ASP platform with the objective to apportion and to settle the revenue between business participants. On the left-hand side, a Traveler purchases a Mobility Package at a Retail Channel that generates NeTEx transactions. The ASP acquires the transactions and checks their consistency. It then apportions the revenue based on configured rules at the ASP. This sequence is carried out multiple times. Then at a given point of time (end of period that could be end of day), the ASP triggers the settlement process that aggregates fund transfers between participants. The remaining of the process (not described) is similar to Mobility Offer apportionment sequence (settlement made available to the TSP, publishing to the Distributed Ledger).

- [UC-FP1-WP19-08] Exchange of disruptions and mitigation strategies information

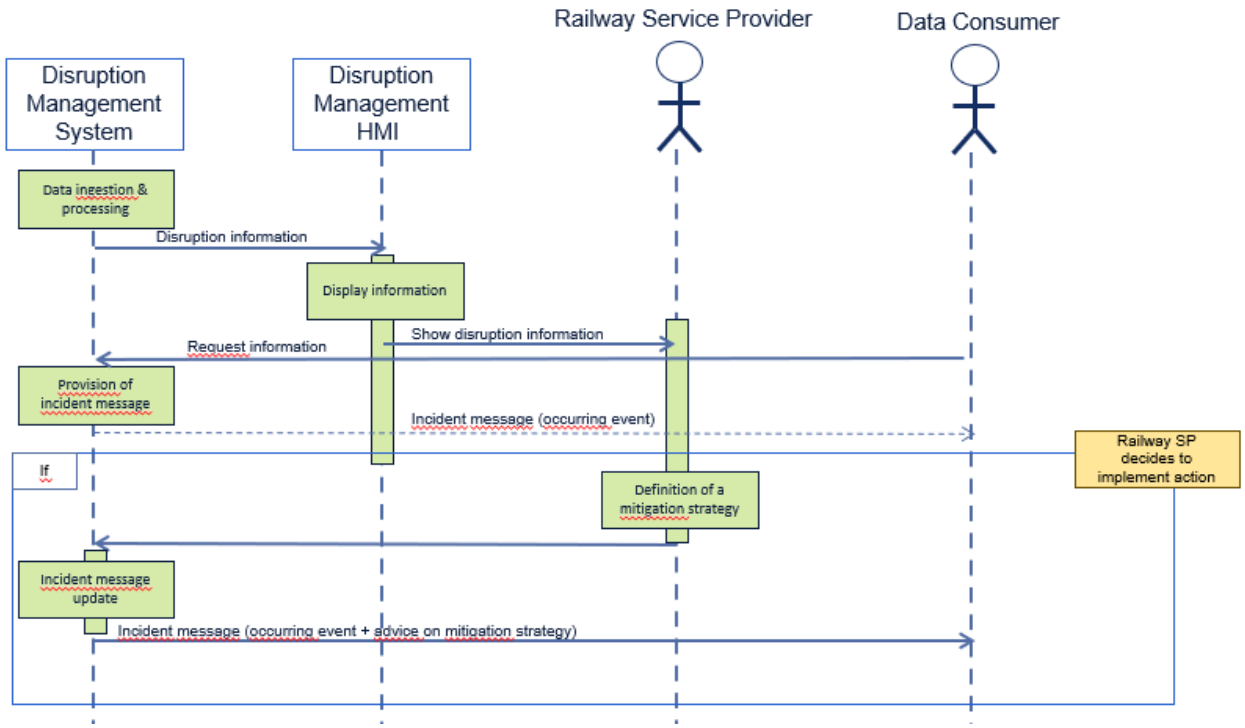

Figure 31: UC-FP1-WP19-08 sequence diagram

This sequence diagram describes the exchange of disruption information messages in a standardized data format: the SIRI Situation Exchange is used to exchange situation content in real-time; each incident can be directly linked to stop point, lines, journeys, etc. Whenever the "Disruption Management System" receives information of a disruption, that data is shown to the railway service provider via HMI. Meanwhile, an incident message can be sent to the data consumer to make aware of the event.
If the rail service provider decides to take action by implementing a mitigation action, the "Disruption Management System" updates the incident message accordingly and sends it to the data consumer.

- [UC-FP1-WP19-09] Unified multimodal information storage and update

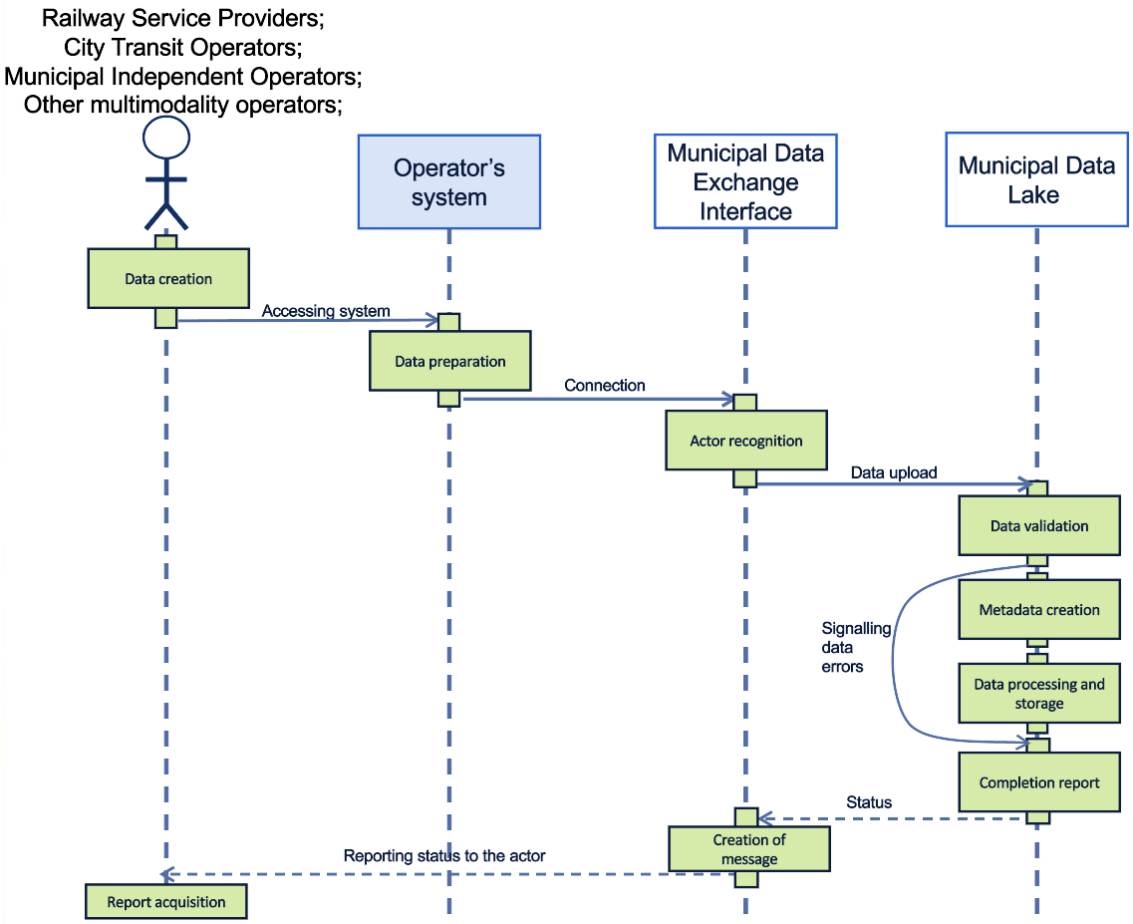

Figure 32: UC-FP1-WP19-09 sequence diagram

Multimodal transport requires municipal level analysis and treatment. Information from railway operators, public city transport operators and smaller service providers has its own local specificity.
Exchange and integration of municipal information in this aspect can be realized with one system designed for storing disparate data i.e., data lake.
Business users will be able to provide relevant information for other municipal level operators for the purpose of travel integration.
Business user (actor) has an ability to use their system to prepare data in necessary format to provide necessary travel plans. Municipal data exchange interface provides a connection layer which recognizes the actor and generates appropriate query. Municipal data lake then validates the data, and if correct generates necessary metadata and processes and stores the data. If successful (or validation detected errors) a completion report is generated and propagated through interface to the user.

- [UC-FP1-WP19-10] Accessing multimodal information data for creating multimodal travel plans between on municipal level

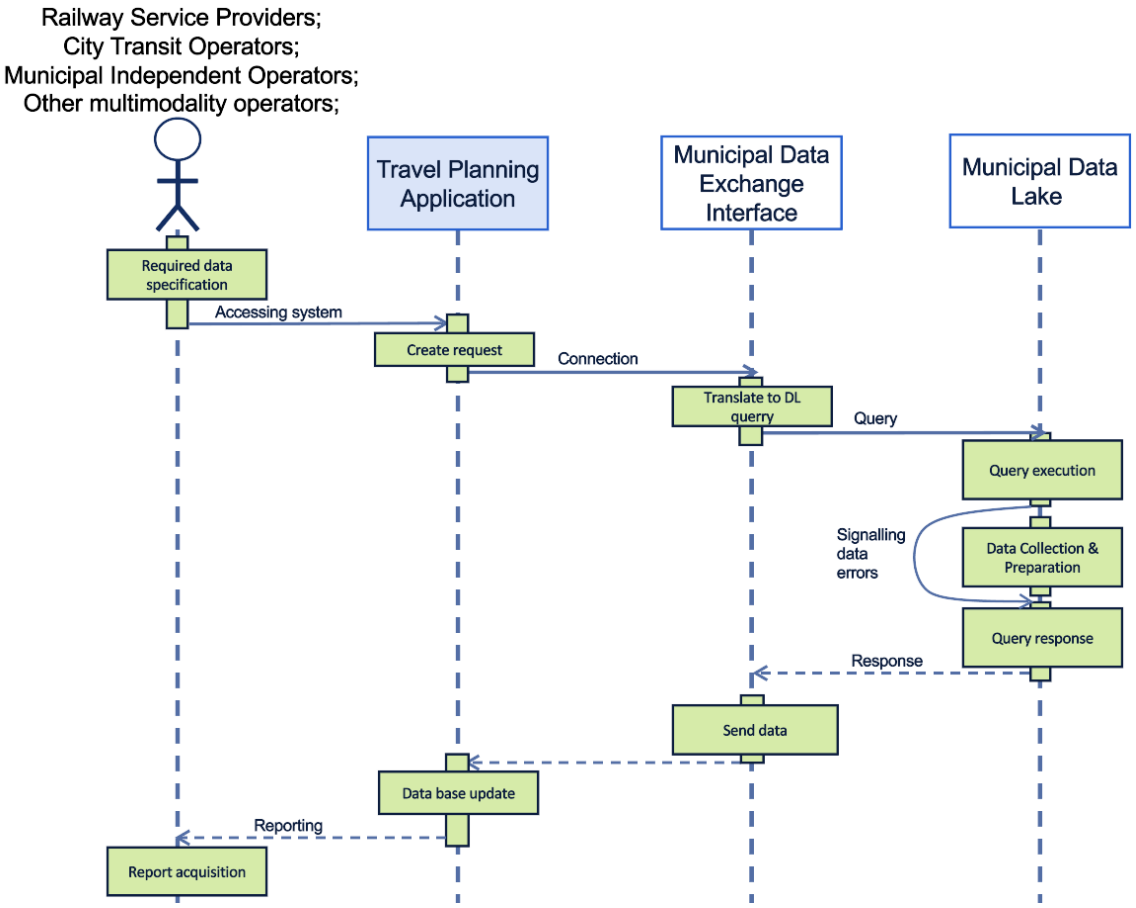

Figure 33: UC-FP1-WP19-10 sequence diagram

Multimodal transport requires municipal level analysis and treatment. Information from railway operators, public city transport operators and smaller service providers has its own local specificity. Exchange and integration of municipal information in this aspect can be realized with a one system designed for storing disparate data i.e., data lake.
This can be used to exchange complete travel plans from one municipality to another. A Travel planning application (B2B partner) can access unified data lake to obtain verified data for their application.
Actor specifies what kind of information is needed and using their Travel Planning Application creates a necessary request to obtain data via Municipal Data Exchange Interface which translates it to a DL query which is then executed by Data Lake. If no errors are found Data is collected and a response query sends data via interface. Actor's database is updated, and actor is informed by a necessary report.

- [UC-FP1-WP19-11] Support for multimodality related decisions for station operator

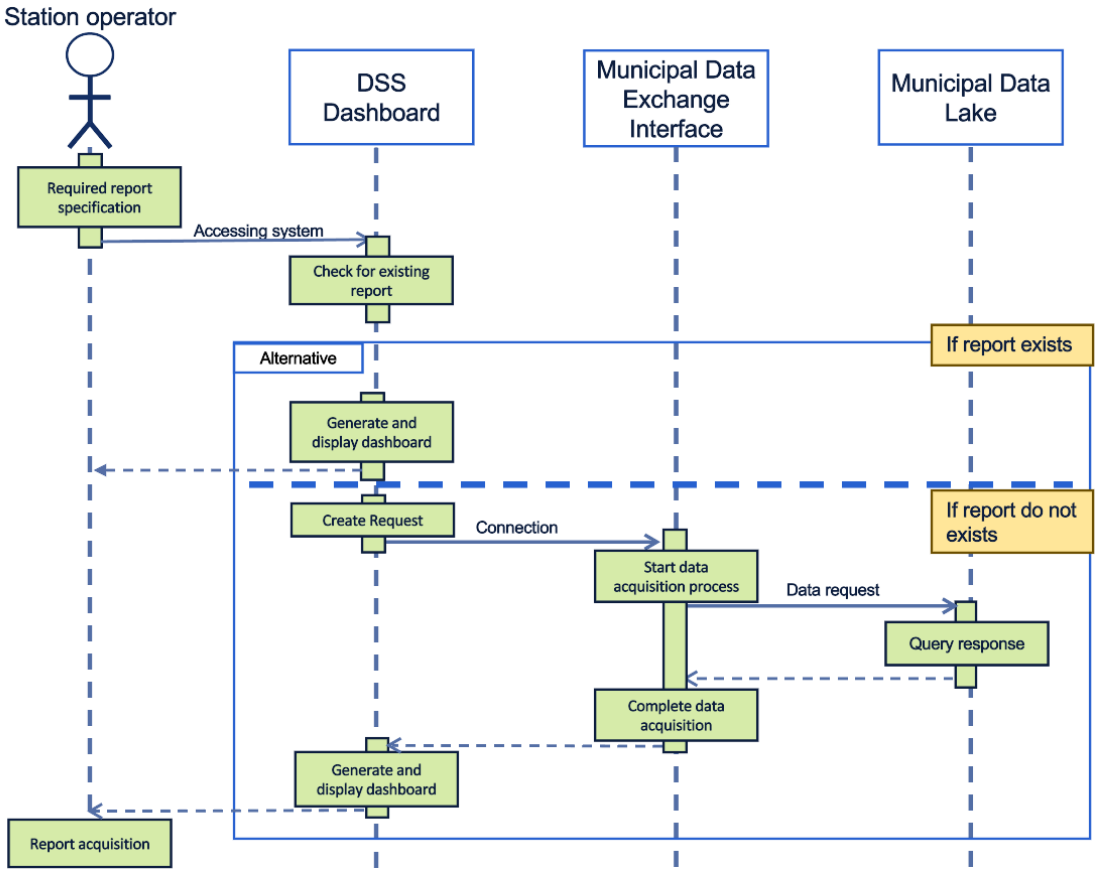

Figure 34: UC-FP1-WP19-11 sequence diagram

Multimodal transport availability is an important aspect when making decision regarding economic effectiveness of station operation. For ensuring effective decision-making process one needs to receive relevant data in accessible and well visualized form.
Proposed use case is based on dashboards and relevant data processing and logic for helping to make an informed decision.
For example, we can visualize areas using geographical maps available from the stations within one or more legs of a multimodal journey.
Station operator specifies the report that is needed for their decision process, and accesses DSS dashboard. Depending on existence of appropriate report it is either generated and displayed or necessary data is requested and acquired via Municipal Data Exchange Interface from Municipal Data Lake.

8.3.2 WP22-23

- [UC-FP1-WP19-12] Totem T-Ais. 1 specific spot for people with visual disability

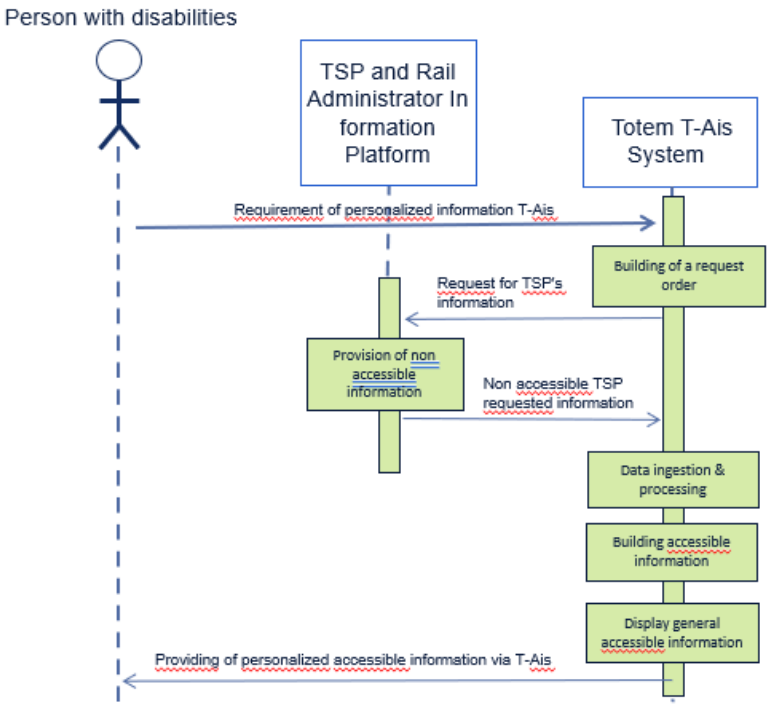

Figure 35: UC-FP1-WP19-12 sequence diagram

Totem T-Ais. 1 constitutes a specific spot where people with visual disabilities of different degrees can access useful information for their trip or better use of the services in the multimodal stations. The way the totem works is to provide specific HW and SW tools for people with visual impairment of different degrees. So, they can access the information from Transport Service Provider and Rail Administrator Information Platform that it transforms making it accessible and providing it by specific HW and SW (e.g.: loudspeaker, magnetic induction loop and others), personalising also this information according to different requests. Examples of information available are useful data for journey or accessible routes through the station.

- [UC-FP1-WP19-13] Totem T-Ais. 2 constitutes a specific spot for people with hearing impairment, PRM, motor disability, cognitive impairment, language misunderstanding and some visual impairments.

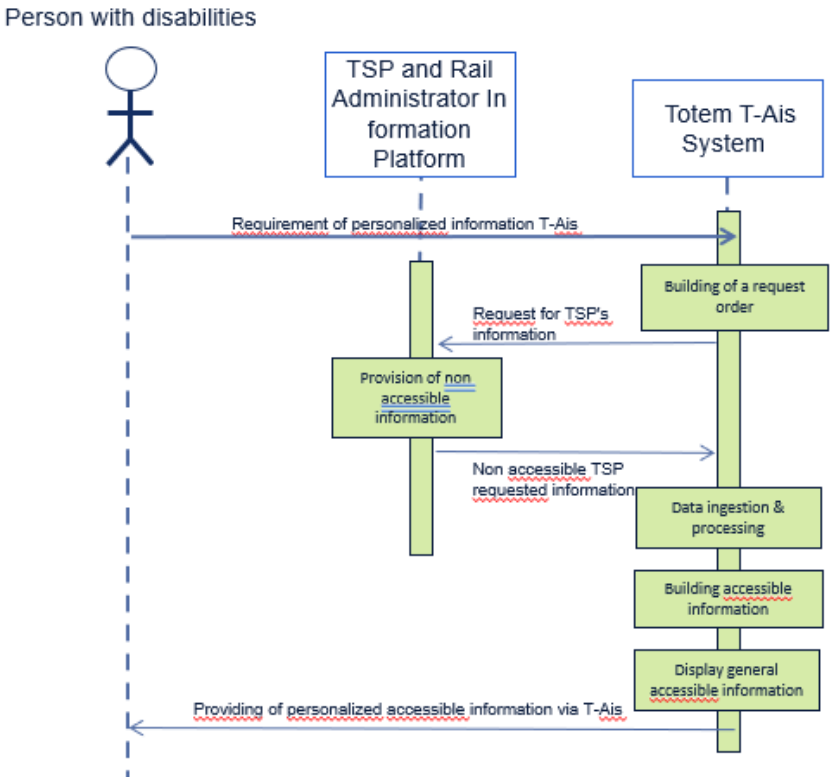

Figure 36: UC-FP1-WP19-13 sequence diagram

Totem T-Ais. constitutes a 1 specific spot where people with hearing impairment, PRM, motor disability, cognitive impairment, language misunderstanding, some visual impairments and also for people with no disabilities can access useful information for their trip or better use of the services in the multimodal stations.
The way the totem works is to provide specific HW and SW tools for people with disabilities. So, they can access the information from Transport Service Provider and Rail Administrator Information Platform that it transforms making it accessible and providing it by specific HW and SW, personalising also this information according to different requests. Examples of information available are useful data for journey or accessible routes through the station.

- [UC-FP1-WP19-14] Gap Filler

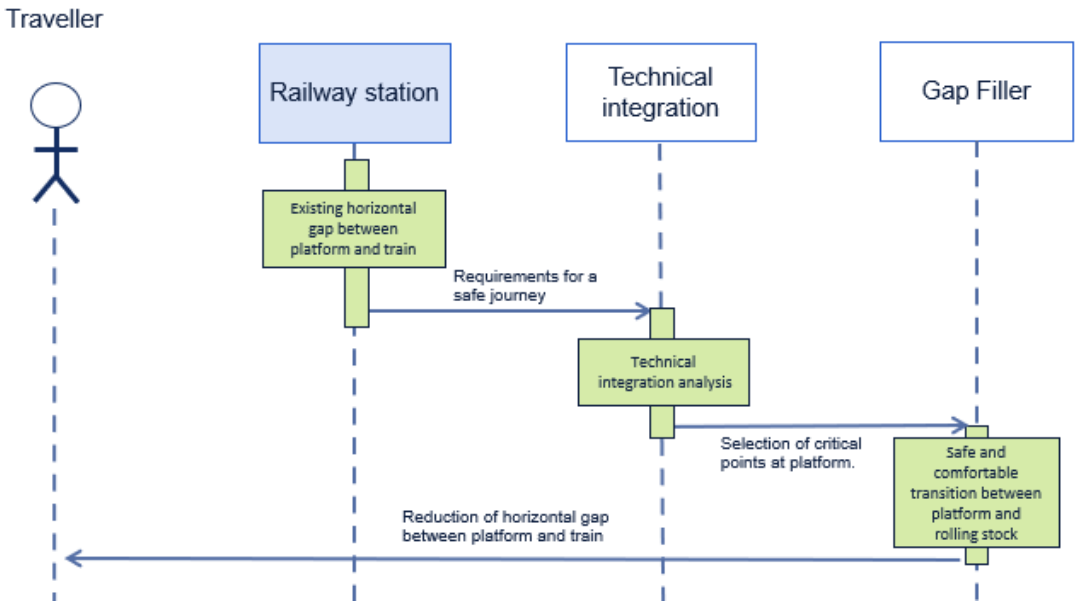

Figure 37: UC-FP1-WP19-14 sequence diagram

Currently in many railway stations there are too wide distances between the rolling stock and the platform. This means that many people may run the risk of inserting their foot between the rolling stock and the platform or falling into the gap, and in the case of persons with disabilities this risk increases drastically. Mainly, this problem occurs in curved stations.
This use case considers implementing a physical element that minimizes the distance between the rolling stock and the platform. This also implies carrying out a technical analysis to define an ideal integration into the infrastructure of this element so that it is in harmony with the rest of the functional elements of the track box and in accordance with current standards.
The results of this technical analysis will allow defining the appropriate location and dimensions of these elements and necessary conditions so that together it is a great contribution to improving the customer safety and experience of the railway network.

- [UC-FP1-WP19-15] Gobo

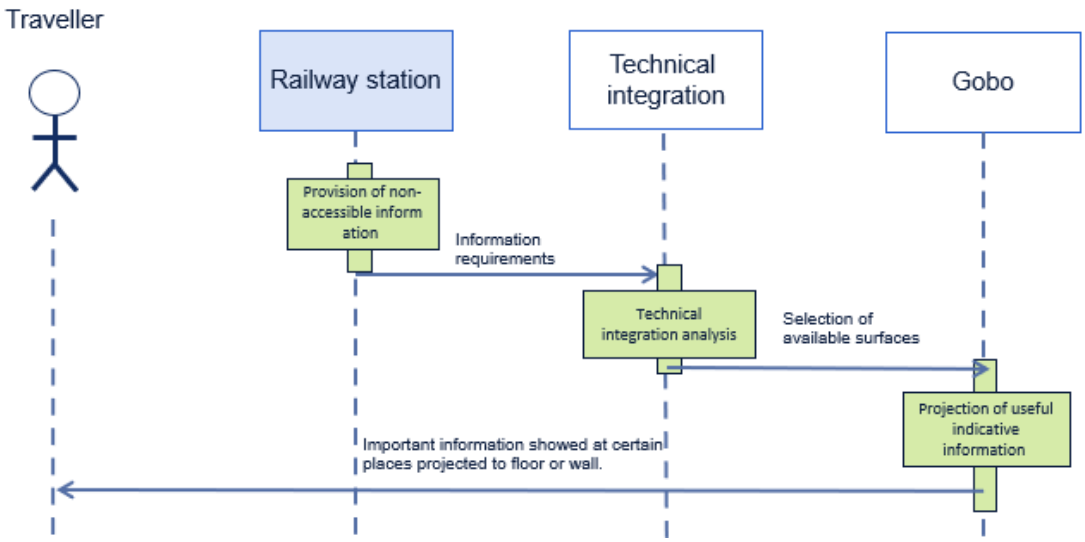

Figure 38: UC-FP1-WP19-15 sequence diagram

Gobo projects useful indicative information for travellers with or without disabilities in strategic places (walls or floor). It is essential to previously establish where to show the message or image, install then one gobo in that area, check whether the visibility is adequate or not, decide between wall or floor to redirect the light and have a test period. Non-accessible information will be provided by the Railway Station administrator, there will be a technical integration analysis to process this information that later on Gobo will project in the selected places.
In order to increase the sources of useful information in multimodal stations in places where they could contribute the most (specially in platforms), it has been proposed to use projected light sources, also called gobos.
For example, one of possible uses could be: the wheelchair icon could be projected so that PRM people can more easily locate the accessible access to the rolling stock. The projection could be done on the platform, but to prevent its visibility from being obstructed at times of high density of travellers on the platforms, it can also be projected on the wall and in this way allow the PMRs to more easily locate said accesses. So, they can position themselves before the platform fills up, thus preparing to be where it is most convenient when their train arrives.

- [UC-FP1-WP19-16] Accessible Robot

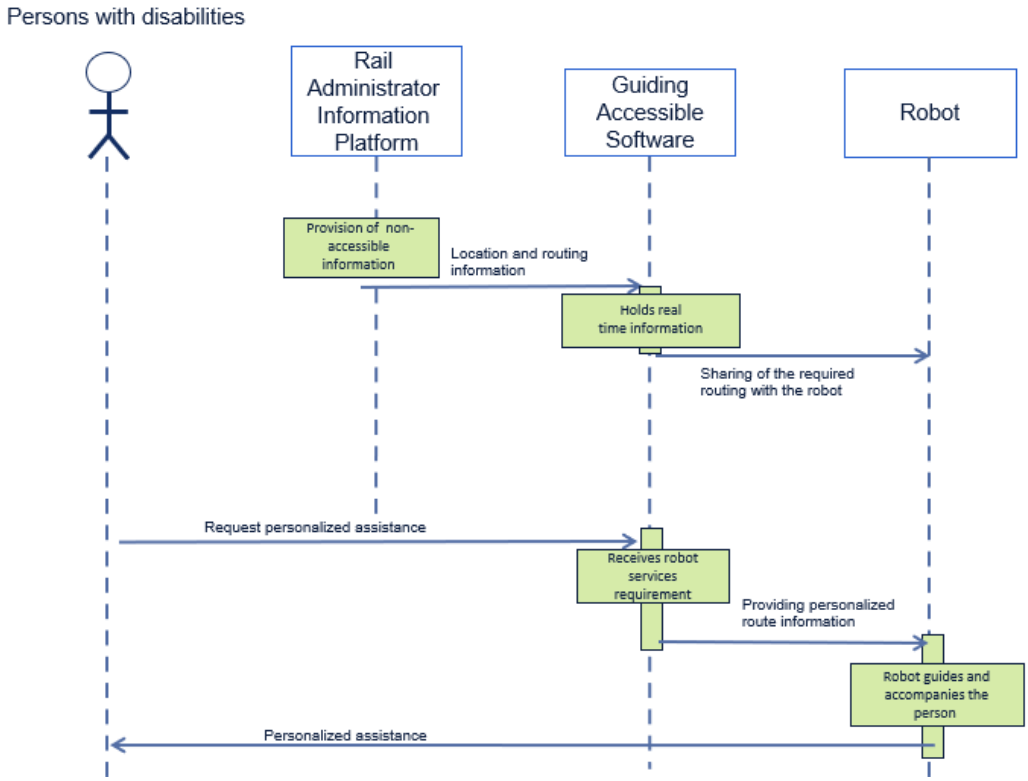

Figure 39: UC-FP1-WP19-16 sequence diagram

In this case, the aim is to use developments and equipment that have been created with the participation of people with disabilities and in this way cover their needs in the most effective way possible, covering their most critical needs and to be aligned with their reality as much as possible. This use case aims to demonstrate the operation of a robot to accompany a person who can also carry luggage. These people could have disabilities or be elderly people who need help finding their way around complex environments such as a multimodal station. The robot can help to transport luggage, as well as to guide people in the station hall to different services (entrance to check-in points, bathrooms, etc.).

- [UC-FP1-WP19-17] Guiding Accessible Software

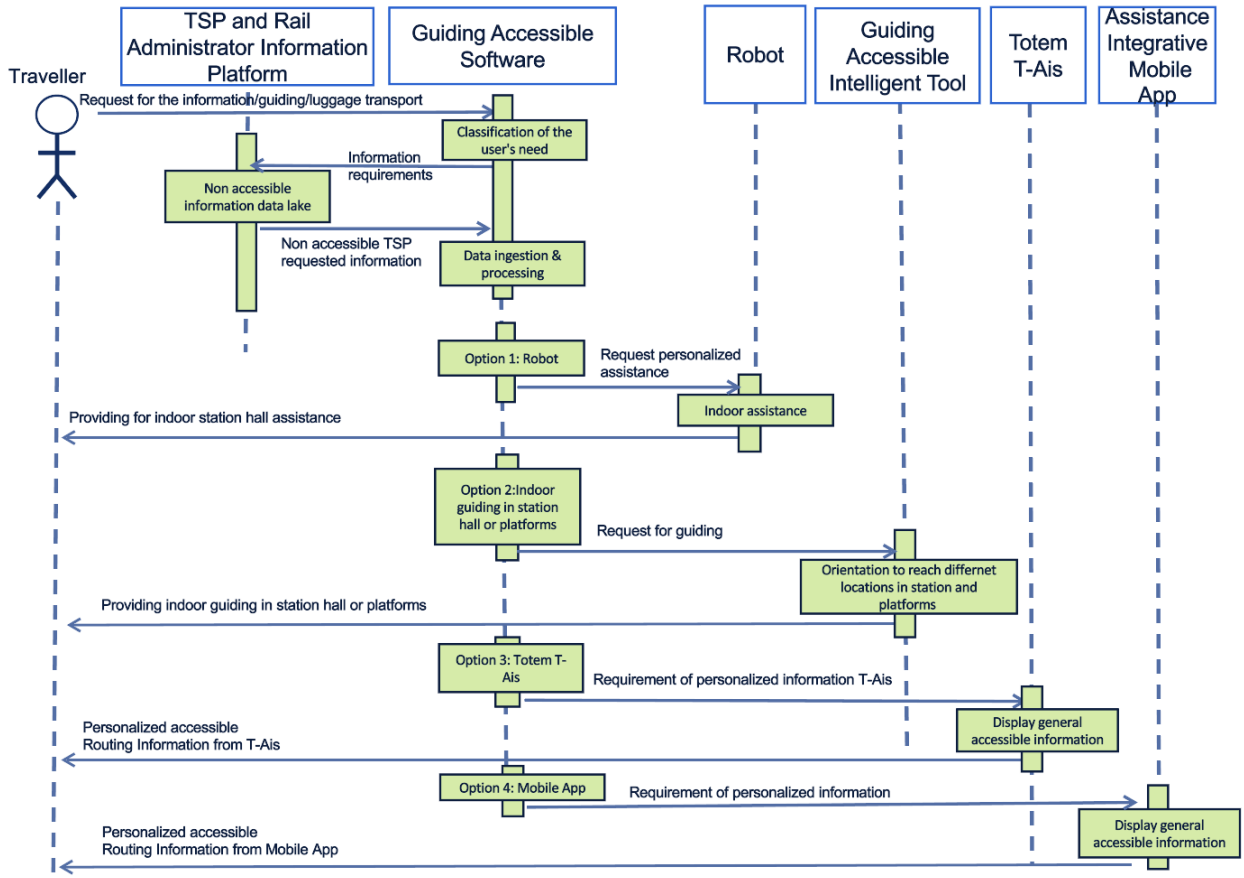

Figure 40: UC-FP1-WP19-17 sequence diagram

The objective of this Use Case is guiding any kind of traveller (specially focused to meet needs of people with disabilities) inside of a multimodal railway station. With this system travellers will be able to easily find accessible routes and information in a station in one tool that integrates different services.

Traveller will make a request for information, guiding or luggage transport through the Guiding Accessible Software. This Software will request and receive relevant information from Transport Service Provider and Rail Administrator Information Platform, also it will have integrations with some elements (such as a robot, a totem, etc.) it will process the received data and send it to the relevant element according to the passenger request: Robot, Guiding Accessible Tool, Totem T-Ais or the Mobile App. The chosen element, depending on the need of the traveller, will fulfil its task providing the personalised information or assistance.

- [UC-FP1-WP19-18] Guiding Accessible Intelligent Tool

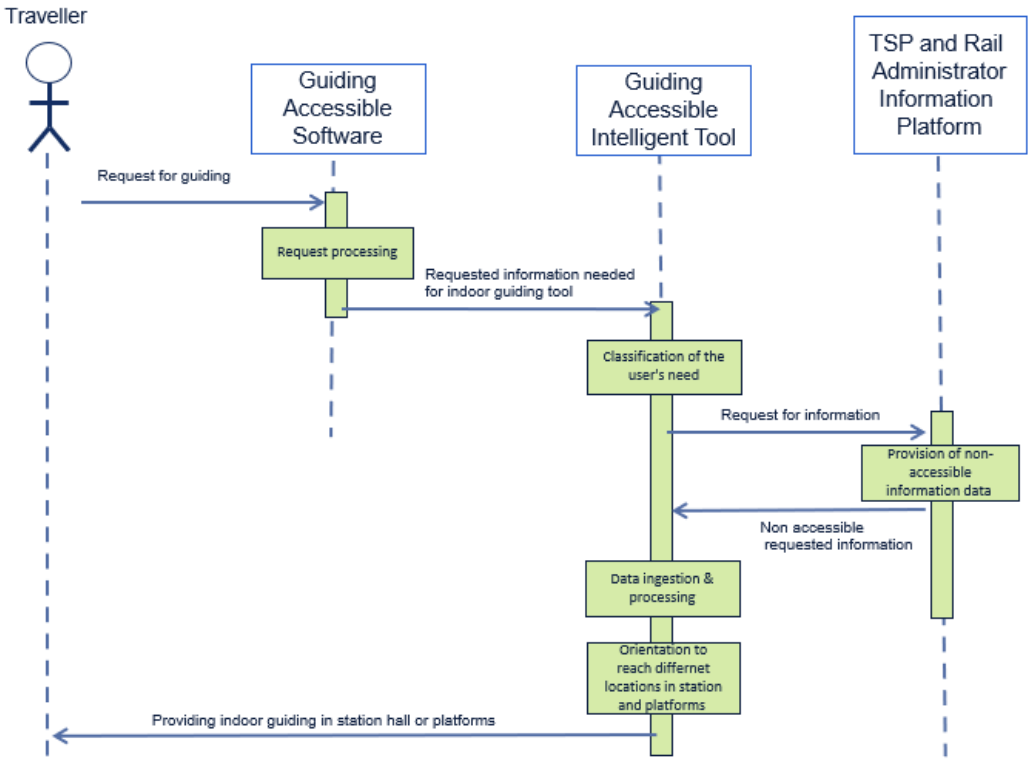

Figure 41: UC-FP1-WP19-18 sequence diagram

This tool combines a digital support that allows traveller to identify elements around: whether it is a person with visual disability (because it includes scannable codes with a very complicated angle and at a certain distance), or for someone who needs help identifying elements around them (cognitive disability, not understanding the local language, etc.).
This help is also complemented by podotactile routing, especially useful for blind people who can have better guidance to reach the points of greatest interest within the station and platforms.
With the information received through the codes in the mobile phone, the person can move around the station independently and more efficiently, with the possibility of making decisions about the points of interest or services to which they want to go, making their journey simpler, safer and more independent.

- [UC-FP1-WP19-19] Frictionless validation

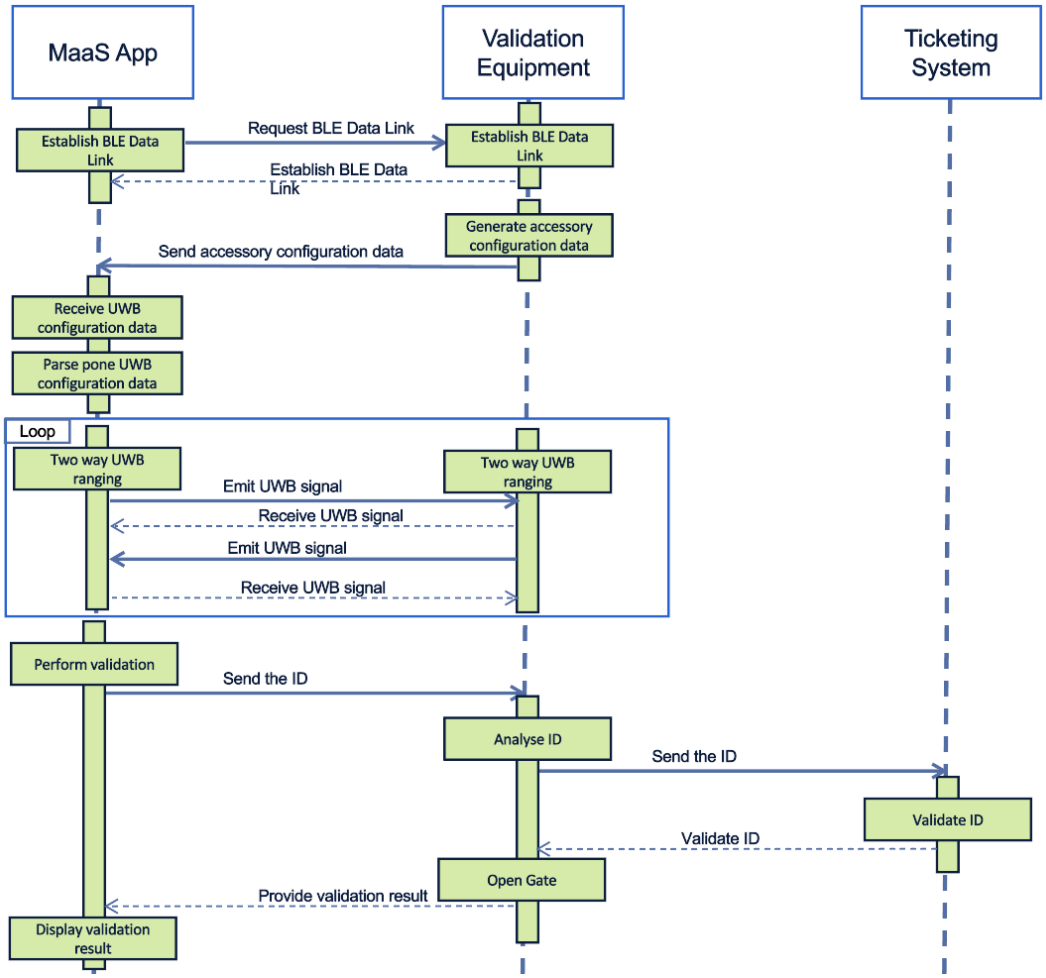

Figure 42: UC-FP1-WP19-19 sequence diagram

The Figure represents the sequence diagram related to Use Case Frictionless Validation. Enabling travellers to validate their tickets seamlessly, without physical interaction with a validator, not only saves significant time but also eliminates the need for a physical ticket. As it can be seen in the Figure, the User app through which the traveller purchased the ticket, establishes a connection with the validator using Bluetooth Low Energy (BLE) technology. Once the BLE connection is established between the Validation equipment and User App, the Validation equipment send the accessory configuration of the User app in order to enable the Ultra-Wideband (UWB) connection. Once the UWB connection is established, the Validation equipment locates the User app and in consequence the traveller on the station in order to know which gate should be open. During this process, the User app sends the ticket ID to the validator. The validator, in turn, forwards this information to the Back-Office for validation and cross-verification. Upon successful validation, the validator opens the correct gate, and a validation confirmation message appears on the application interface.

- [UC-FP1-WP19-20] Indoor guidance

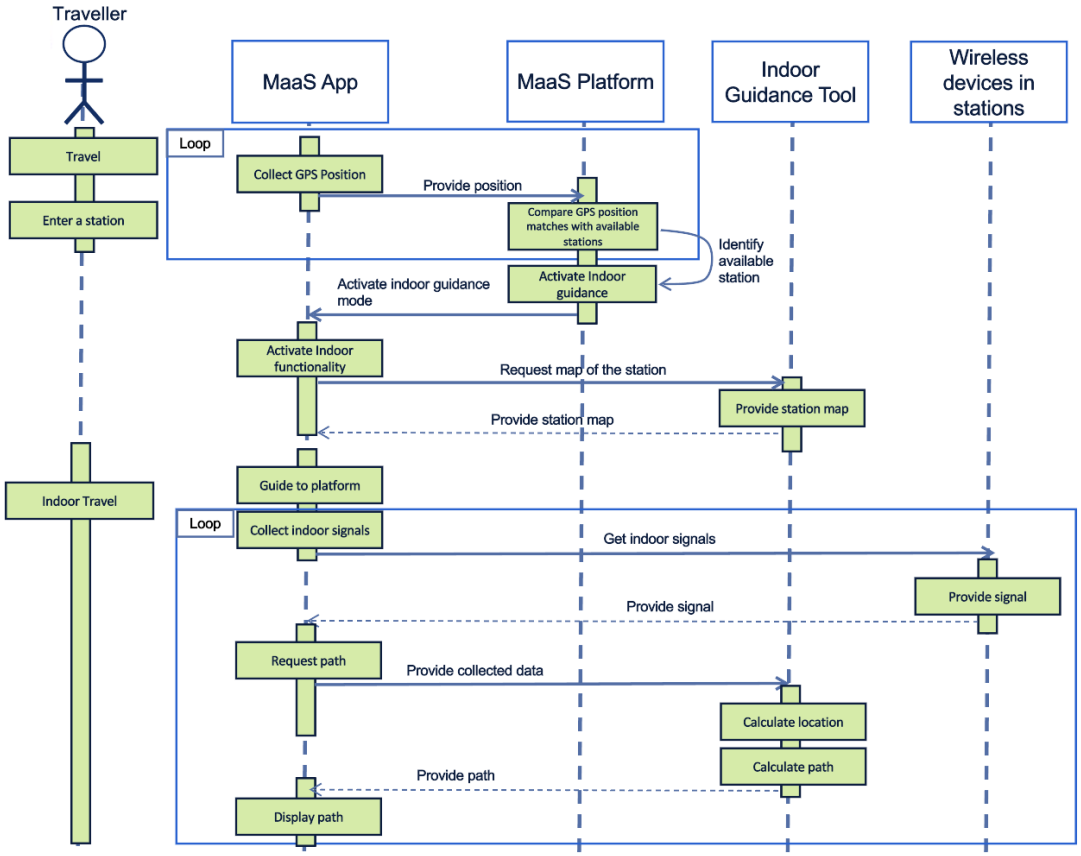

Figure 43: UC-FP1-WP19-20 sequence diagram

The Figure represents the sequence diagram related to Indoor Guidance. The primary objective of this use case is to assist travellers with reduced mobility (PRM) by providing them with navigational guidance within a station using a map. The Indoor Guidance takes as a pre-requisite that the user is already travelling following an itinerary provided by the MaaS Platform and as part of this trip the MaaS platform collects GPS position of the Traveller in order to provide real-time information depending on its location.

Once the MaaS platform detects that the traveller is close to the station of the itinerary and in case there is an indoor map of the station, the MaaS platform activates the Indoor location functionality, prompting the request for a station map to guide the traveller effectively.

The subsequent stage involves capturing indoor signals from various wireless devices strategically placed within the station. These devices facilitate the precise localization of the traveller within the station premises. Once the indoor guidance tool accurately determines the traveller's location, it calculates the optimal path leading to the desired platform. This calculated path is then displayed within the user application, providing step-by-step guidance to the traveller.

- [UC-FP1-WP19-21] Account based ticketing

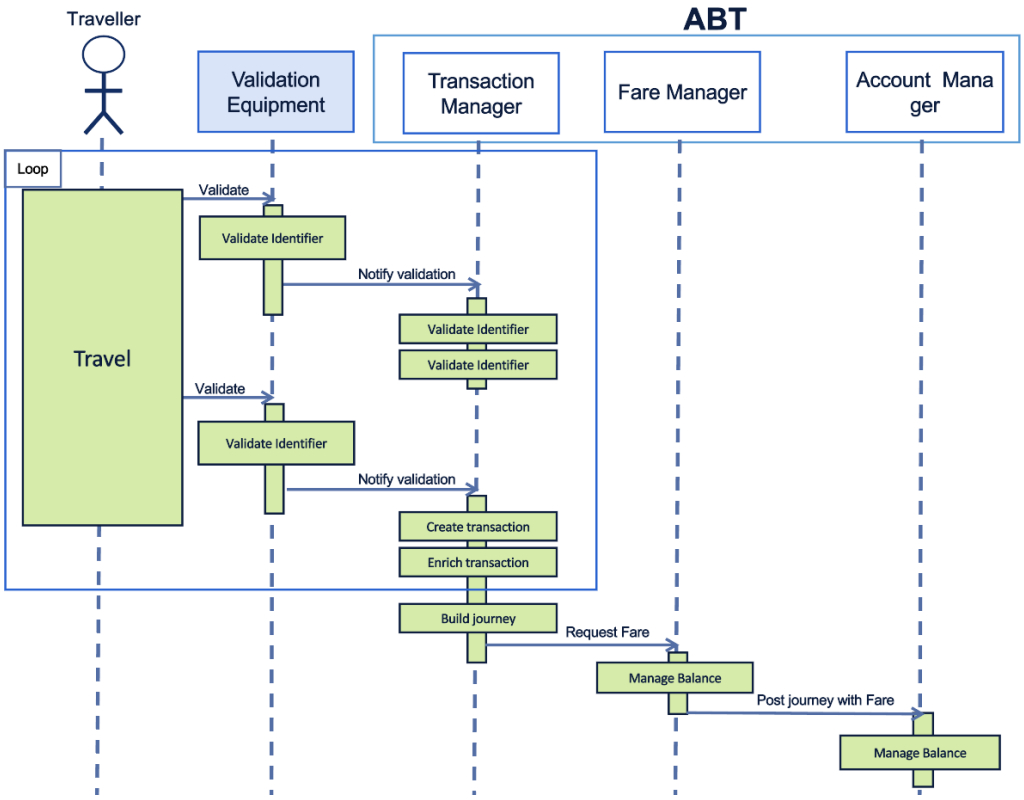

Figure 44: UC-FP1-WP19-21 sequence diagram

The figure represents the sequence diagram related to Account Based Ticketing. The main objective of the Account Based use case is to facilitate ticketless travel. The fare calculation, based on the number of taps and locations occurs seamlessly and is billed after the completion of the journey. As it can be seen in the Figure, the user needs to be identified once it is entering or leaving a platform/vehicle depending on the transport mode, as it is usually do with the ticket but in this case, the user needs to be identified by its user application.
In this process, travellers validate across different modes of transport using the validation equipment. Subsequently, the equipment transmits the notifications to the Account Based Ticketing System. This system is subdivided, comprising distinct components. The Transaction Manager validates each scan conducted throughout the journey, culminating in the final scan where it assimilates all detected identifiers to construct the comprehensive travel record.
Following the completion of this journey, the Fare Manager calculates the fare and subsequently transmits the conclusive amount to the Account Manager. The Account Manager, in turn, meticulously calculates the balance of the account, ensuring accuracy and reliability in the entire process.

- [UC-FP1-WP19-22] Hands Free. UWB Walk-in

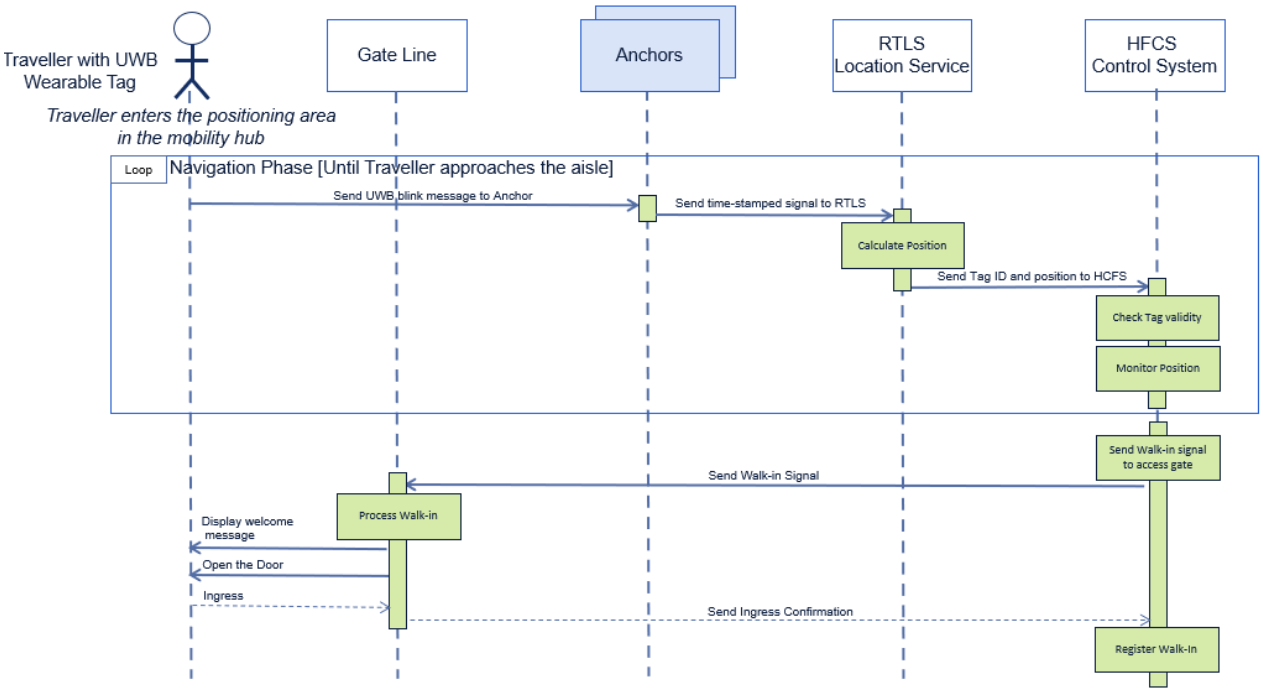

Figure 45: UC-FP1-WP19-22 sequence diagram

This sequence diagram shows the automatic entry of a Traveler into the closed area of a mobility hub using UWB hands free processing. On the left-hand side, the Traveler having an UWB wearable enters the detection area where UWB Anchors receive the signal. The Anchors send the time stamped signals and wearable identifier to the RTLS server that computes the position. This information is sent to the HFCS server on the right-hand side that checks the wearable validity and monitors the position. This sequence is carried out multiple times until the Traveler reaches the entry side of a gate (UWB location precision is 10-30 cm). The HFCS server sends the walk-in signal to the gate that lets the Traveler enter with the associated processing (light, message, …). The gate reports the entry to the RTLS.

- [UC-FP1-WP19-23] Hands Free. UWB Walk-out

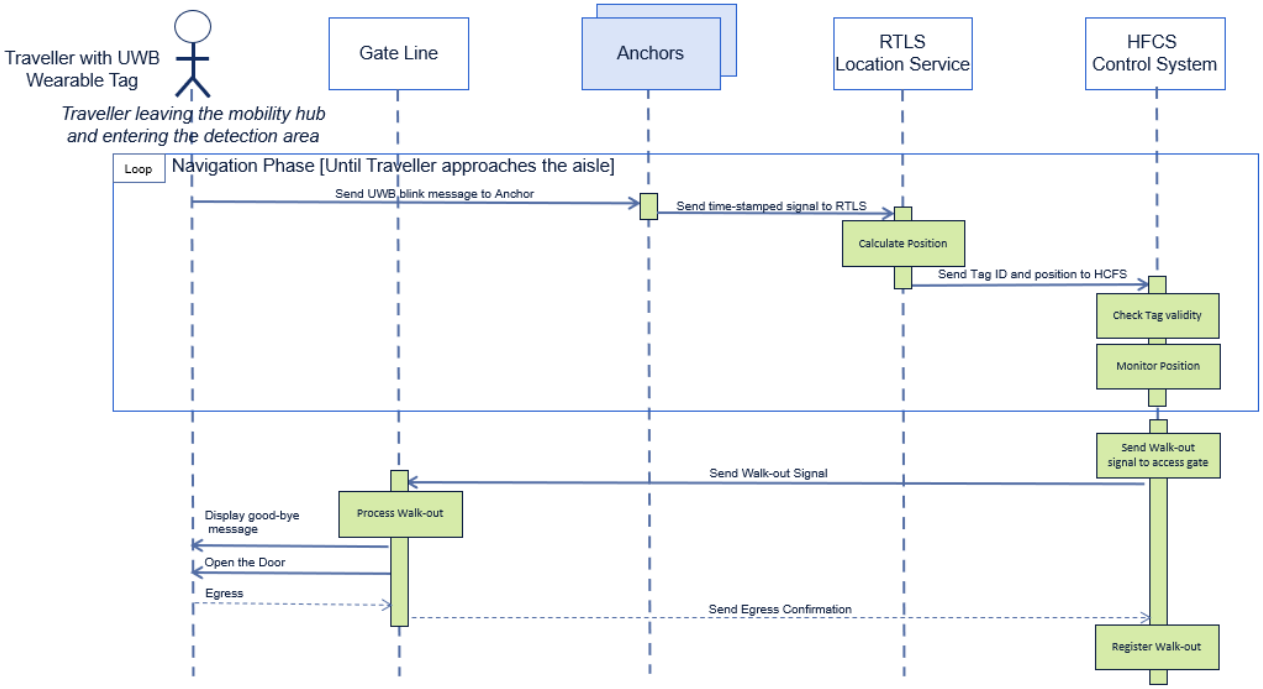

Figure 46: UC-FP1-WP19-23 sequence diagram

This sequence diagram shows the exit of a Traveler from the closed area of a mobility hub using UWB hands free processing. On the left-hand side, the Traveler having an UWB wearable enters the detection area where UWB Anchors receive the signal. The Anchors send the time stamped signals and wearable identifier to the RTLS server that computes the position. This information is sent to the HFCS server on the right-hand side that checks the wearable validity and monitors the position. The wearable shall be configured to allow the travellers to leave the hub. This sequence is carried out multiple times until the Traveler reaches the exit side of a gate (UWB location precision is 10-30 cm). the HFCS server sends the walk-out signal to the gate that lets the Traveler exit with the associated processing (light, message…). The gate reports the entry to the RTLS.

- [UC-FP1-WP19-24] Hands Free. UWB Intermodal transfer

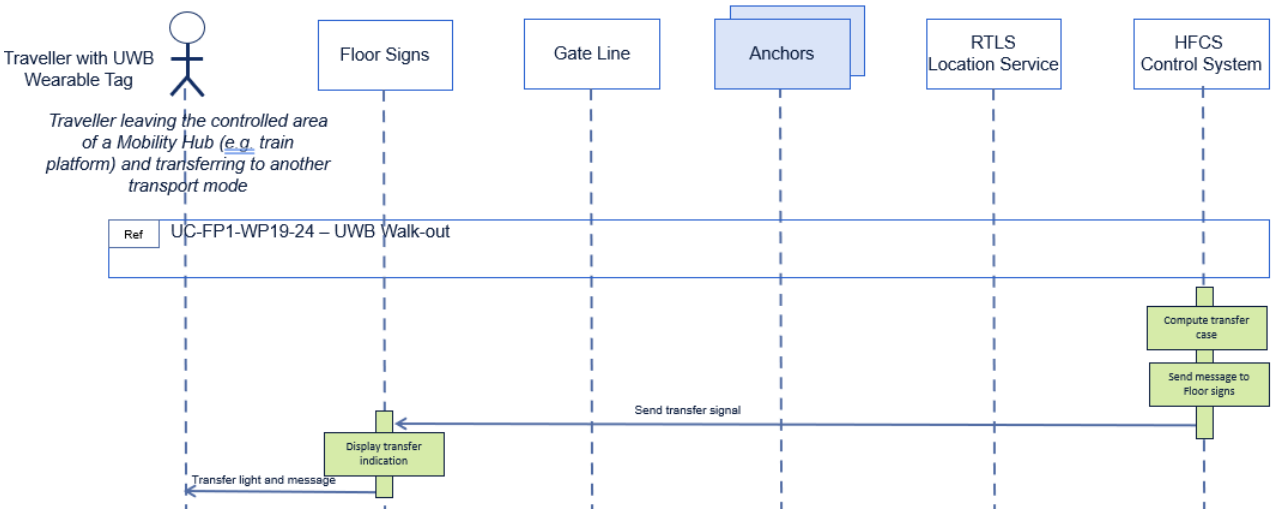

Figure 47: UC-FP1-WP19-24 sequence diagram

This sequence diagram shows an intermodal transfer where the Traveler is assisted by UWB hands free processing. The processing follows a walk-out sequence described separately. The Traveler on the left-hand side leaves the closed area of the mobility hub (assumed to be train platform or equivalent) and is about to transfer to another mobility mode. The HFCS system, on the right-hand side detects based on the wearable association to travel data that another travel episode follows the current travel. It sends a message to Floor Signs (on the right) that displays the adequate transfer indication to the Traveler.

- [UC-FP1-WP19-25] Hands Free. UWB In station assistance

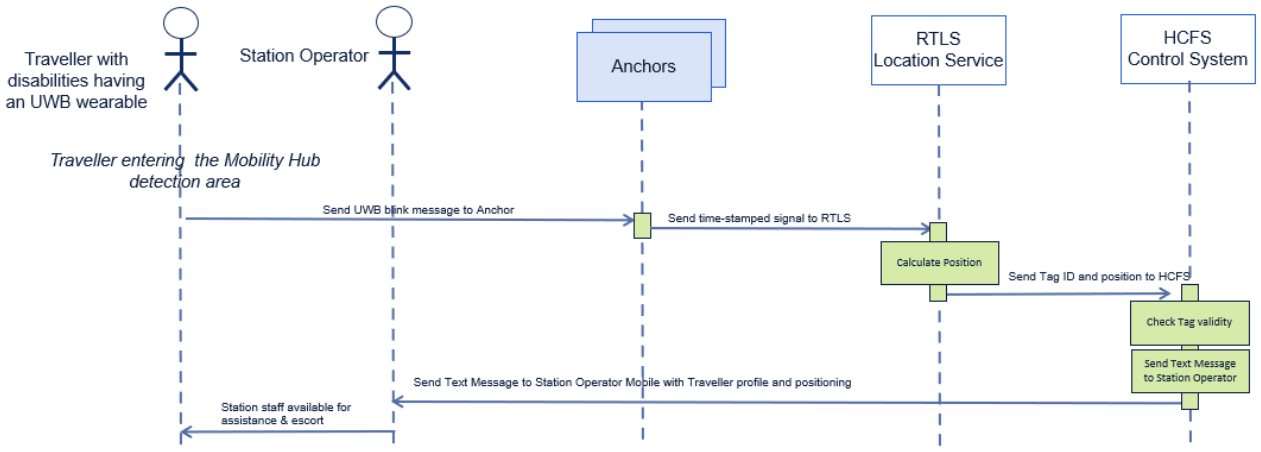

Figure 48: UC-FP1-WP19-25 sequence diagram

The sequence diagram shows the triggering of station assistance (staff) by detection of the arrival of a Traveler with disabilities through UWB. On the right-hand side, a Traveler having a UWB wearable enters the mobility hub. A UWB detection area is available at this place. The UWB signal is received by the Anchors that send the time stamped signal and wearable identifier to the RTLS

service that in turn calculates the position. The position is forwarded to the HFCS control system on the right-hand side. The HFCS works-out the wearable details and identifies that it is associated with a disabled profile. A text message is sent to the Station Operator with details on Traveler position and profile. Then, and this is an operational process, the Station Operator goes to meet the Traveler with the appropriate support (e.g., wheelchair).

- [UC-FP1-WP19-26] Hands Free. Face Recognition Walk-in

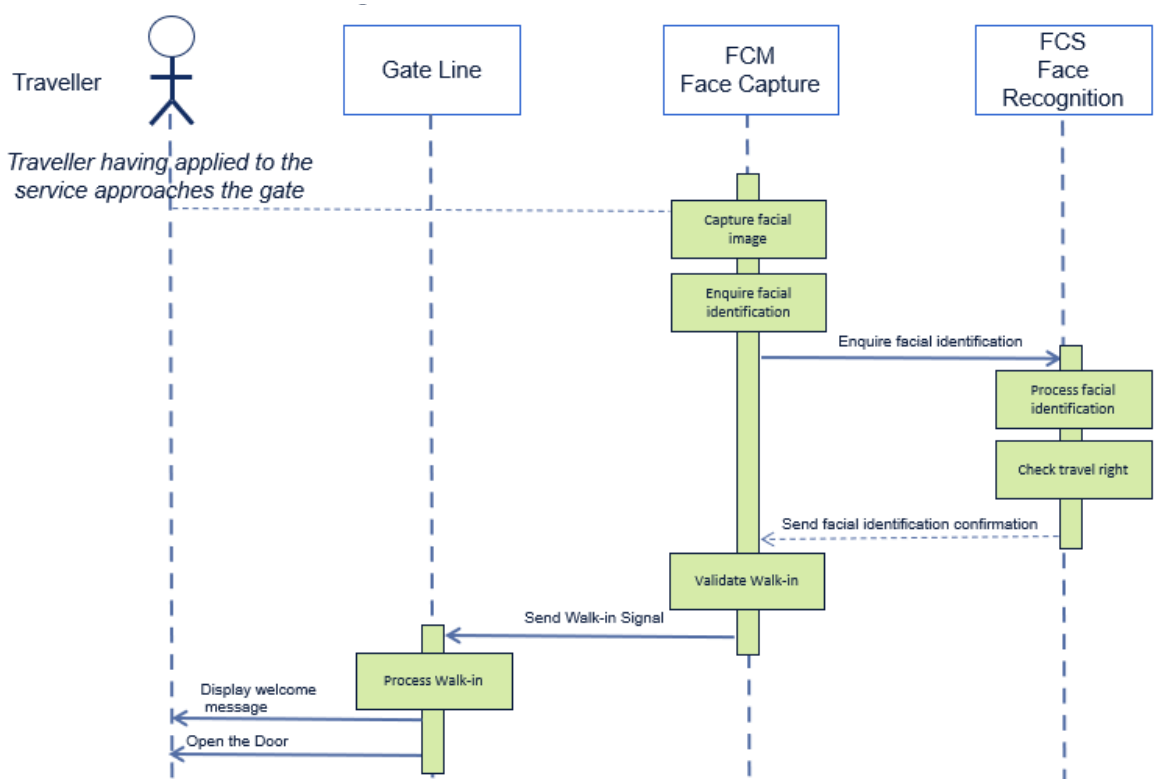

Figure 49: UC-FP1-WP19-26 sequence diagram

This sequence diagram shows the processing of the entry of a registered Traveler into a closed area of a mobility through automatic face recognition. On the left-hand side a Traveler is approaching a gate aisle. The Face Capture Module (FCM) is mounted on the gate cabinet. When the traveller is at capture distance (say, lower than one meter), the FCM captures a facial image and works out the associated signature. It then sends an online query to the Fare Recognition Serve, (FRS) on the right-hand side that checks the facial signature against the one stored in the database, the objective being a 1: N match. Upon positive identification, the traveler reference is retrieved and travel rights are checked. The FRS sends back, still in real time, the confirmation to the FCM that in turns pilots the Walk-In sequence on the gate (message and doors management).

- [UC-FP1-WP19-27] Hands Free. Face Recognition Walk-out

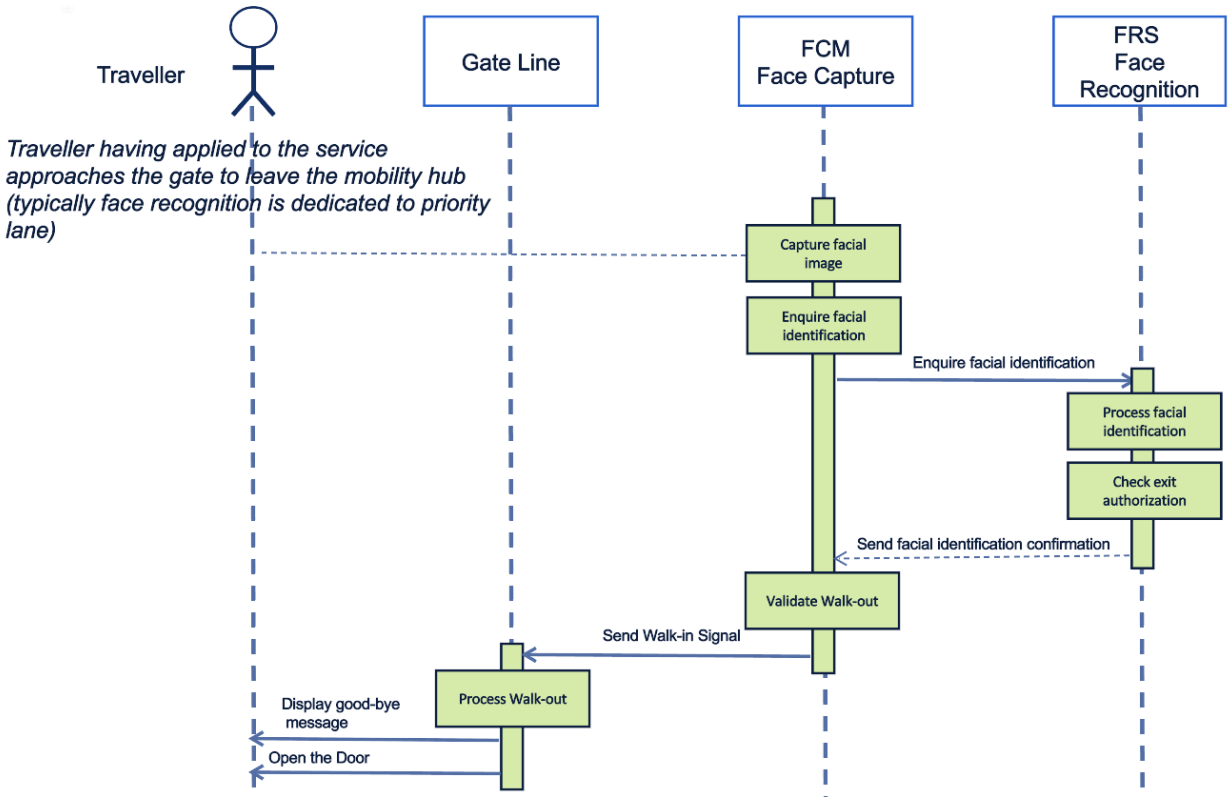

Figure 50: UC-FP1-WP19-27 sequence diagram

This sequence diagram shows the processing of the exit of a Traveler from the closed area of a mobility hub using a priority line where access is granted through face recognition. On the left-hand side the Traveler is approaching a gate aisle. The Face Capture Module (FCM) is mounted on the gate cabinet. When the traveller is at capture distance (say, closer than one meter), the FCM captures a facial image and works out the associated signature. It then sends an on-line query to the Fare Recognition Serve, (FRS) on the right-hand side that checks the facial signature against the one stored in the database, the objective being a 1: N match. Upon positive identification, the Traveler reference is retrieved and access authorization is checked. When access is confirmed, the FRS sends back, still in real time, the confirmation to the FCM that in turns pilots the Walk-Out sequence on the gate (message and doors management).

- [UC-FP1-WP19-28] Illuminated platform edge – Attention

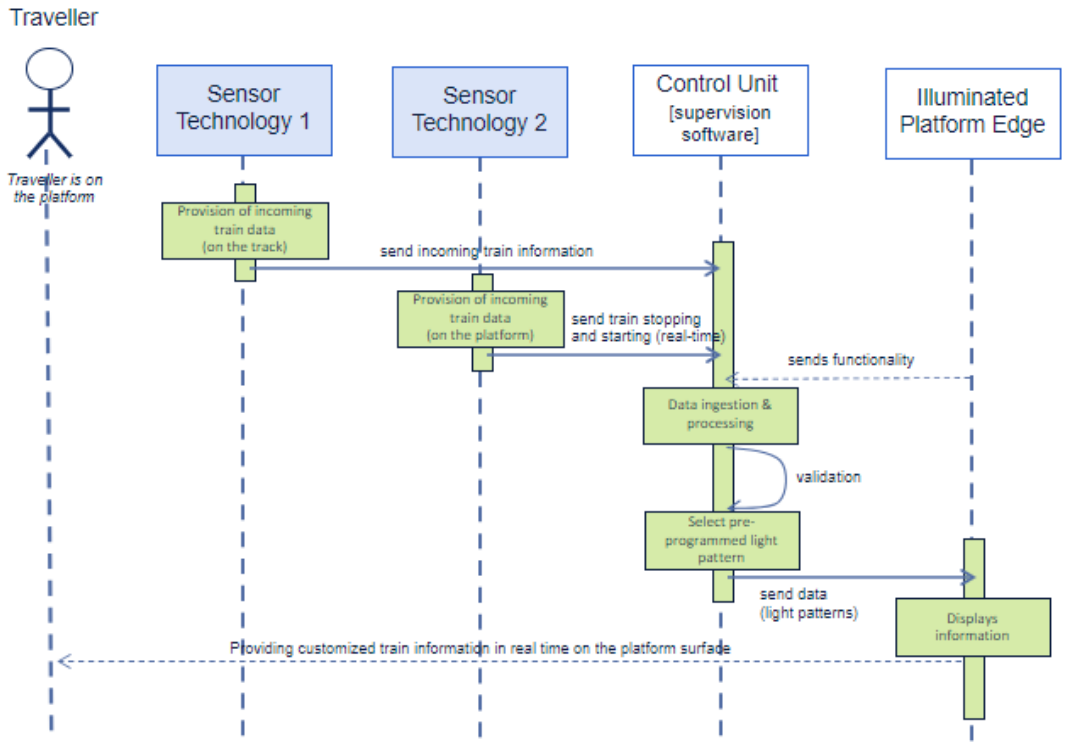

Figure 51: UC-FP1-WP19-28 sequence diagram

This diagram describes the use case of the Illuminated Platform Edge (IPE) to increase the safety and attention of the traveller on the platform. A permanent red glow along the LED elements in the platform surface indicates the track area. Flashing red lights warns of train arrival and departure. For this purpose, entry times of the coming train are recorded via a sensor (sensor technology 1) and forwarded in real time to the control unit via internet connection. The supervision software will indicate the right preprogrammed light pattern and sent it to the IPE via cable connection. About 20 seconds before the train arrives at the station, the permanent red light changes to flashing red and warns that the train is approaching. The information when the train has come to a standstill is provided by a second sensor on the platform (sensor technology 2) and the IPE lights up green for the train to be processed. After the train starts moving again, sensor 2 detects this and forwards the information to the control unit and the edge starts flashing red again. 10 seconds after the train has departed, the IPE switches back to the basic setting of permanent red.

- [UC-FP1-WP19-29] Illuminated platform edge – Orientation

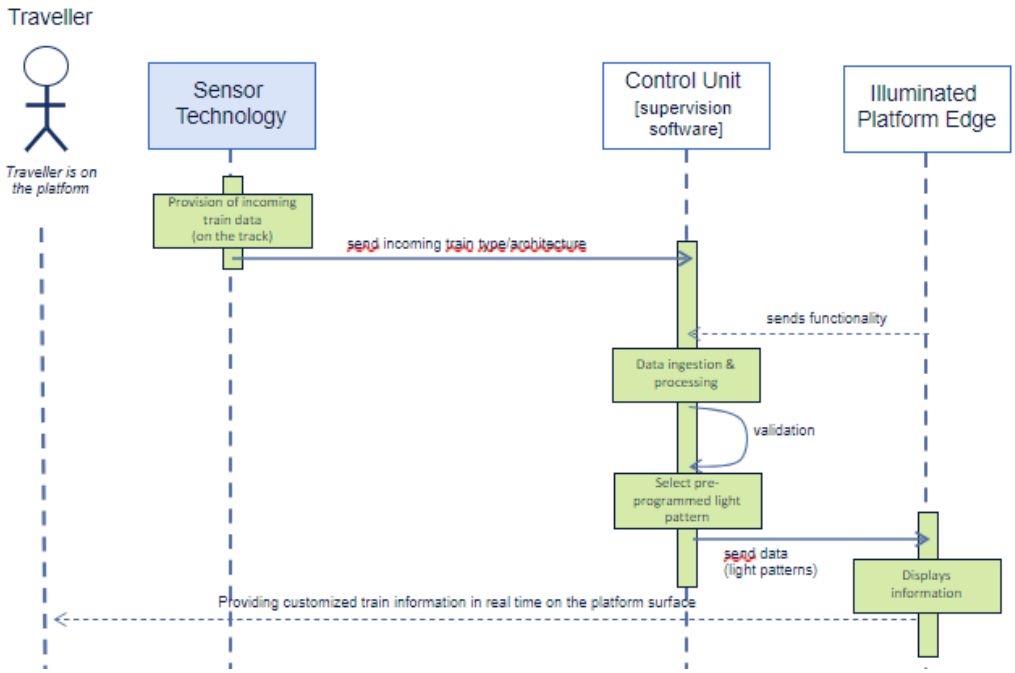

Figure 52: UC-FP1-WP19-29 sequence diagram

This diagram describes the use case of the Illuminated Platform Edge (IPE) to increase the orientation of the traveller on the platform. A running white (or green) light along the LED elements in the platform surface indicates to the train stopping position. For this purpose, entry times of the coming train and the train lengths (train architecture) are recorded via a sensor (sensor technology) and forwarded in real time to the control unit via internet connection. The supervision software sent the preprogrammed display patterns to the IPE via cable connection. The IPE will display the running light and indicates the area on the platform where the train will not stop and runs towards the last train compartment, for example when a short train arrives. During train dispatch and afterwards the system switches to the previous use case (UC-FP1-WP19-28 “attention”).

- [UC-FP1-WP19-30] Illuminated platform edge – Capacity

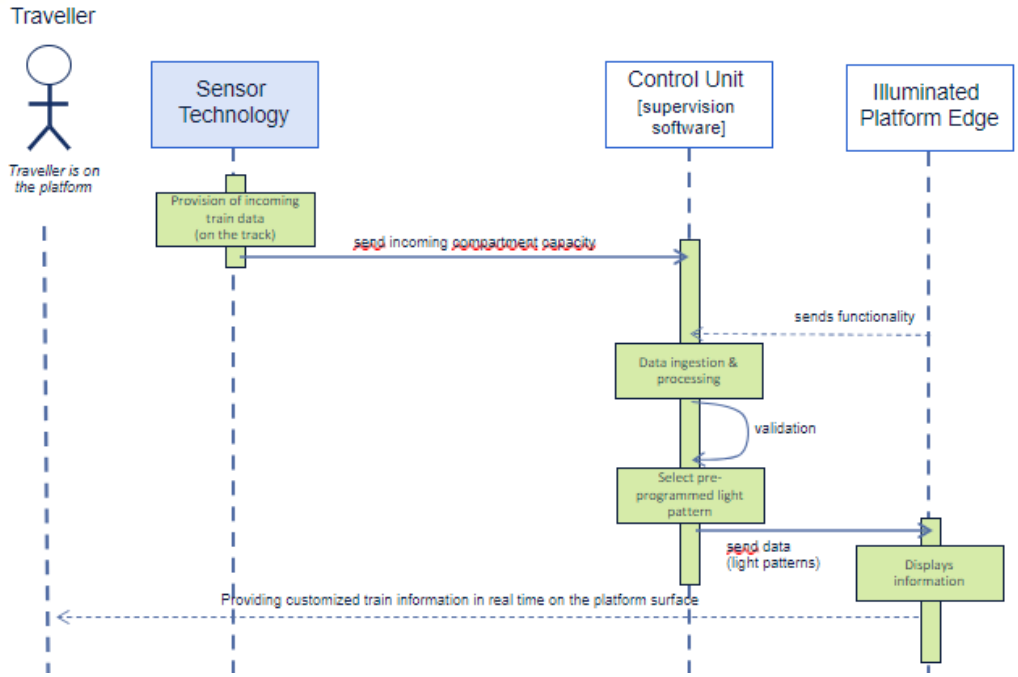

Figure 53: UC-FP1-WP19-30 sequence diagram

This diagram describes the use case of the Illuminated Platform Edge (IPE) to improve platform capacity and train dispatch. The occupancy of the incoming train is displayed along the edge of the platform in the colours red, yellow and green. For this purpose, entry times of the coming train and the different occupancy of the train compartments are recorded via a sensor on the track (sensor technology) and forwarded in real time to the control unit via internet connection. The supervision software sent the preprogrammed display patterns to the IPE via cable connection. Depending on the compartment occupancy the IPE will displays this information in the assigned areas on the platform by using green, yellow and red light. During train dispatch and afterwards the system switches to the previous use case (UC-FP1-WP19-29 “orientation”).

8.3.3 WP24-25

- [UC-FP1-WP19-31] Notices for other modes of transport with connections at the railway station

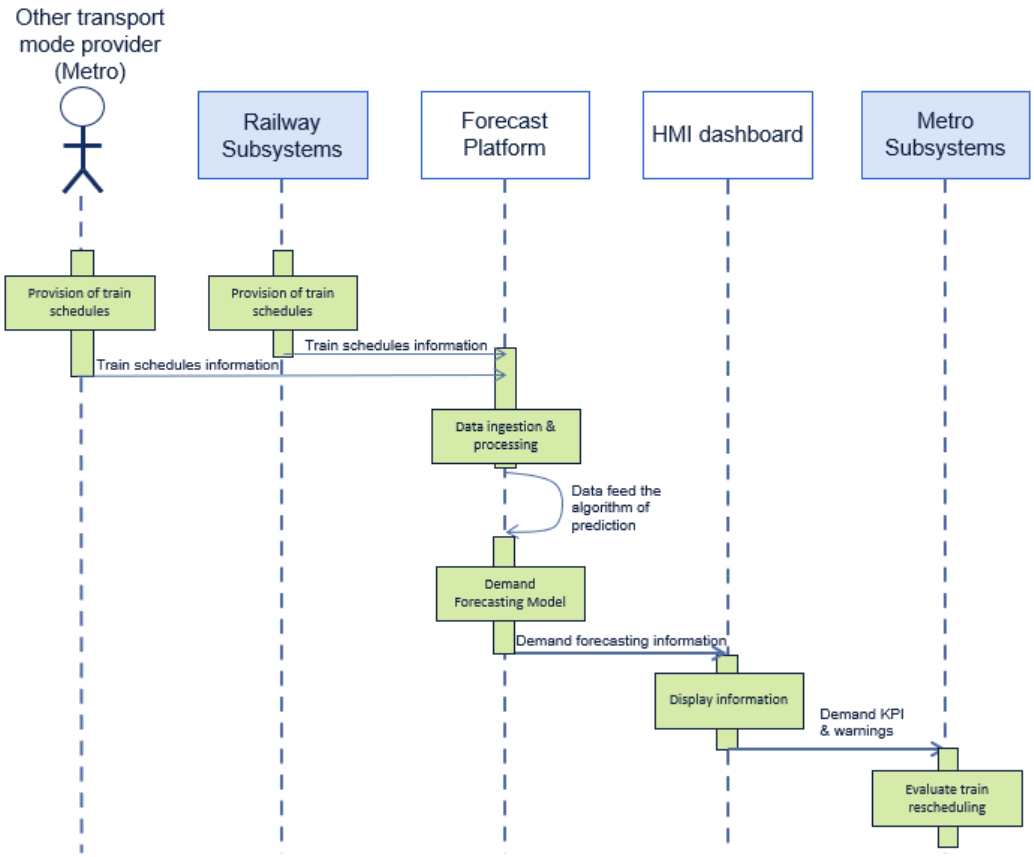

Figure 54: UC-FP1-WP19-31 sequence diagram

With this Use Case warnings will be created to inform other operators providing transport services at the station in order to improve/adequate the provision of their services.
Schedule information will be made available by the transport service providers to feed a Forecast Platform that will process it and generate a Demand Forecast Model whose outputs will be displayed in the HMI dashboard and from there, demand KPI and warnings will help Metro Subsystems evaluate a possible rescheduling.
When comparing data from the prediction model with the average data obtained for the same period of the day, it could be determined whether there is a significant increase in demand that requires additional services from the other transport operators at the station.

- [UC-FP1-WP19-32] Notifications for activation of passenger flow management protocols

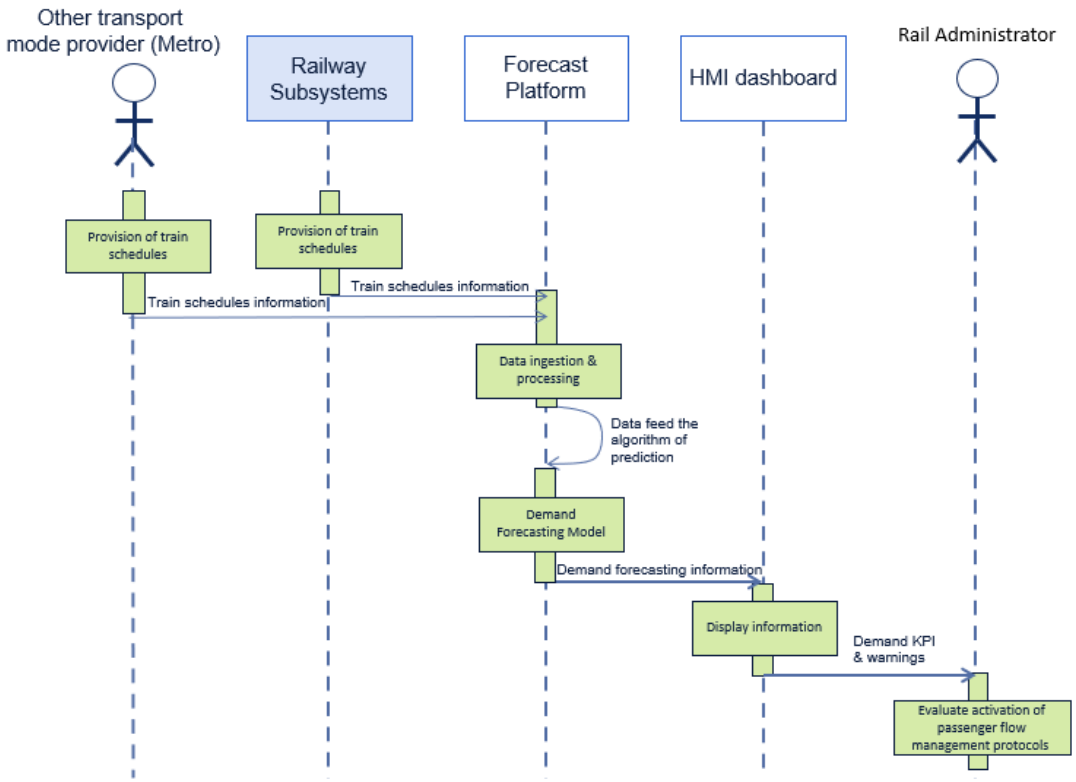

Figure 55: UC-FP1-WP19-32 sequence diagram

This Use Case establish the process to alert about the results of short-term passenger demand model forecast showing a substantial increase in demand compared to the usual station demand for a timetable. A series of protocols for passenger flow management at the station may be applied. These protocols shall be developed by the station manager and shall define the different safety levels to be applied depending on the increase in demand.
Schedule information will be made available by the transport service providers to feed a Forecast Platform that will process it and generate a Demand Forecast Model whose outputs will be displayed in the HMI dashboard and from there, demand KPI and warnings will help Rail Administrator evaluate the activation of passenger flow management protocols.

- [UC-FP1-WP19-33] Disruption management through Transport Data Hub

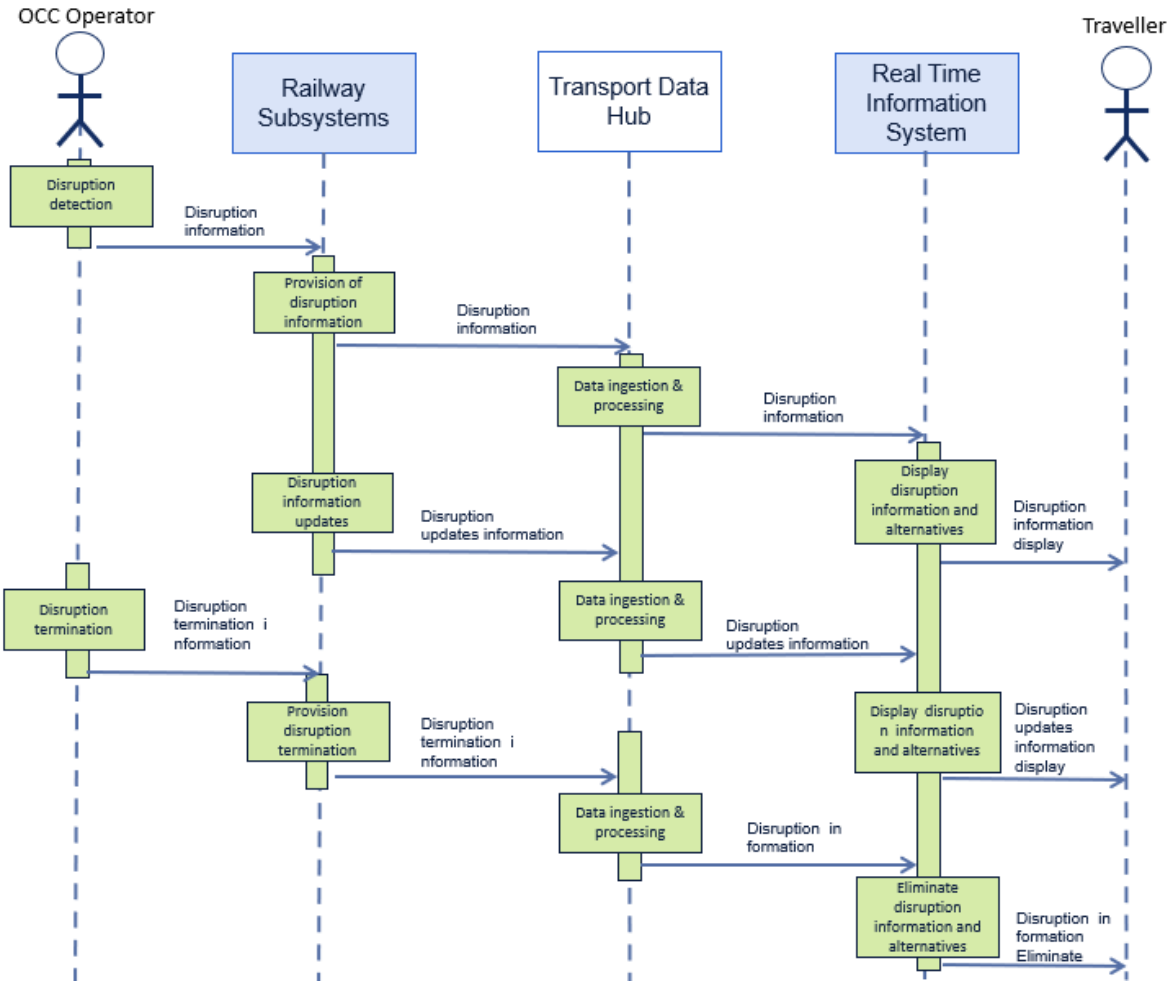

Figure 56: UC-FP1-WP19-33 sequence diagram

The Figure represents the sequence diagram related to Disruption management through Transport Data Hub. The fundamental purpose of this use case is to ensure that users of the transport service are promptly and accurately informed about potential incidents in real time. In this operational framework, should an Operator in the Operations Control Centre (OCC) detect any disruptions, they promptly send this information to the pertinent railway subsystems. These subsystems serve as conduits, channelling the incident data to the Transport Data Hub, which acts as the central system responsible for disseminating this critical information.
It falls upon the Transport Data Hub to transmit these incident updates to the various Real-Time Information Systems placed across different infrastructures. These systems are designed to display the information, thereby providing travellers with timely and relevant updates. This process is diligently repeated each time there is an update regarding the incidents or when the incident itself has been resolved.

- [UC-FP1-WP19-34] Reporting of external events influencing the multimodal transport on the municipal level

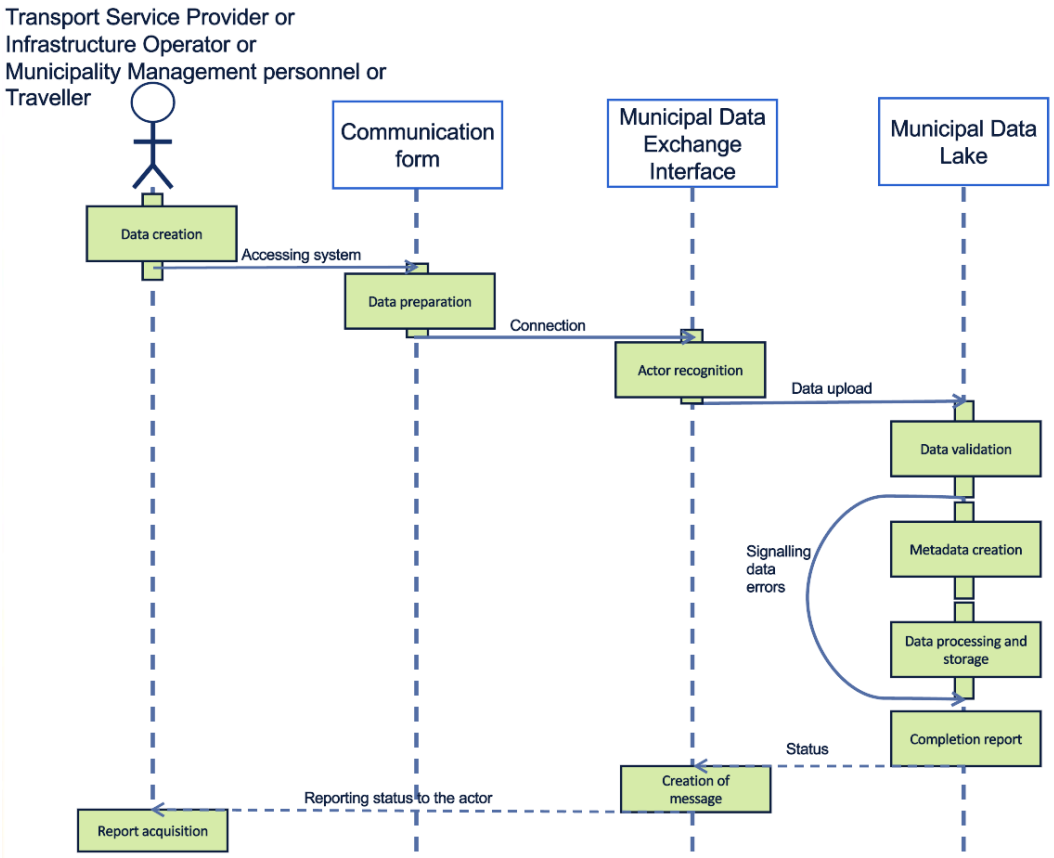

Figure 57: UC-FP1-WP19-34 sequence diagram

Individual localized disruption events on a municipal level have to be reported to data sharing infrastructure. Because such events have disparate character (positive and negative) they have to have an appropriate data structure and input mechanisms (communication forms) to report their different kinds to the data lake.

When an actor (as listed) decides to provide the information about existing disturbance (roadblock, roadworks, weather related blockage, people related event etc.) they fill the necessary communication form which creates data in appropriate format. Municipal data exchange interface provides a connection layer which recognizes the actor and generates appropriate query. Municipal data lake then validates the data, and if correct generates necessary metadata and processes and stores the data. If successful (or validation detected errors) a completion report is generated and propagated through interface to the user.

- [UC-FP1-WP19-35] Information exchange standard for disparate mode operators allowing swift and thorough propagation of disruption specification

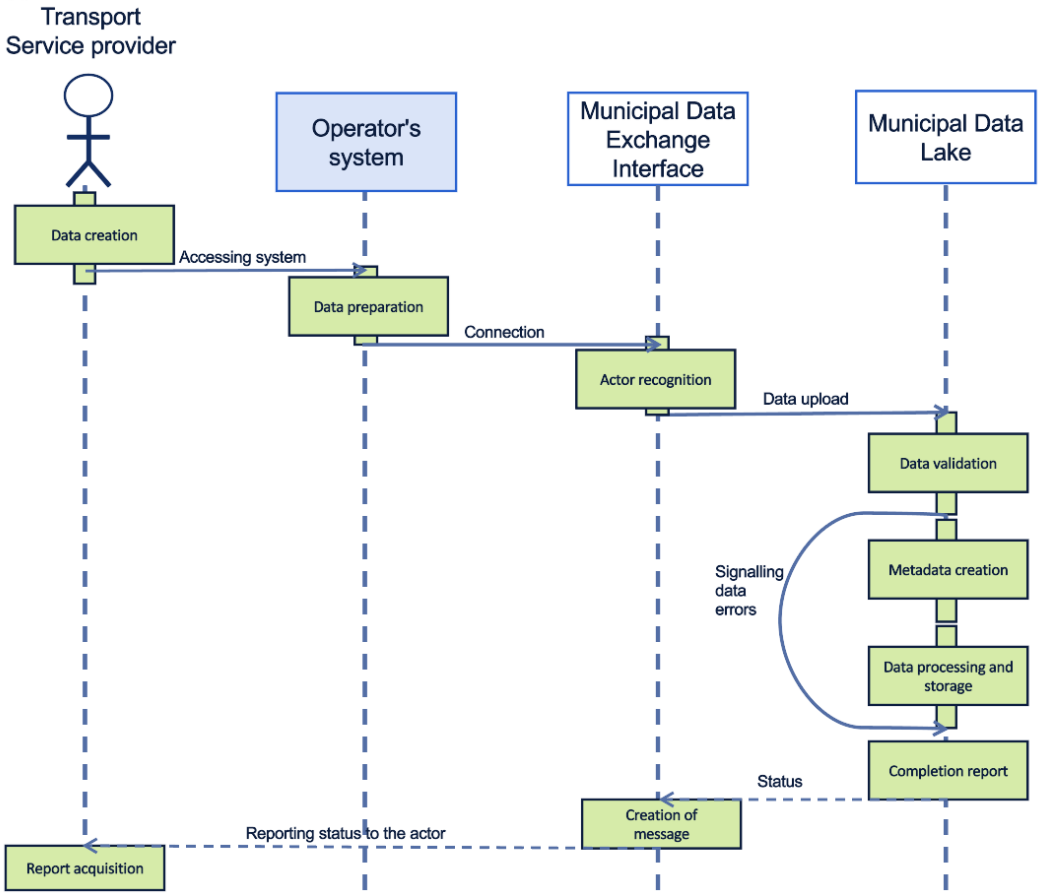

Figure 58: UC-FP1-WP19-35 sequence diagram

Certain disruptions on municipal level have organizational effect. For example, because of random causes operator has to cancel certain connections or reduce their capabilities. Such effects have distributed character and require different treatment than individual events and integration with operator's systems. When an actor (as listed) decides to provide the information about existing systemic disturbance (cancelation of a bus line, change of rolling stock capacity etc.) they use their planning system which creates data in appropriate format. Municipal data exchange interface provides a connection layer which recognizes the actor and generates appropriate query. Municipal data lake then validates the data, and if correct generates necessary metadata and processes and stores the data. If successful (or validation detected errors) a completion report is generated and propagated through interface to the user.

- [UC-FP1-WP19-36] Ex-ante timetable punctuality

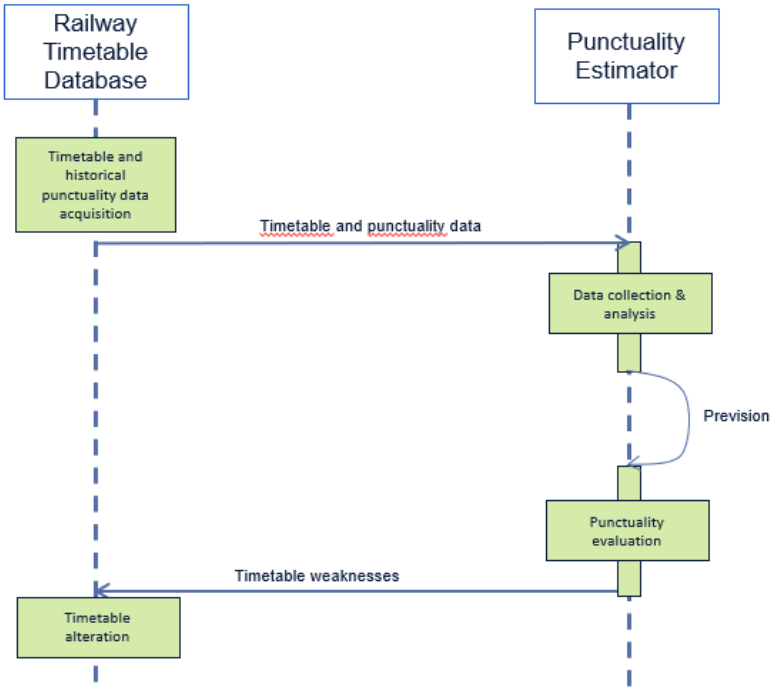

Figure 59: UC-FP1-WP19-36 sequence diagram

This Use Case aims to evaluate ex-ante punctuality based on the Italian infrastructure setting and a given timetable scenario, highlighting the fragilities of the train timetable. After collecting and preprocessing timetable and historical punctuality data stored in a database, prediction models and statistical methods are implemented in order to estimate ex-ante punctuality. The results provided by the punctuality estimator will allow to detect timetable weaknesses and, eventually, suggest how to alter the initial timetable to increase its robustness.

- [UC-FP1-WP19-37] Timetable optimization based on MCT (Minimum Connection Time)

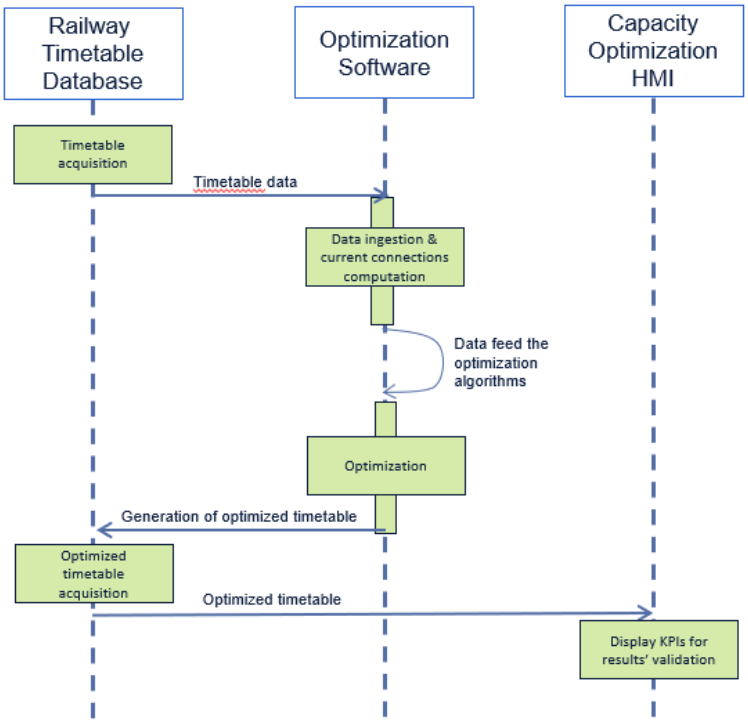

Figure 60: UC-FP1-WP19-37 sequence diagram

This Use Case is based on a mixed integer linear programming formulation able to generate optimal connections by modification of an initial timetable. After acquiring timetable data in GTFS format into a database, the current connections in the stations of the network are elaborated and the optimisation algorithm is executed. The resulting timetable will be stored in the database and will be validated by specific KPIs to measure the number of transfers. Results will be shown in a specific HMI.

- [UC-FP1-WP19-38] Railway disruption management through optimization processes

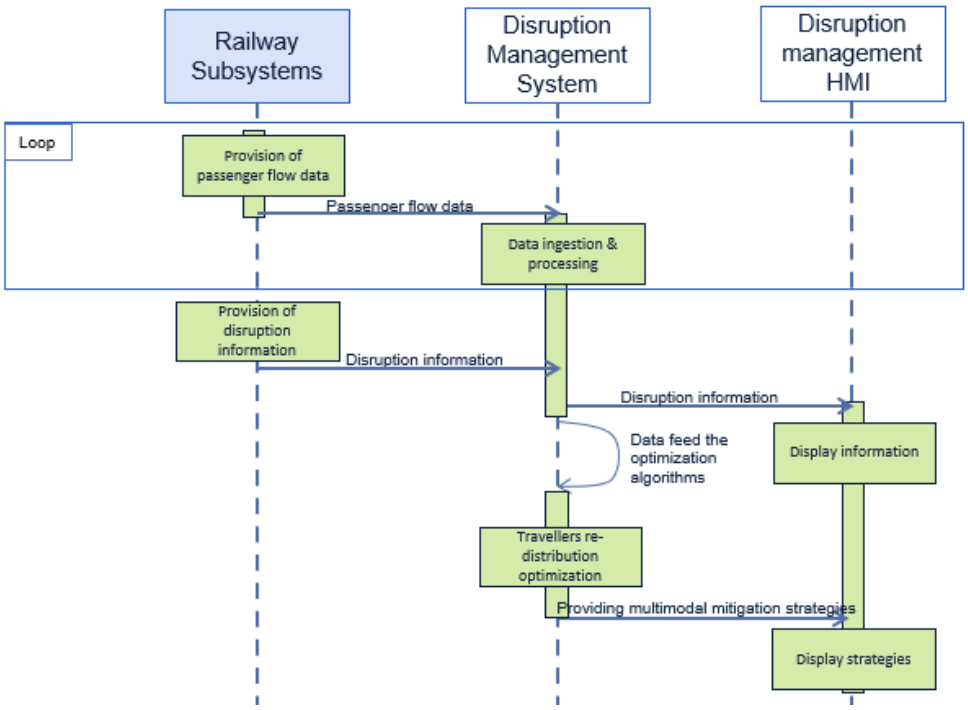

Figure 61: UC-FP1-WP19-38 sequence diagram

This use case aims to support the railway service provider by proposing alternative solutions in case of disruptions. The disruption management system component continuously receives information about passenger flow in trains. When a disruption occurs, the information is received and processed. A dedicated HMI for the train operator displays the acquired disruption information. Meanwhile, the disruption management system, with the information received, looks for possible solutions (if needed) to allow passengers to continue their journey by alternative modes of transportation (taxi, bus, etc.). These mutually exclusive strategies, characterized by appropriate KPIs, are then shown in the HMI to the operator allowing him to choose the solution he deems most appropriate.

- [UC-FP1-WP19-39] Generation of the library of situations

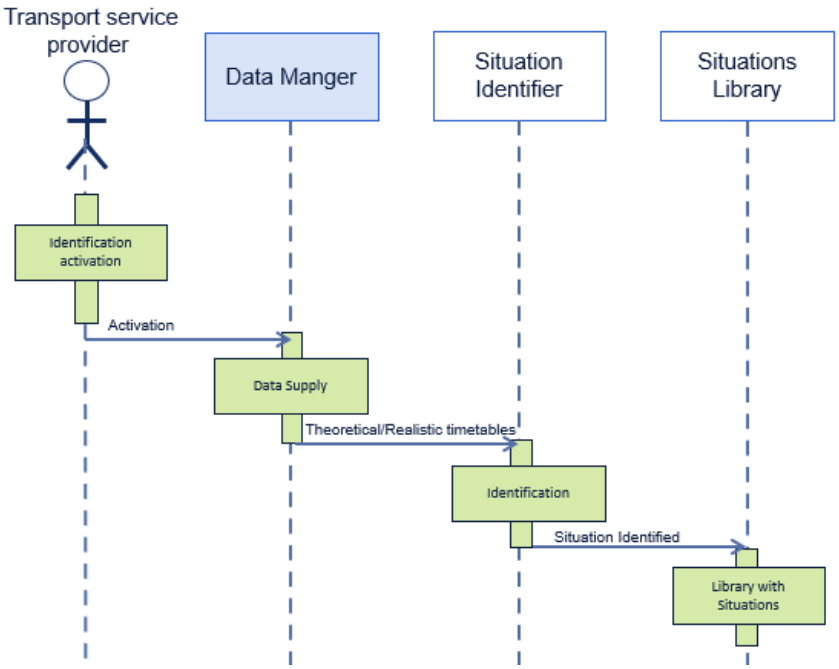

Figure 62: UC-FP1-WP19-39 sequence diagram

This use case aims to generate a Situation Library from historical data. Historical data is made up of temporary records that contain the variables that describe the state of Multimodal Mobility. To do this, the Transportation Service Provider activates the identification of the situations so that the Data Manager provides the Historical Data available to be processed by the Situation Identifier. This makes use of unsupervised learning algorithms to identify the situations that occur. The identified situations are characterized by the centroids of the variables of all the records associated with that situation. This information is stored in the Situation Library.

- [UC-FP1-WP19-40] Detection of situations

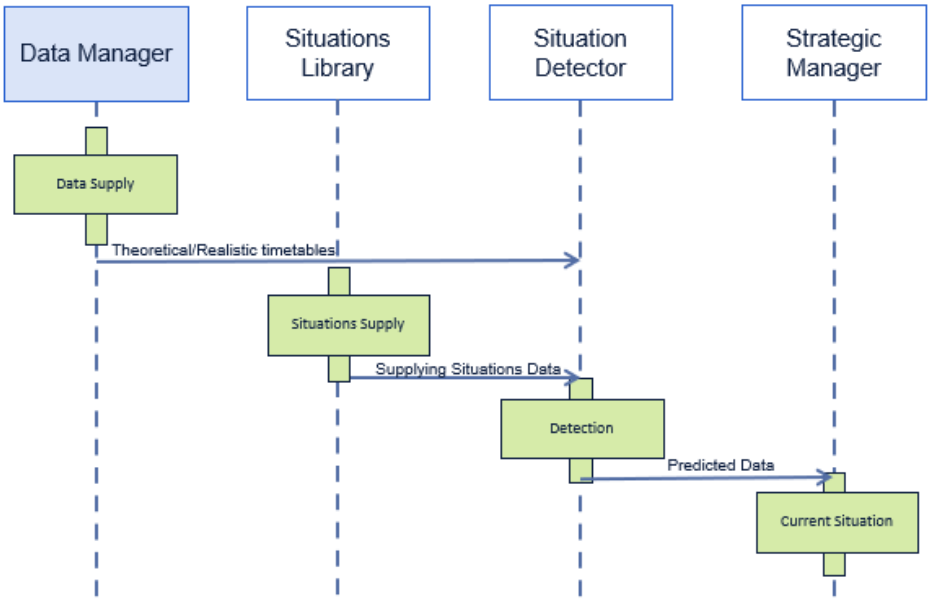

Figure 63: UC-FP1-WP19-40 sequence diagram

The purpose of this use case is to adapt the management of Multimodal Mobility to the situations that occur in it. Activating the strategy that best adapts to each situation.
To do this, the Data Manager continuously supplies data in real time that describes the Mobility situation and the Situations Library supplies information that characterizes each of the Situations it manages. The Situation Detector compares the actual information with the situations managed by the library and determines whether they match. In that case, inform the Strategic Manager to activate the strategy associated with that situation and disseminate it to be executed by the different mobility managers.

- [UC-FP1-WP19-41] Supporting timetabling decisions with visualisation and severity estimation of present disturbances in the municipality

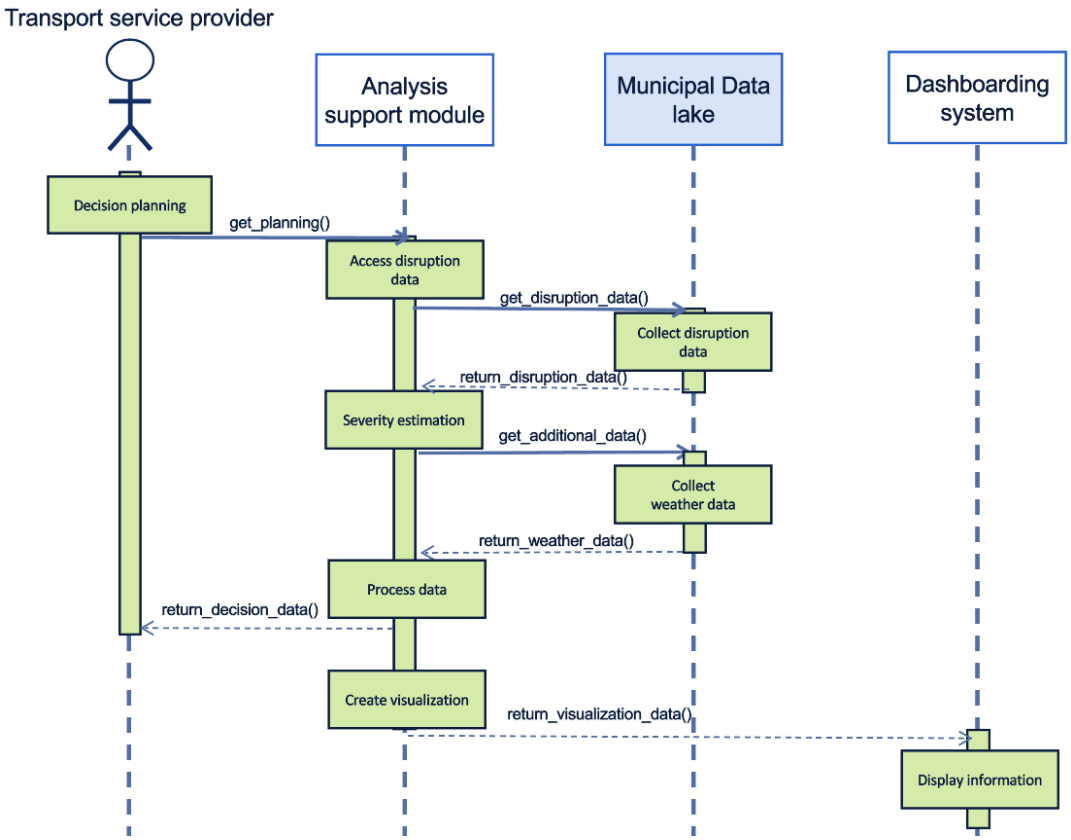

Figure 64: UC-FP1-WP19-41 sequence diagram

During planning of operation (resource allocation) and timetabling information is needed are there any disruptions/events that require special activity. Proposed system provides decision support using a relevant dashboard with necessary information. Planner of transport service provides wants to use decision support. They start the analysis support module, which gets the disruption data from the municipal data lake and then estimates its severity and supplements it with weather data. All those are processed in a way that will provide planner with the data in useable form along with visualisation using the dashboarding system.

- [UC-FP1-WP19-42] Decision support for incidents management

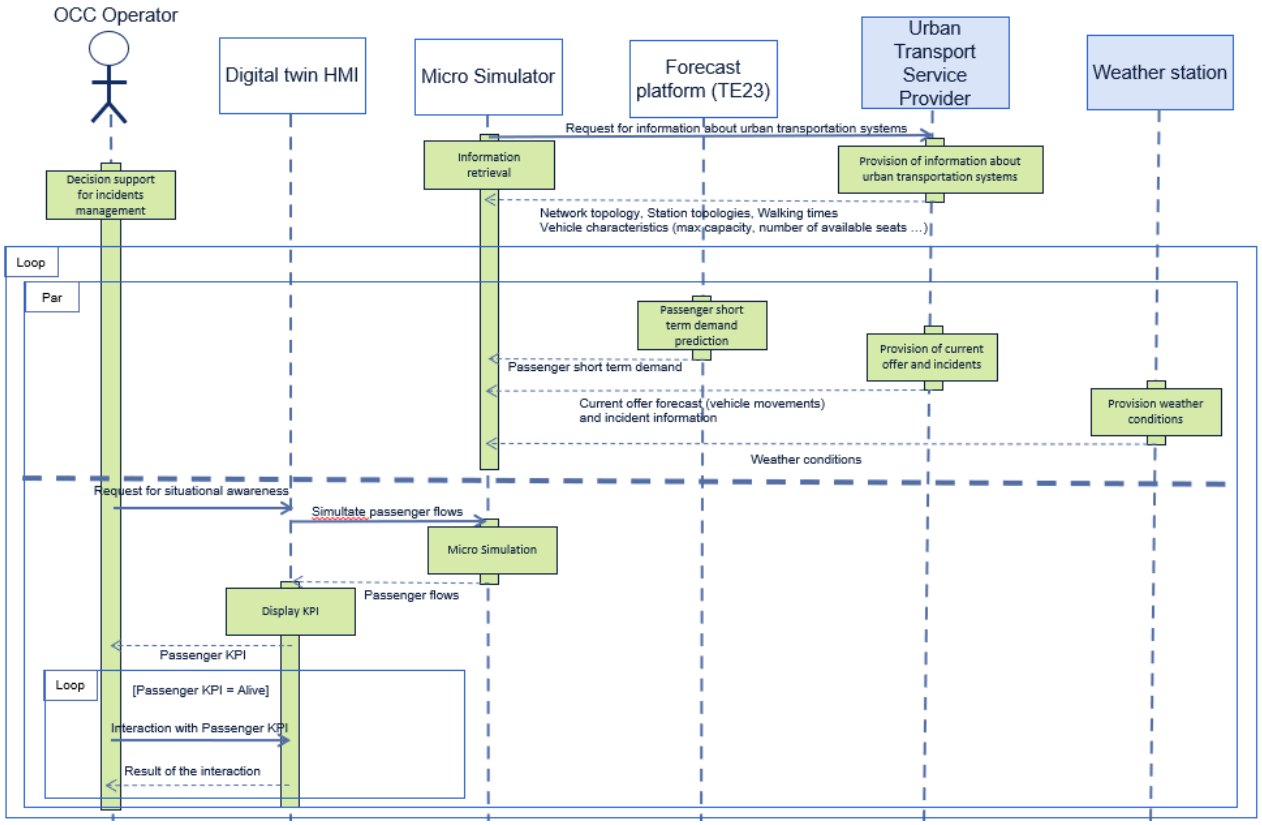

Figure 65: UC-FP1-WP19-42 sequence diagram

The aim of this use case is to assist the OCC Operator in managing incidents on the urban transport network and implementing corrective actions, such as reinforcing services, by utilizing short-term passenger flow prediction.

As described in the sequence diagram above, the following steps are taken to achieve this:

1. The micro simulator initializes with information about the urban transportation systems that it has previously requested from the Urban Transport Service Provider.
2. The micro simulator collects continuously current offer forecast (vehicle movements) and incident information from the Urban Transport Service Provider, as well as the passenger short-term demand from the Forecast platform and weather conditions from weather station.
3. In parallel, each time the OCC Operator requests situational awareness, the micro simulator simulates how passengers flow across the urban transport network, the Digital twin HMI then displays Passenger KPI based on the simulation, and the OCC Operator interacts with them to get a better idea of how to manage the incidents.

- [UC-FP1-WP19-43] Sandboxing for test of incident mitigation scenarios

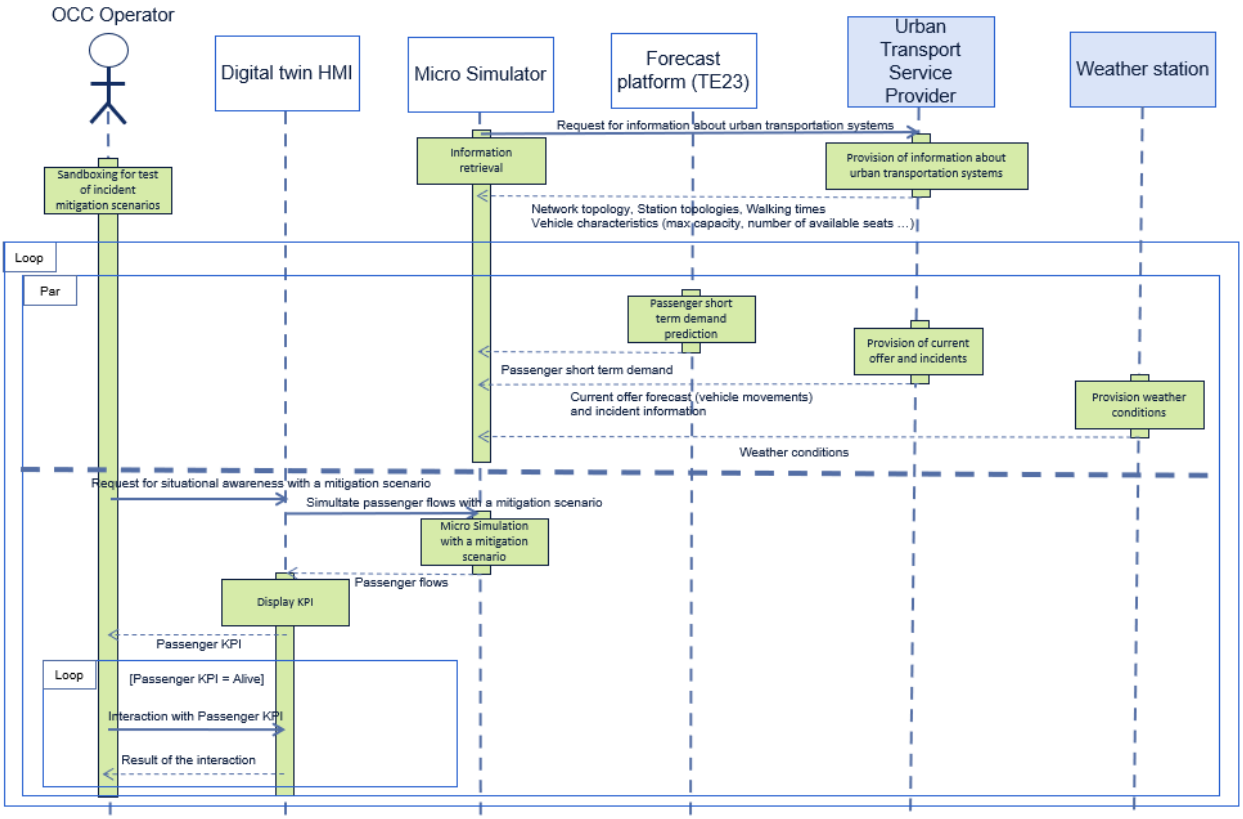

Figure 66: UC-FP1-WP19-43 sequence diagram

This use case extends the behaviour of the "[UC-FP1-WP19-42] Decision support for incidents management" use case by providing the OCC Operator with a digital twin acting as a sandbox where he can simulate different scenarios and assess the impact of potential changes or improvements. By experimenting in the sandbox, the operator can test new strategies and make data-driven decisions before implementing them in the physical world. Therefore, the sequence diagram is similar to UC-FP1-WP19-42 one, except for the last part where the OCC Operator can test a scenario to mitigate an incident.

- [UC-FP1-WP19-44] Alert for Possible Overcrowding Situations based on Occupancy Forecast Data

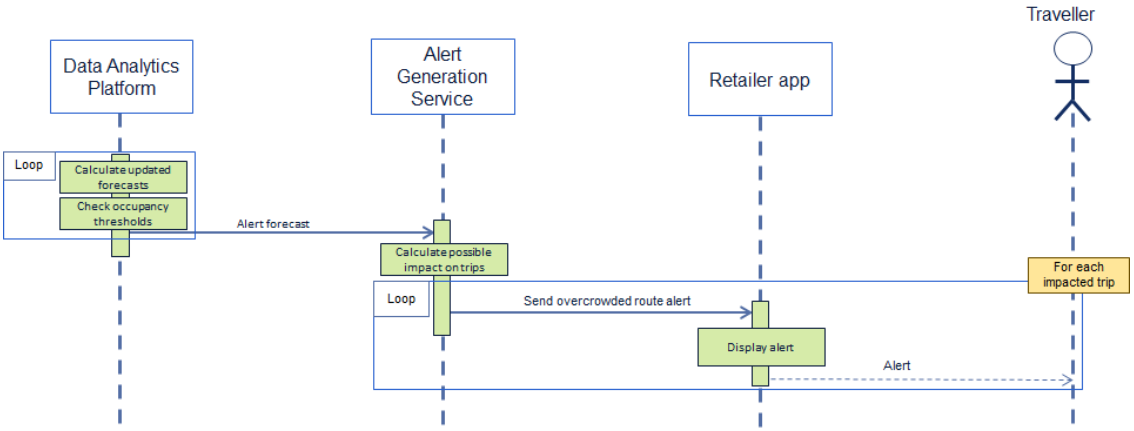

Figure 67: UC-FP1-WP19-44 sequence diagram

The Data Analytics Platform continuously updates its forecast and checks for occupancy threshold which may trigger an alert to the Alert Generation Service that the level of occupancy exceeded such a threshold. The Alert Generation Service calculates the potential impact of that alert on trips and notifies the Travellers on these trips about the forecasted occupancy via the Retailer App.

- [UC-FP1-WP19-45] Request Journey alternatives to avoid crowded routes

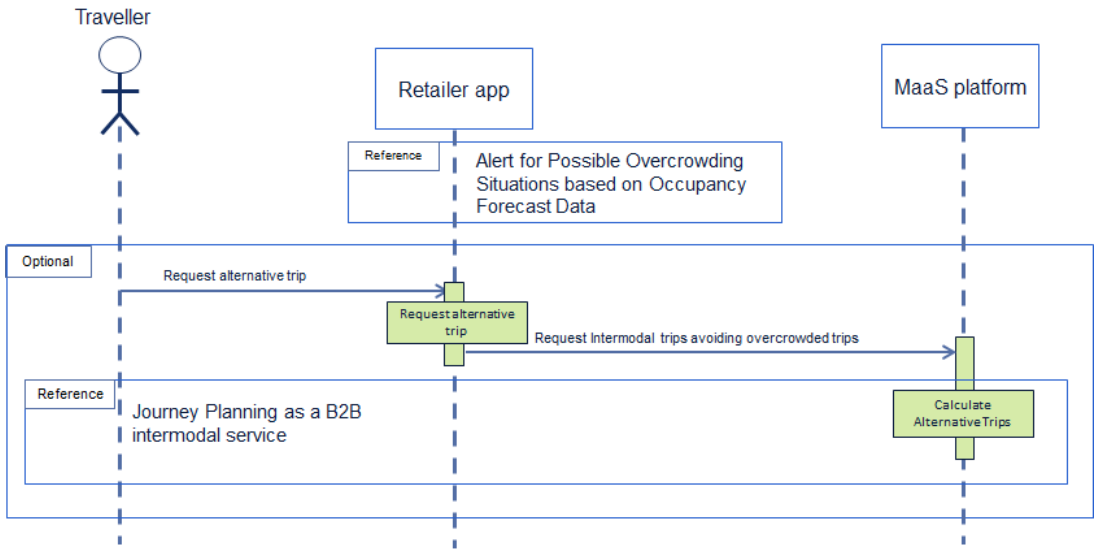

Figure 68: UC-FP1-WP19-45 sequence diagram

If the Traveller received the occupancy forecast alert, the Traveller may choose to request alternatives that avoid overcrowded trip legs via the Retailer App. The Retailer App requests trips from the MaaS Platform with the parameter to consider the occupancy forecast and avoid highly occupied vehicles.

- [UC-FP1-WP19-46] Training of the Short-term Prognosis Model

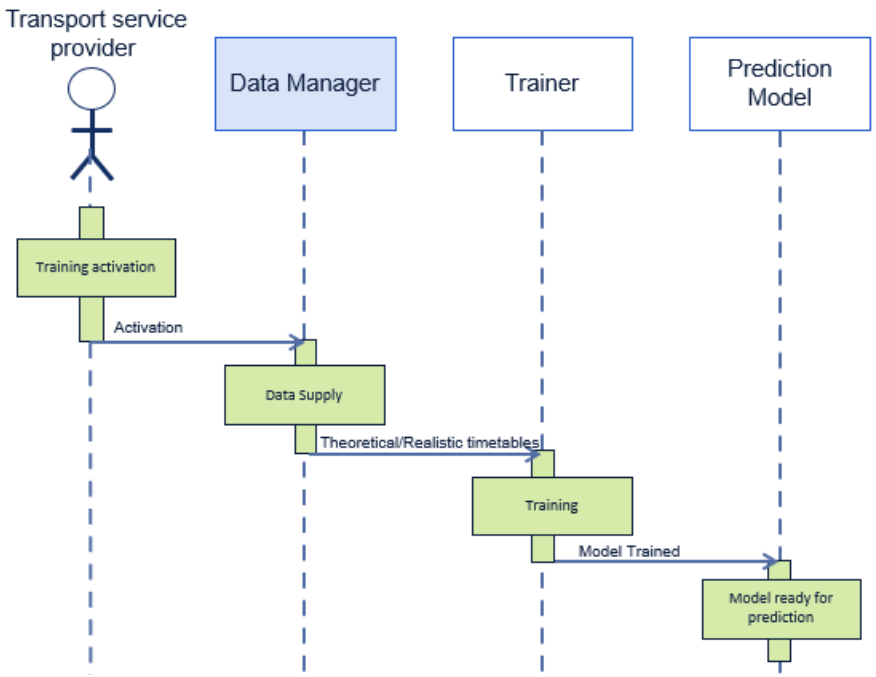

Figure 69: UC-FP1-WP19-46 sequence diagram

This use case aims to train the demand prediction model. To do this, the Transport Service Provider activates the training so that the Data Manager provides the available historical data that is processed by the Trainer. This feeds a recurrent deep learning model with the data and adapts the parameters that characterize the prediction model. Once training is completed, the model is ready for prediction.

- [UC-FP1-WP19-47] Short-term prognosis

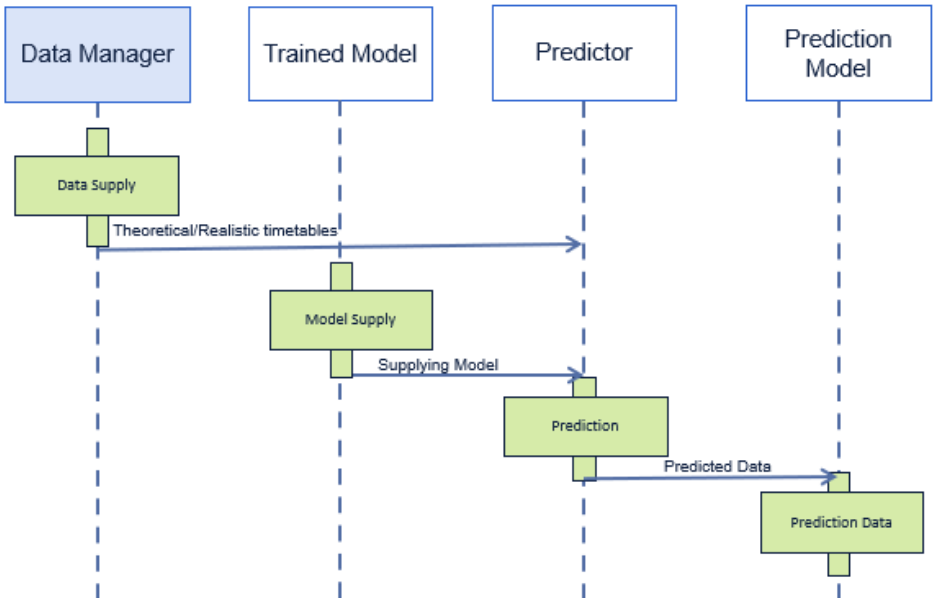

Figure 70: UC-FP1-WP19-47 sequence diagram

This use case aims to predict short-term demand using a prediction model based on a deep recurrent neural network. The model is fed with the data just received and uses the data from several previous periods. The data corresponding to each period includes the demand for the previous period and the set of variables that affect the behaviour of future demand. To do this, the Data Manager provides all this data in real time, so that, using the neural network model previously trained with historical data, the Predictor forecasts the demand data for the next period. This process is repeated periodically as new data becomes available.

- [UC-FP1-WP19-48] Decision support system for short term forecasting on municipal level

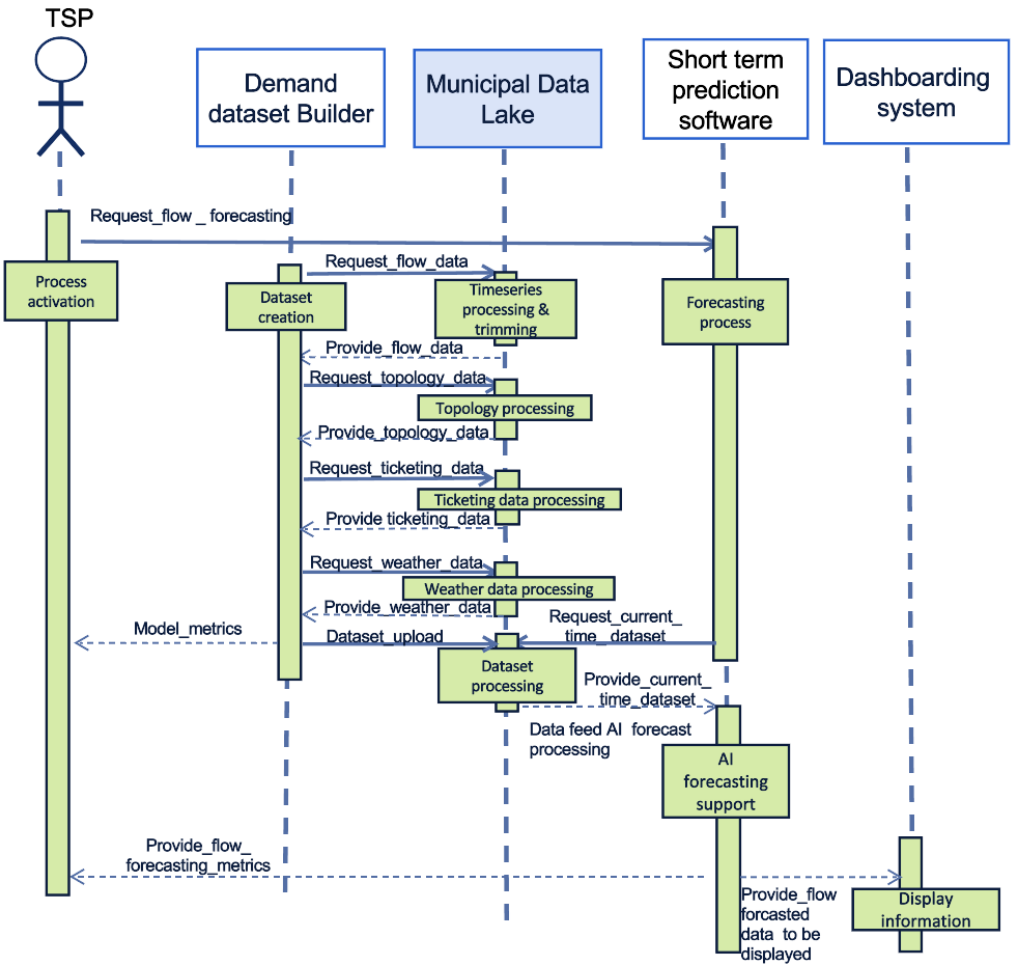

Figure 71: UC-FP1-WP19-48 sequence diagram

Forecasting concerns the short-term aspect. The sequence diagram includes modules such as Demand dataset Builder, Municipal Data Lake, Short term prediction software, among others. Municipal Data Lake is responsible for the acquisition of data from train operators as well as other sources of information, e.g., weather stations. The Demand dataset Builder builds a dataset for use in modulo prediction, taking into account interpolations over time and geographical markers. Dataset builder creates the necessary dataset from data stored in Municipal Data Lake, and then stores it for future use via forecasting process. Decision support information is displayed using Dashboarding system.

- [UC-FP1-WP19-49] Forecast Occupancy of vehicles using journey planning request data

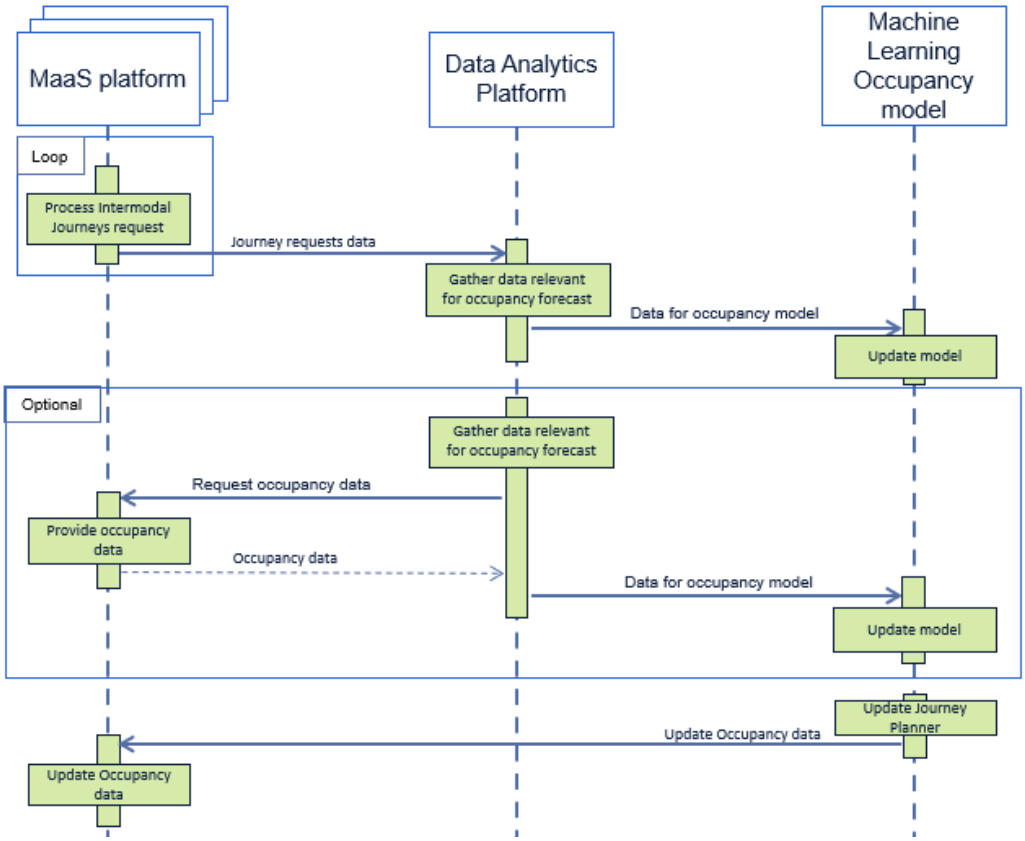

Figure 72: UC-FP1-WP19-49 sequence diagram

The MaaS Platform continuously forwards the Journey Planning requests to the Data Analytics Platform which optionally may also additionally retrieve occupancy data from the MaaS Platform to gather and relevant for occupancy forecasting. This gathered data is forwarded to the Machine Learning Occupancy Model which updates itself accordingly. After the update was done, the new model is forwarded to the MaaS Platform which incorporates the information into its Journey Planning functionality.

- [UC-FP1-WP19-50] Display forecasted occupancy information to travellers when planning trips

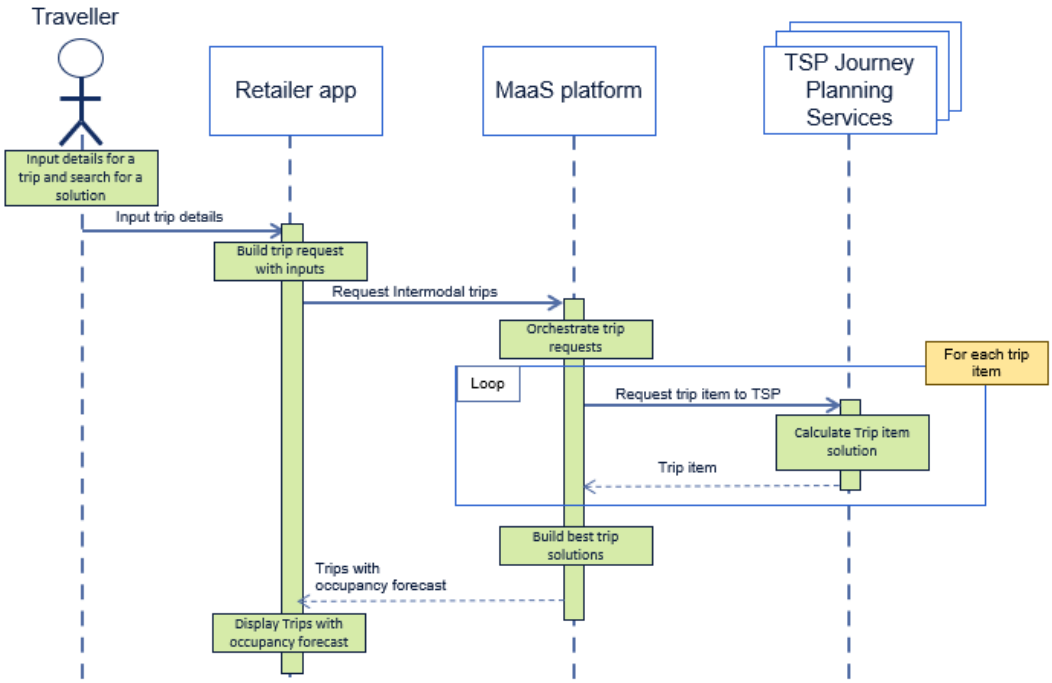

Figure 73: UC-FP1-WP19-50 sequence diagram

The Traveller requests a trip via the Retailer App from the MaaS Platform which orchestrates the distributed Journey Planning across itself and integrated TSP Journey Planning Services. The result may contain the occupancy information for each trip leg if the TSP Journey Planning Services and the MaaS Platform incorporated the previously created occupancy data model.

- [UC-FP1-WP19-51] Estimation of station staff required to provide quality customer service

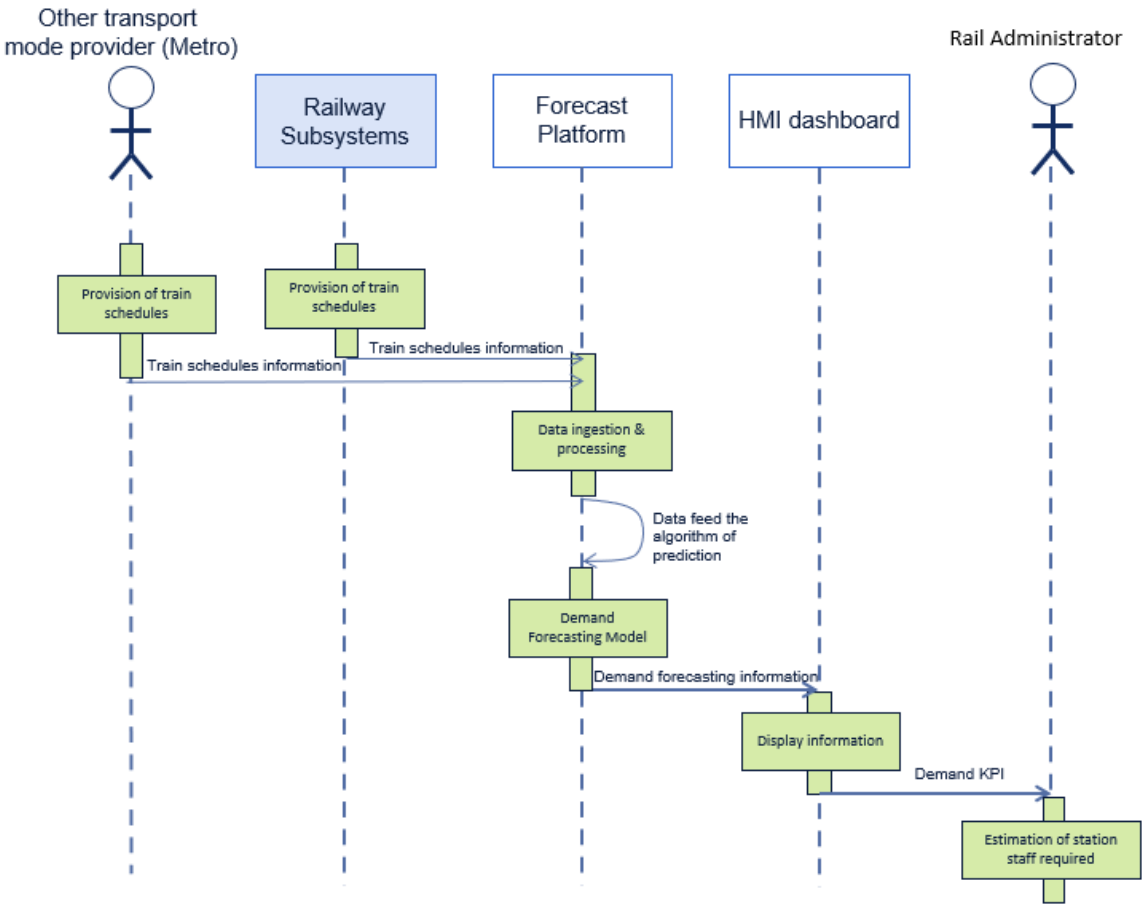

Figure 74: UC-FP1-WP19-51 sequence diagram

In the event that the results of long-term passenger demand forecasts imply a substantial increase in demand compared to the usual station demand, it will be necessary to adequately size the staff required to meet this demand while complying with minimum quality standards.
Schedule information will be made available by the transport service providers to feed a Forecast Platform that will process it and generate a Demand Forecast Model whose outputs will be displayed in the HMI dashboard and from there, demand KPI and warnings will help Rail Administrator estimate the required staff.

- [UC-FP1-WP19-52] Decision support system for long term forecasting on municipal level

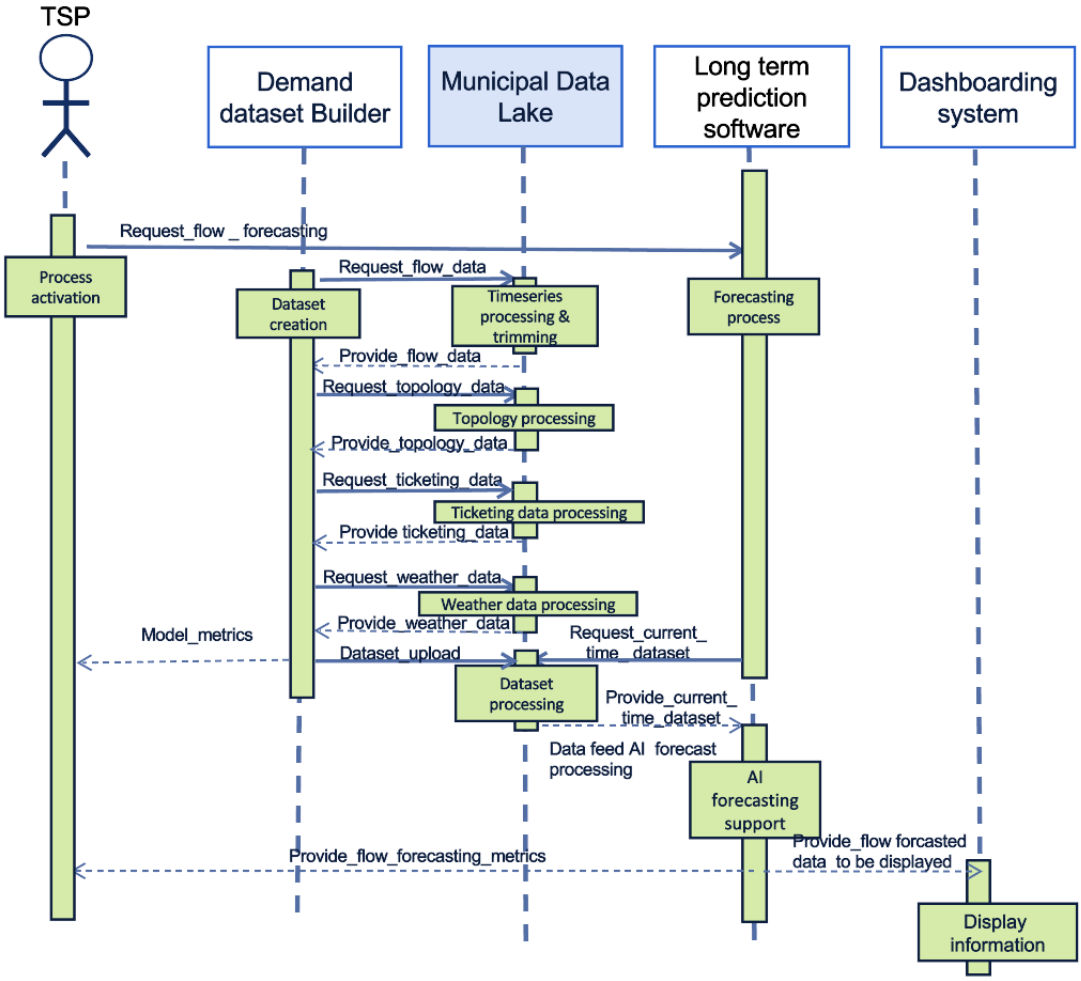

Figure 75: UC-FP1-WP19-52 sequence diagram

The issue [UC-FP1-WP19-52] is similar to [UC-FP1-WP19-49] concerning traffic volume prediction with the difference that it concerns the long-term forecasting aspect. The sequence diagram includes modules such as Demand dataset Builder, Municipal Data Lake, Long-term prediction-software, among others. Municipal Data Lake is responsible for the acquisition of data from train operators as well as other sources of information, e.g., weather stations. The Demand dataset Builder builds the dataset to be used in the prediction module, taking into account interpolations over time and geographical markers. Dataset builder creates the necessary dataset from data stored in Municipal Data Lake, and then stores it for future use via forecasting process. Decision support information is displayed using Dashboarding system.

- [UC-FP1-WP19-53] Transport offer optimisation

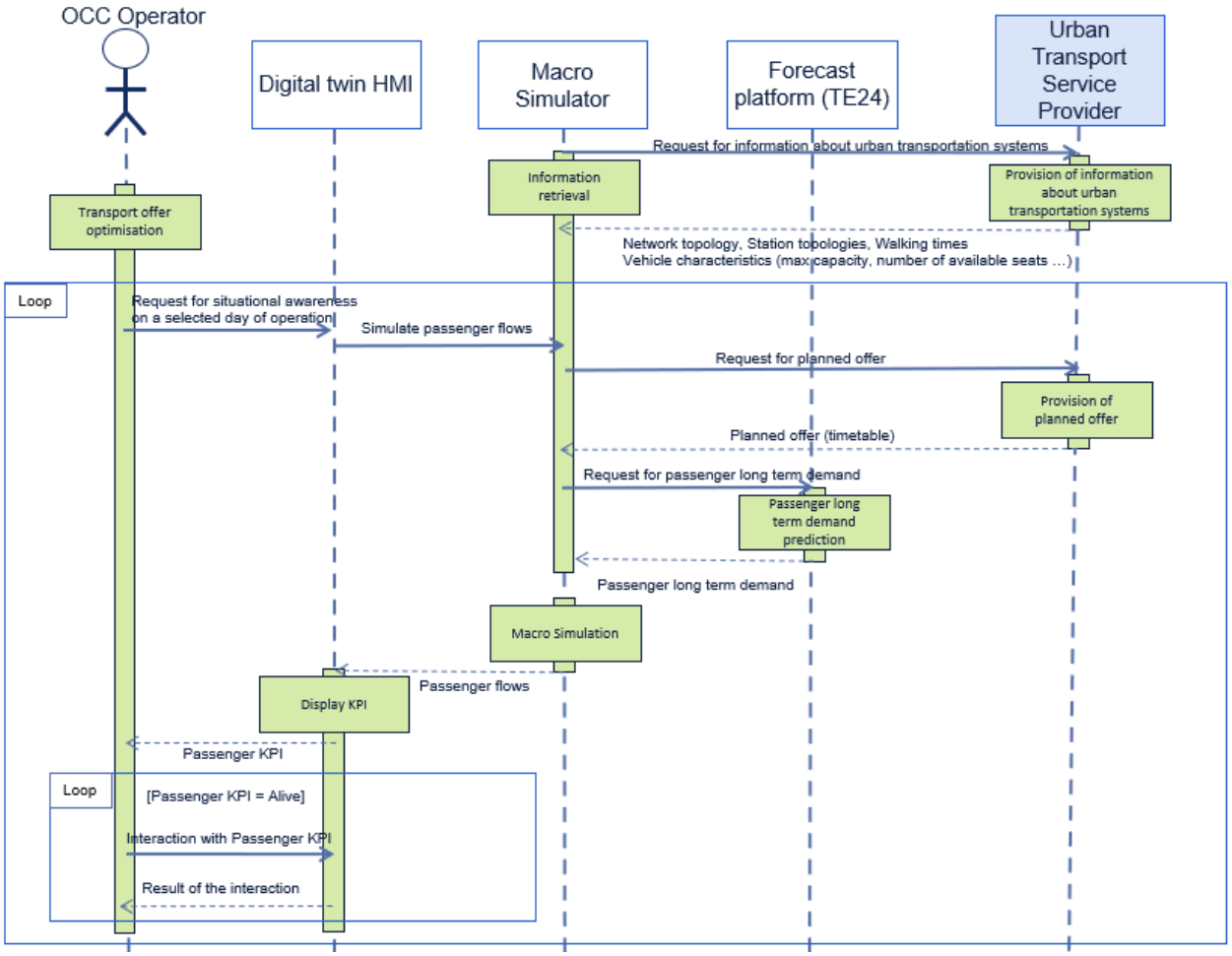

Figure 76: UC-FP1-WP19-53 sequence diagram

The aim of this use case is to assist the OCC Operator in optimizing the transport offer at a macro level. As described in the sequence diagram above, the following steps are taken to achieve this:

1. The macro simulator initializes with information about the urban transportation systems that it has previously requested from the Urban Transport Service Provider.
2. Each time the OCC Operator requests situational awareness on a selected day of operation, the macro simulator collects the planned offer for that day from the Urban Transport Service Provider, as well as the passenger long-term demand from the Forecast platform.
3. The macro simulator then simulates how passengers flow across the urban transport network.
4. At the end, the Digital twin HMI displays Passenger KPI based on the simulation, and the OCC Operator interacts with them to get a better idea of how to optimize the offer.

- [UC-FP1-WP19-54] Analysis of Travel Demand Data based on Forecasted Data

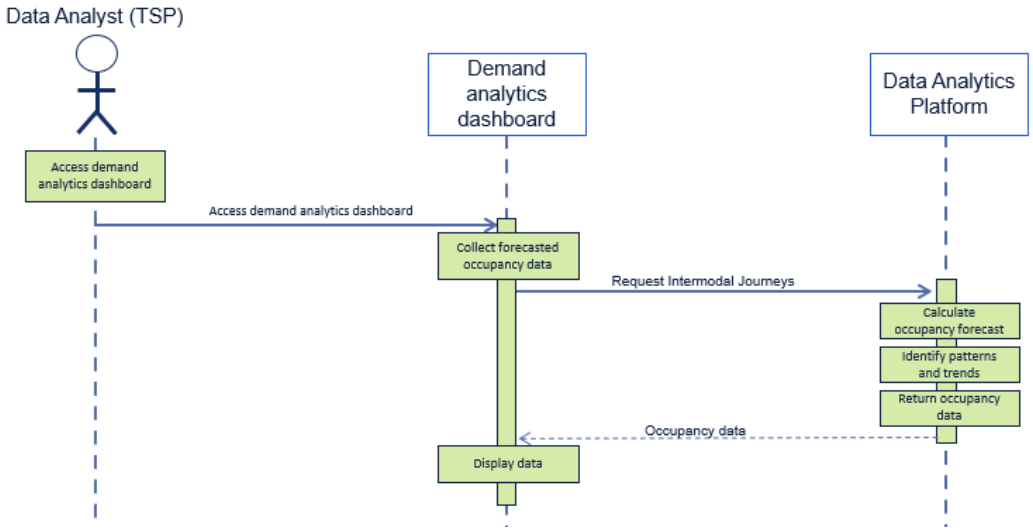

Figure 77: UC-FP1-WP19-54 sequence diagram

The Data Analyst of a TSP can access the Demand Analytics Dashboard to inspect the Demand data. The Demand Analytics Dashboard requests the intermodal Journey from the data Analytics Platform which calculates occupancy forecasts, identifies patterns and trends and ultimately returns the occupancy data to the Demand Analytics Dashboard which displays the result to the Data Analyst.

8.4 Interfaces & standards

The following table describes the standards which will be used within WS1.3: each interface is linked with the corresponding ID number of the TSI (Technical Specifications for Interoperability) Input Plan, a document defined by the System Pillar to coordinate the harmonization outputs and needs from the EU-RAIL programme.

Interface	Description	Data Model - [Data Objects used]	Data model Description	TSI Input plan ID number
Distribution of itineraries	Messages describing the journey planning requests and responses between different platforms, enabling distributed journey Planning with additional functionalities such Location information, Line Information, etc.	OJP - [Location, InformationRequest, TripRequest]	The OpenAPI for distributed Journey Planning (OJP) contains services to request trips, location information, line information, and more. It can be used to address a single external journey planner or to facilitate a distributed journey planning across journey planners.	11
Distribution of tickets	An OpenApi describing the messages to be	OSDM - [Locations	The OpenApi specification covers all messages from	12

	used to implement a sales flow between a Retailer and a Distributor of transport products (osdm.io). OSDM covers the messaging for location search and trip search optionally. The core part is on the offer search, booking and fulfilment (tickets). OSDM additionally covers booking interaction between a distributor and a carrier or fare provider and the offline data exchange between distributors and carriers, but these are not explicitly part of the USE cases demonstrated).	(optional), Trips (optional), Passengers, Offers, Bookings, Fulfillments, After sales Offers, Compensations (optional)]	location search, to receiving Offers making bookings, change bookings enable after sales procedures and compensation procedures to bookings and fulfilments (tickets).	
Fare Transactions	Acccounting processing following the sale of Mobility Packages in a multimodal environment. This accounting processing focusing mainly on revenue distribution uses a standard transaction format as input	CEN NeTEx part 3 - [Sales Transactions]	CEN NeTEx part 3 covers Fare information. In this area the Sales Transaction model is used	14
Disruption messages	Messages describing an occurring disruption used to inform other platforms or, directly, travellers	SIRI SX - [Response]	The SIRI Situation Exchange service covers the exchange of information describing an incident, typically an unplanned event such as a disruption, but also planned events that affect public transport or its use, such as engineering works, or major public events that will affect the use or availability of transport.	13
Timetables	Open Standard used to distribute relevant information about	GTFS Schedule- [stops.txt, routes.txt,	GTFS Schedule contains information about routes, schedules, fares, and	17

	transit systems. It allows public transit agencies to publish their transit data in a format that can be consumed by a wide variety of software applications.	trips.txt, stop_times.txt, calendar.txt, calendar_dates.txt, shapes.txt]	geographic transit details, and it is presented in simple text files.	

Table 79: Interfaces and standards used in WS1.3

9. Demonstration overview

The following sections describe the demonstrations expected for WS1.3. Each demonstration is defined through an explanation of all its linked TEs. The analysis of available datasets and information to be used on demos is not included in this section since a deliverable which will address this specific issue is planned (D2.1 - Research Data Management Plan).

9.1 WP21 Demonstrations

This subchapter describes the demonstrations associated to TE18 and TE19.

Demo	TE 18	TE 19	TE 20	TE 21	TE 22	TE 23	TE 24	TE 25	TE 26	TE 27
T21.2 – Demonstration in Madrid (INDRA, MDM)	X	X	(X)	(X)						
T21.3 – Demonstration in Lodz (PKP, PTO)	X	X								
T21.4 – Demonstration HACON (HACON, DB, PTO)	X	X								
T21.5 – Demonstration GTSD (GTSD)	X	X								
T21.6 – Demonstration Hitachi (STS)	X	X								(X)

Table 80: Demos to TEs mapping – WP21

- Task 21.2 - Demonstration in Madrid

TEs	Demonstration Description
TE18-19	Indra plans two demonstrations to cover Enabler 18 and Enabler 19. The provided MaaS platform for B2B intermodal services will be demonstrated and additional services for this platform developed within WP20 and 21. The Communication with platforms of other consortium partners (e.g., OJP, OSDM) will be based on Standardised Interfaces in appropriate settings. The efforts will focus on standards and industry interfaces (OJP, OSDM).

Table 81: T21.2 demonstrator

- Task 21.3 - Demonstration in Lodz

TEs	Demonstration Description
TE18-19	The PKP demonstrator is located in the municipality of Lodz and focuses on decision support system on the passenger level allowing efficient multimode travel planning realising door-to-door mobility. It relies on a software architecture standard for sharing disparate data between multimodal hubs consisting of one or more stations and data analytic solutions enabling information exchange and integration management (developed in WP20). This covers an interface, which allows to integrate a variety of sales channels of various transport modes. Data stream integration is realised with a Data Lake solution allowing sharing and

	using disparate data and data including rail and other transport modes, other service data, BMSs, video, etc.

Table 82: T21.3 demonstrator

- Task 21.4 - Demonstration HACON

TEs	Demonstration Description
TE18-19	HACON plans multiple demonstrations with different scope to cover Enabler 18 and Enabler 19. The provided MaaS platform for B2B intermodal services will be demonstrated and additional services for this platform developed within WP20 and 21. This includes the following topics: • Communication with platforms of other consortium partners (e.g., OJP). • Demonstrating the potential benefit for operators of their included Mobility Service Providers on the platform (e.g., through the integration of intermodality in the data analyses, improved analysis on used services, identification of potential service areas). • The developments regarding Standardised Interfaces reach TRL 7-8 and are demonstrated in appropriate settings. The efforts will focus on standards and industry interfaces, such as OJP and OSDM. Furthermore, all other developments within WP20 and 21 and the associated enhancements of existing standards are demonstrated appropriately.

Table 83: T21.4 demonstrator

- Task 21.5 - Demonstration GTSD

TEs	Demonstration Description
TE18-19	A demonstration covering the deployment of financial services (revenue apportionment and settlement) in a public cloud is planned. This covers the processing at TRL6 and includes the interface with participant operators if available. Otherwise, simulated data generated based on the real transportation network will be used.

Table 84: T21.5 demonstrator

- Task 21.6 - Demonstration Hitachi

TEs	Demonstration Description
TE18-19	Hitachi demonstrator aims at the implementation of a platform (enabler 18) able to integrate data coming from railway subsystems (and/or other mobility modes) and provide value-added services for the service provider (e.g., disruption management). The platform will be based on existing standardized data models (SIRI, etc.) in order to

	facilitate the information exchange between different platforms (enabler 19).

Table 85: T21.6 demonstrator

9.2 WP23 Demonstrations

This subchapter describes the demonstrations associated to TE20, TE21 and TE22.

Demo	TE 18	TE 19	TE 20	TE 21	TE 22	TE 23	TE 24	TE 25	TE 26	TE 27
T23.1 – Demonstration in Madrid (INDRA, MDM)				X	X					
T23.2 – Demonstration in Malaga (ADIF)			X		X					
T23.3 – Demonstration in Amsterdam (GTSD)			X	X						
T23.4 – Demonstration in Berlin (DB)					X					

Table 86: Demos to TEs mapping – WP23

- Task 23.1 - Demonstration in Madrid

TEs	Demonstration Description
TE21-22	The demonstration is focused on the demonstration of the PRM Assistance solution that would facilitate travelling and the hands-free solution that would allow the demonstration of innovative solutions developed within Task 22.1 and 22.2. This demonstration is connected with the demonstration described in Task 21.4 as the solutions will be integrated within the MaaS intermodal platform developed within WP20/21.

Table 87: T23.1 demonstrator

- Task 23.2 - Demonstration in Malaga

TEs	Demonstration Description
TE20	In this task ADIF FM aims to demonstrate an app and an informative totem which will serve to help people with disabilities to gain more autonomy at the station and its near surroundings, being able to reach all the services they need to in the more seamless. One of the objectives is to demonstrate the functionality of the totem T-Ais, selecting appropriate HW and making all work together with all the information received from the station in real-time, all installed in a real totem to offer people with disabilities the possibility to prove it at demonstration events. The information that is planned to be available for the travellers is related to the services accessible in the station, accessible routing, warnings about incidents with trains which can be traduced into delays, offer of alternative transports nearby, improvement of visual and auditory tools to detect accessible

	entrances, etc.
TE22	The solution to be demonstrated will be oriented to help people with disabilities (not only PRM, but also with other limitations) to be more autonomous and dispose of installations that are more accessible and safer. The solution will include the development of information system and guided routing maps which would help to locate relevant points in the station and signs that could guide them to the point they need to inside the station.

Table 88: T23.2 demonstrator

- Task 23.3 - Demonstration in Amsterdam

TEs	Demonstration Description
TE20-21	This demonstration will happen in an intermodal hub. A station with ideally train, metro, bus, will be selected. The exact place will be defined as part of the setting-up of the demonstration taking into account intermodal objectives and the expectation to have a real operational environment. Enablers in scope include mainly 21, 'hands free solution for travellers ' with the ambition to demonstrate the smooth integration of new technologies from the operators and passenger perspective, the impact on passenger flow, the value added for managing connections, the traveller experience. The targeted Enabler 20 that focuses on assistive tools is also part of the demonstration.

Table 89: T23.3 demonstrator

- Task 23.4 - Demonstration in Berlin

TEs	Demonstration Description
TE22	The demonstration is focused on the PRM Assistance solution that would facilitate travelling e.g., by integrated sensors in the construction or solutions for a better indoor navigation. Demonstration will also cover platform-based guidance systems: one technical solution is planned, by integrated LED, elements in the surface of the platform for a better passenger flow and guidance on high frequented train stations. The illuminated platform edge has to be connected to the passenger information systems or sensors via data interface and thus enables the realization of various use cases to optimally guide and distribute people on the platform to increase the punctuality and capacity and to warn them of the track area. Other planned activities are market research for existing technologies and user journey implementation with a focus of sensors to provide the necessary data e.g., train architecture/lengths, time schedule and utilization of the train. An extension of the pilot to a station with long-distance traffic is to be examined. A detailed plan and timeline will be established for setting up the demonstration and performing testing and the execution of the demonstration. A detailed analysis and assessments of results will be performed after the demonstration.

Table 90: T23.4 demonstrator

9.3 WP25 Demonstrations

This subchapter describes the demonstrations associated to TE23, TE24, TE25, TE26 and TE27.

Demo	TE 18	TE 19	TE 20	TE 21	TE 22	TE 23	TE 24	TE 25	TE 26	TE 27
T25.1.1 – Setting up and execution of Hitachi/FS demonstration (STS, FS)	(X)	(X)							X	X
T25.1.2 – Setting up and execution of PKP demonstration (PKP)						X	X		X	X
T25.2 – ADIF/INDRA Demonstration (ADIF, INDRA)		(X)				X	X			
T25.3 – HACON Demonstration (HACON)						X	X			X
T25.4 – ETRA I+D Demonstration (ETRA I+D)		(X)				X			X	X
T25.5 – GTSD Demonstration (GTSD)						(X)	(X)	X		
INDRA Demonstration (INDRA, new PTO)										X

Table 91: Demos to TEs mapping – WP25

- Task 25.1.1 - Setting up and execution of Hitachi/FS demonstration

TEs	Demonstration Description
TE26-27	Hitachi/FS demonstrator aims at the implementation of different services for the improvement of multimodal traffic management systems. Through the analysis of transport data and subsequent optimisation, the objective is to provide support systems and value-added services for the operator: • Evaluation of ex-ante timetable punctuality based on infrastructure settings and timetable scenario. • Evaluation of Minimum Connection Time (MCT) among different transport modes, using AI and neural networks, and subsequent optimisation. Updating/synchronizing timetables to maximize connections (mono-modal and multi-modal routes) in stations and multimodal hubs. • Decision Support System (DSS) for the operator to manage both unplanned and planned disruptions. In both cases the system shall propose different suggestions/strategies to the operator who may choose the one to be implemented. The proposed mitigation strategies will take into account both operator's and passenger's costs and will be aimed at finding alternative mobility solutions (e.g., already existing bus lines or ad-hoc bus shuttles or taxi services). These services will be demonstrated in an Italian multimodal context

	with the cooperation of FS and its multimodal affiliates.

Table 92: T25.1.1 demonstrator

- Task 25.1.2 - Setting up and execution of PKP demonstration

TEs	Demonstration Description
TE23	Developing algorithms for determining short-term demand forecast based on working time data (e.g., ticket data, short-term weather forecast, passenger flows). Conducting disruption analysis and their use to modify demand forecasting algorithms. Creation of a simplified package for calculating short-term demand forecast based on these algorithms. The execution phase will demonstrate at TRL 6-7 the following prototypes: • Methods of load estimation and prognosis efficiency in transport management decision support. • Flexibility of developed systems in case of observed disruptions and handling them. Those will be implemented on a limited scale as a decision support system for use in planning by operators.
TE24	Creating long-term demand forecasting algorithms with an emphasis on data analysis based on various sources (e.g. public events, holiday calendar) and operator data. Conducting a disruption analysis and using it to modify demand forecasting algorithms. Creation of a simplified long-term demand forecasting package using these algorithms. All analysis will be focused on the municipal level. The execution phase will demonstrate at TRL 6-7 the following prototypes: • Methods of load estimation and prognosis efficiency in transport management decision support. • Flexibility of developed systems in case of observed disruptions and handling them. Those will have a form of decision support system for use of the operator.
TE26	Demonstration in Lodz will include decision support tools providing the planner ability to verify predicted demand and presence of disruptions. The purpose of this tool will be enhancing the manual optimization of the timetable by the planner.
TE27	Demonstration in Lodz Municipality, as a decision support system for the administrator would provide potential information about disruptions to the system. In the scope of disruption management, the demonstration will be very limited – essential functionalities will be specified and open for future implementation.

Table 93: T25.1.2 demonstrator

- Task 25.2 – ADIF/INDRA Demonstration

TEs	Demonstration Description

TE23	The estimation of short-term rail passenger demand models depends mainly on the particularities of each station and the quality of the data provided to feed the model. This TE will be developed for the Málaga Station so the calibration of the model will be carried out with data referring to this station, both railway and the different means involved in the modal chains that originate or end in this station. The modelling of the demand prediction will be carried out using the Big Data platform developed by Indra, this platform has already been used previously for the prediction of travellers in airports with highly satisfactory results. Once the prediction model has been developed and calibrated, its quality will be tested based on a set of previously defined KPIs comparing model predictions with actual data. For the demonstrator the minimum KPIS defined in the project specifications for short-term demand is to achieve an accuracy of at least 80% for a one-hour forecast.
TE24	The estimation of long-term rail passenger demand models depends mainly on the particularities of each station and the quality of the data provided to feed the model. This TE will be developed for the Málaga Station so the calibration of the model will be carried out with data referring to this station, both railway and the different means involved in the modal chains that originate or end in this station. The modelling of the demand prediction will be carried out using the Big Data platform developed by Indra, this platform has already been used previously for the prediction of travellers in airports with highly satisfactory results. Once the prediction model has been developed and calibrated, its quality will be tested based on a set of previously defined KPIs comparing model predictions with actual data. The minimum KPIS defined in the project specifications for long-term demand is to achieve an accuracy of at least 65% for a one-week ahead forecast.

Table 94: T25.2 demonstrator

- Task 25.3 – HACON Demonstration

TEs	**Demonstration Description**
TE23	Our work related to Short-term demand forecast calculations takes occupancy information via wireless communication of traveller application into account. To improve all demand forecast calculations, additional sources of information with the goal to increase accuracy will be considered. The demonstration will be performed in collaboration with an operator and the location will be chosen based on availability of data, which is analysed in WP19 and planned technical developments in WP24.
TE24	Our work will take a variety of sources for long term demand forecast (e.g., seat availability, occupancy information, historic demand information, disruption information). The demonstration will be performed in collaboration with an operator and the location will be chosen based on availability of data, which is analysed in WP19 and planned technical developments in WP24.
TE27	The work will focus on the of a short-term demand calculation concept merged with the management of disruptions across modes, using the

	same operators' data as in TE23 and TE24.

Table 95: T25.3 demonstrator

- Task 25.4 – ETRA I+D Demonstration

TEs	Demonstration Description
TE23	In the demonstration, a platform will be available that integrates short-term forecasting functions with those of strategic management. The platform will allow the visualization of the variables involved in the predictions, the results of the prediction and the characterization of the situations and associated strategies. The platform will include a geographical representation of the information, the visualization of tables and alphanumeric data and different types of graphs. It will also be possible to visualize the action strategies associated with certain situations. For the analysis of the short-term prediction, it will be possible to visualize the temporal evolution of the predicted variables together with the real variables obtained a posteriori. Graphs can also be displayed representing the actual variables against the predicted ones. The KPIs that describe the quality of the prognosis will be displayed.
TE26-27	In the demonstration, a platform will be available that integrates short-term forecasting functions with those of strategic management. The platform will allow the visualization of the variables involved in the predictions, the results of the prediction and the characterization of the situations and associated strategies. The platform will include a geographical representation of the information, the visualization of tables and alphanumeric data and different types of graphs. It will also be possible to visualize the action strategies associated with certain situations. There will be a record of the situations detected and the strategies activated.

Table 96: T25.4 demonstrator

- Task 25.5 – GTSD Demonstration

TEs	Demonstration Description
TE25	The objective is the demonstration with implantation of real data of the concepts elaborated in WP24 Task 24.3, and as such raise the TRL level to TRL5. The integrated traffic simulation and demand forecast in a Digital Twin is split into the following parts: • Macro simulation: using passenger long term demand and planned offer, giving expected passenger KPI. It includes the approach to feed/integrate the result of the long-term demand forecast into the Digital Twins in order to analyse the impacts and to contribute to the optimisation of the offer. Such integration would be done on Macro level and its scope is limited to the urban transport offer and demand. • Micro Simulation: connecting passenger short term demand and current forecast offer, giving expected passenger KPI,

	modelling exchange time and crowd flow. It encompasses full Digital Twin that simulates the flow of passenger through the different transport system. On Line, Digital Twin connected to operation enables the short-term flow prediction and allows operator to perform corrective actions (service reinforcement for example). Micro simulation would be able to take into account degraded situations by modelling passenger behaviour in case of incident. The focus is on the integration in Digital Twins of passenger behaviour in case of incident and includes the urban transport segment only.

Table 97: T25.5 demonstrator

- INDRA Demonstration (INDRA, new PTO)

TEs	Demonstration Description
TE27	In the demonstration, a platform will be available that is able to integrate disruption information. The platform will allow user to visualise the real-time information through the devices that are installed on the station or vehicles. It will also be possible to visualize alternatives with certain situations.

Table 98: WP25 Indra demonstrator

10. Conclusions

The main objective of Europe's Rail FP1 MOTIONAL is to focus on improving network management planning and control, as well as rail mobility management in a multimodal environment in Europe. Research and innovation activities are broken down into several Work Streams (WS) grouping the TEs (Technical Enablers). WP19 is part of WS1.3 "Integration of rail traffic with door-to-door mobility", which includes enablers from 18 to 27.

In this context, D19.1 aims to describe the specification phase by using 3 subsequent steps:

- Operational phase includes the presentation of use cases and involved actors.
- System analysis phase is focused on the introduction of system capabilities (linked with TEs) and requirements.
- Logical architecture phase shows the high-level architectures of development WPs, the components and functions description (and links with requirements), the sequence diagram of each use case and an overview of interfaces and standards included in use cases.

D19.1 also describes the knowledge transfer for each TE from previous projects and the demonstrations declared by each partner to be performed during the demonstration period.
The presented deliverable is an introductory document for the development of the mentioned aspects; future developments and results will be described in deliverables D20.1 "Integrate Rail with other transport modes – Development Report" (WP20, TE18-19), D22.1 "Services for inclusive rail-based mobility – Development Report" (WP22, TE20-21-22) and D24.1 "Anticipate demand leading to improved resource utilization – Development Report" (WP24, TE23-24-25-26-27).

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Table 99: References