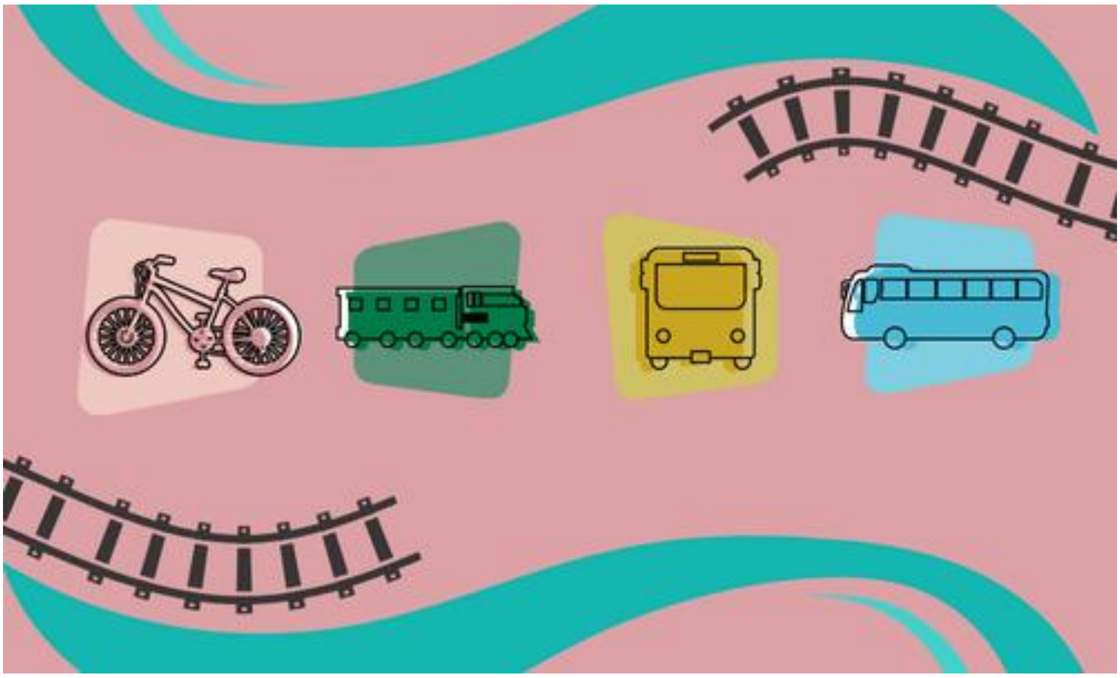
D1.2 - Use Cases and strategies for social optimum



Multimodal Optimisation leveraging Data Acquisition from Local Stakeholders towards a Holistic Improvement of Freight and People Transport

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Project Information

Grant Agreement Number	101203040	**Acronym**	MODALSHIFT
Full Title	Multimodal Optimisation leveraging Data Acquisition from Local Stakeholders towards a Holistic Improvement of Freight and people Transport		
Call and topic identifier	HORIZON-CL5-2024-D6-01-06		
Duration	42 months		
Start Date	1 June 2025	**End date**	30 November 2028
Website	https://modalshift.eu/		
Coordinator	Instituto Tecnológico de Aragón (ITA)		

Document Information

Beneficiary responsible	Véronique Rottier (ID4M)
Author/-s	Véronique Rottier (ID4M)
Co-author(s)	Lilly Rödel (ID4M), Lucie Tristant (ID4M), Eléonore Mennecier (ID4M) Ana V. Silva (ATOBE)
Work Package	1
Deliverable	D1.2

Nature of the deliverable		
R	Document, report (excluding the periodic and final reports)	X
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, etc.	
DATA	Data sets, microdata, etc.	
DMP	Data management plan	
ETHICS	Deliverables related to ethics issues	
SECURITY	Deliverables related to security issues	
OTHER	Software, technical diagram, algorithms, models, etc.	

Dissemination level		
PU	Public, fully open, e.g. web (Deliverables flagged as public will be automatically published in CORDIS project's page)	X
SEN	Sensitive, limited under the conditions of the Grant Agreement	

Quality procedure			
Date	**Version**	**Reviewer**	**Action**
20/02/2026	V1	Cécile Fligny (EQY)	General review of the document
25/02/2026	V1	ITA	General review of the document

DISCLAIMER

ACKNOWLEDGEMENT

This document is a deliverable of MODALSHIFT project. This project has received funding from the European Union's Horizon Europe Programme under grant agreement No 101203040.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 PROJECT ABSTRACT

The vision of **MODALSHIFT** lies in the creation of a transport network and traffic management optimisation framework, trusted and valuable for local stakeholders, that bridges the data from infrastructures, logistics and mobility operators.

New IoT devices - a smart box enabling Capacity-as-a-Service, and a e-subscription device for public transport access for vulnerable people, will increase the sources for data collection. A mobility data space, associated to novel geolocation data anonymisation, will be set up in the 3 Case Studies (Bulgaria, Italy, Spain) to ensure trusted and secure data exchange between data providers and users. This multisource data will enhance traffic state forecasting and increase the detection rate of events by 15%. On this basis, predictive and prescriptive analytics and synchromodality-based scenarios, tested in digital twins and early pilots, will identify optimal actions of transport stakeholders for adjusting their operations, towards a reduction of 25% of the interconnection or transhipment delays.

Agent-based modelling will identify how a modal shift towards low-carbon, active and shared mobility services can be acceptable by end-users and support a reshape of the public transport services and the use of urban space. A multimodal traffic management platform will orchestrate, upon the data space, the cooperation of stakeholders at network and multimodal hub scales. It enables the connection of dynamic optimisation algorithms to operational drivers' tool for mobility operators, and of static models to visual interface for transport planners. The determination of governance models, values for each stakeholder, dynamic pricing and business models, will steer the participation of 8 stakeholders for each Case Study in the multimodal traffic management system.

With this approach, MODALSHIFT stimulates new uses of the transport network to reduce traffic congestion for low-carbon and inclusive mobility, avoiding pernicious rebound effects.

2 EXECUTIVE SUMMARY

2.1 PURPOSE

The deliverable *D1.2 Use Cases and strategies for social optimum* aims at providing an overall updated and enriched version of the milestone *MS2 Initial service design scenarios and UCs (Use Cases)*. By giving a refined description of the MODALSHIFT Case Studies' characteristics in the three different environments (Trieste, Varna and Madrid) it sets a clear basis for all of the project's testing activities. Thanks to the integration of local stakeholders' feedback from the three Case Study environments, the initially identified problems could be refined, and the planned testing activities could be reoriented to tackle real local mobility problems in the most effective way. Local stakeholders' feedback moreover enabled the MODALSHIFT project partners to ensure the relevance and the compatibility of the 11 MODALSHIFT technical solutions and services to be developed within the project with real-world application. Hence, this deliverable sets the direction for all technical developments performed by MODALSHIFT project partners, gives a clear and detailed picture of the specific circumstances and the problems in the different Case Study environments as well as of how MODALSHIFT solutions will help tackle these problems measurable using a number of specific Key Performance Indicators (KPIs).

2.2 INTENDED AUDIENCE

The content of this deliverable is first and foremost addressed to MODALSHIFT project partners involved in technical developments, in local stakeholders' contact as well as in testing activities. Project partners responsible for the developments of solutions and services can come back to detailed technological descriptions as a guide for their developments, they maintain an overview of all developments and have the possibility to include local stakeholders' needs and peculiarities into their work. In the same way, project partners involved in testing activities can use this document as a guide for Use Case scenarios. Project partners involved in local stakeholders' contact such as the Case Study (CS) partners AVANZA, ADF and VARNA can leverage on this document to give clear presentations about MODALSHIFT project activities and objectives.

Consequently, the content of this document is also addressed to external stakeholders from the three Case Study environments strongly involved in the project as they can leverage on the detailed Use Case descriptions to get details about service and solution developments as well as planned testing activities.

2.3 DESCRIPTION OF THE MAIN ACTIVITIES

The preparation of Deliverable D1.2 was supported by a structured and iterative set of activities carried out from the early stages of the project. First, a comprehensive review of the project's strategic and reference documents was conducted by Month 3 (MS2) to ensure a shared understanding of the objectives, scope, and expected outcomes across the consortium. Based on this initial review, all project partners contributed to refining and correcting the descriptions of the services, drawing in particular on inputs gathered during local kick-off meetings and dedicated one-to-one exchanges with CS partners.

In parallel, a local kick-off meeting was organised for each case study in a phygital format, combining an online presentation of the project by ITA and ID4Mobility with on-site or local follow-up discussions held in the local language. This approach was deliberately chosen to reduce language barriers and to facilitate open and detailed exchanges with local stakeholders. Building on these interactions, relevant stakeholders were identified for each case study, and several of them were actively involved in the project activities to enrich the analysis with external perspectives.

Furthermore, a series of interviews with external stakeholders was prepared and conducted to better understand their mobility-related challenges and to assess the relevance and potential uptake of the MODALSHIFT developments. The analysis of these interviews provided valuable qualitative insights. The outcomes of this stakeholder engagement process were then used to complement and fine-tune the content of D1.2, ensuring that the deliverable reflects both consortium expertise and real-world needs and expectations.

Note: some interviews remained to be performed, and this deliverable will be updated accordingly when relevant. Notably, for the Madrid's use case, Non-Disclosure Agreements (NDAs) needs to be signed beforehand due to the highly competitive environment.

2.4 KEY RESULTS

Deliverable D1.2 provides a set of key results that establish a robust and shared foundation for the subsequent technical developments and demonstration activities of the MODALSHIFT project. First, it delivers precise and structured descriptions of the solutions and services to be developed, explicitly aligned with the needs, constraints, and operational realities of local mobility stakeholders. This alignment ensures that all MODALSHIFT partners follow a clear and coherent development path, focusing their efforts on solutions that directly address real-world mobility challenges while remaining compatible with stakeholders' existing capabilities and practices.

In addition, D1.2 defines in detail the testing activities to be implemented within each case study. These descriptions provide partners with a clear and common understanding of the scope, objectives, and conditions of the forthcoming testing phases, enabling them to anticipate potential operational, technical, or organisational issues and to identify in advance any specific data, resources, or complementary information required to ensure effective implementation.

2.5 RESEARCH AND IMPLICATIONS

Although the content of this document is designed above all to help MODALSHIFT project partners coordinate their work, the results described in this deliverable can represent a useful basis for subsequent research activities.

On the one hand, detailed descriptions of technical solution developments and of how they work together to target effectively the MODALSHIFT project challenges give a clear understanding of the project's plan. Since they have been updated according to local stakeholders' feedback from the three Case Study environments, the issues MODALSHIFT services and solutions are going to tackle are confirmed by real-world application. Subsequent research will be able to build on this plan to find other angles to address multimodal mobility and traffic fluidity issues.

On the other hand, the provided concrete and detailed descriptions of Case Study problems and testing activities will allow other, especially Horizon Europe, research projects to find similarities between European Case Studies and benefit from each other's experience.

2.6 POLICY IMPLICATION

The insights from D1.2 offer clear policy-relevant conclusions by highlighting the mobility challenges and needs identified by local stakeholders in the three case study environments. These findings can inform European, national, and regional policymakers in designing transport policies that are better aligned with real-world conditions and stakeholder expectations. Local authorities can use this deliverable to understand the barriers and opportunities faced by mobility operators and service providers, guiding more effective interventions to support modal shift.

2.7 CONCLUSION

The first objective of this deliverable was to establish a clear and shared foundation for all MODALSHIFT development and testing activities. This objective has been achieved through the preparation of updated and detailed descriptions of all technical services and solutions to be developed, as well as the refinement of the case study and testing schemes. These descriptions have been further enriched by integrating the direct feedback of a diverse set of local external stakeholders operating in Varna, Trieste, and Madrid, with particular emphasis on active stakeholder engagement. The resulting definitions, insights, and stakeholder perspectives will shape the future of the project by guiding partners toward solutions that are well-aligned with real-world mobility challenges, facilitating coherent and efficient development, and ensuring the relevance of testing activities. The next project steps will build directly on this information, using the refined service definitions, testing schemes, and KPIs to implement, monitor, and assess the pilot demonstrations, while maintaining continuous engagement with local stakeholders to ensure both project outcomes and potential policy impacts are maximized.

3 ABBREVIATIONS

Table 1: list of abbreviations

Abbreviation	Definition
ABM	Agent Base Modelling
B2B	Business-to-business
CS	Case Study
DL	Deliverable
DT	Digital Twin
EFTi	Electronic Freight Transport information
GTFS	General Transit Feed Specification
KPIs	Key Performance Indicators
MoCs	Memorandums of Cooperation
MTM	Multimodal Traffic Management
MTOs	Multimodal Transport Operators
NDAs	Non-Disclosure Agreements
OBU	On-board unit
PMDs	Personal Mobility Devices
PRs	Project Results
SUMP	Sustainable Urban Mobility Plan
TEN-T	Trans-European Transport Network
TOS	Terminal Operating Systems
T&T&M	Track & Trace & Monitoring
UCs	Use Cases
WPs	Work Packages
ZKP	Zero-Knowledge Proofs

4 INTRODUCTION

Deliverable D1.2 provides a comprehensive definition of the solutions and services to be developed within the MODALSHIFT project, as well as the planned case study activities. It builds on the initial project strategy and incorporates insights from local stakeholders involved in the supply or use of mobility data, gathered through targeted interviews. By integrating these stakeholder perspectives, the deliverable refines case study and testing definitions and adjusts the development plan to better reflect real-world operational and technical requirements. In doing so, D1.2 establishes a clear and shared foundation for all subsequent project activities, ensuring that development, testing, and demonstration efforts are aligned, coherent, and responsive to the needs of the communities and mobility operators involved.

5 CASE STUDY DEFINITIONS

I

This first deliverable presents a detailed exploration of the three case studies envisioned within the MODALSHIFT project, which will unfold at the port of Trieste, the municipality of Varna, and the Estación Sur multimodal hub in Madrid. The following sections will delve into each case study by examining their geographical and demographic contexts, the current state of mobility in these areas, and the proposed testing frameworks—including how these tests will be designed and implemented.

For each location, the discussion will encompass the city and its broader context, the leading partner overseeing the initiative, the stakeholders and end users involved, and key insights gathered during the kick-off meetings. It will also address the existing tools already in place, the specific mobility challenges being tackled, the objectives and main goals—though these are not ranked by priority and may evolve over time—the technologies and data types to be employed, and the expected benefits for each case.

In addition, this deliverable introduces the range of services to be developed as part of the project:

- A: E-subscription device for public transport
- B: T&T&M cargo-bike reservation tool
- C: Dynamic fleet management and drivers' traffic optimisation tool
- D: Road & Rail traffic forecasting tool
- E: Smart lockers & boxes Capacity-as-a-service
- F: Multimodal, trust-by-design & secure data space
- G: Agent-based transport modelling tool
- H: Transport planning, what-if & visualization tool leveraging on the already existing Sustainable Urban Mobility Plan (SUMP)
- I: Cooperative Multimodal Traffic Management System
- J: Shunting operations optimization

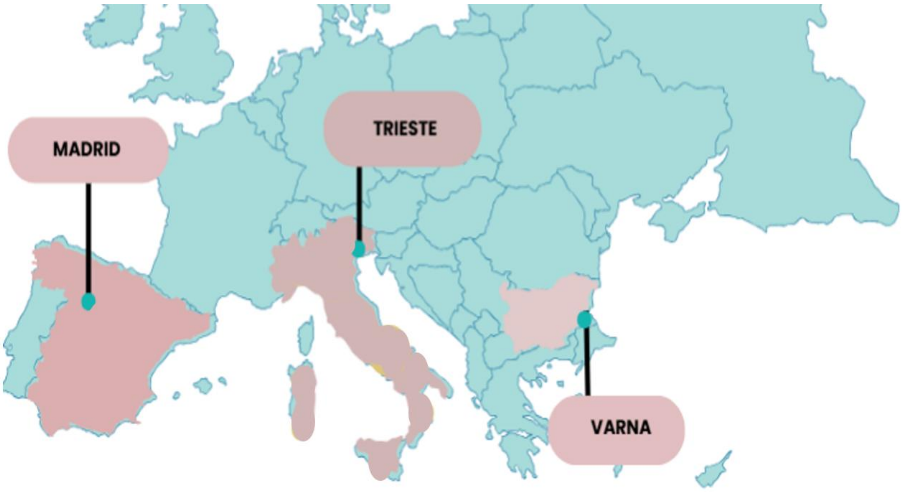


Figure 1: Case studies

5.1 TRIESTE

The Port of Trieste Case Study will be focussing on testing the MODALSHIFT solutions in logistics' applications. Especially improving the smoothness of goods' flows between waterway, railway and last mile logistics thanks to shared data are at the centre of this case study.

The testing phase will run from February 2027 (M21) to November 2028 (M42). Tests will be conducted across all seasons to ensure comprehensive evaluation.

The involved transport modes include passenger trains, freight trains, cargo ships, shunting vehicles and machines, as well as last-mile logistics trucks.

Figure 2: TRIESTE

5.1.1 GLOBAL CONTEXT

Trieste, the capital of the Friuli-Venezia Giulia region in Italy, is located on the Gulf of Trieste near the Slovenian border. With 199,311 inhabitants and an area of 85.11 km², the city has a humid subtropical climate. The Port of Trieste is a **strategic node in the regional logistics chain** and **Italy's leading port for goods traffic**, as well as the largest oil port in the Mediterranean. It is a **key link in the European TEN-T Mediterranean and Adriatic-Baltic corridors**, connecting Austria, Slovenia, and Eastern Europe. Therefore, it is a key node of the regional logistic chain with **significant rise in railway traffic** (over 12,000 trains in 2023), it's an important element for the region's railway service efficiency and competitiveness. However, the port faces for example challenges due to aging railway infrastructure and a lack of interoperability between water, rail, and road transport modes, leading to disruptions and delays. On the technical side, the port docks can be served directly by tracks enabling direct shunting and train composition. The upcoming infrastructural works at Campo Marzio station, the core station of the Port, will constrain operational capacity and track availability for the 2026 and part of the 2027, but will then create a more performing workspace.

5.1.2 LEADER PARTNER

ADF (ADRIAFER SRL), a subsidiary of the Eastern Adriatic Sea Port Network Authority (PNEAS), is the sole shunting operator in the Port of Trieste. ADF will provide real-time data on shunting and train composition and co-develop a collaborative digital platform to enhance efficiency and interoperability among rail, road, and maritime operators.

5.1.3 STAKEHOLDERS & END USERS

Important stakeholders at the Trieste port case study can be divided into 6 groups.

- Freight suppliers inwards and outwards responsible for routing goods from previous destinations to the Trieste port hub and the other way around (such as freight forwarders, the national railway authority – RFI, shipping operators and cargo owners)
- Inwards and outwards logistics operators assuring the reception of goods, transporting them internally and coordinating the outwards goods' flow (such as terminal operators, last mile logistics operators - ADRIAFER, customs agencies and security bodies)
- Internal management operator *PNAEAS* coordinating all the information flows based on the Port Community System.
- Logistics operations' users receiving transported goods (such as other inland ports)
- Enabler entities giving valuable information to the Trieste port (such as port networks, local and regional public administration, research and university stakeholders, chamber of commerce)
- Regulators setting regulation framework and controlling the Trieste port activities (such as the Counsellorship of transport of the Friuli Venezia Giulia autonomous region, the national EFTi Gate and climate condition surveillance).

5.1.3.1 Stakeholders' Roles and Relevance in the Local Transport Ecosystem (interviews)

The interviews represent a diverse range of public and private actors, each contributing distinct expertise to the port and logistics sector in the North Adriatic region.

- The University of Trieste leads academic research and innovation, specializing in maritime and rail transport modelling, digitalization, and sustainability within the port sector.
- HHLA PLT Italy operates as a multipurpose terminal in the Port of Trieste, serving as a critical southern hub for HHLA's European logistics network. Their focus is on intermodal sea-rail connectivity.
- TMT functions as the primary gateway for containerized traffic in the North Adriatic. They handle ultra-large container vessels and manage one of the region's most efficient rail hubs, linking global maritime routes with Central and Eastern European markets such as Austria, Germany, Hungary, and Slovakia.
- Gruber Logistics acts as a bridge between shippers and infrastructure, organizing goods flow across the Trans-European Transport Network (TEN-T) corridors.
- The Port Network Authority, a public body, oversees the planning, coordination, and promotion of port operations in Trieste and Monfalcone. They manage public domain assets, ensure logistics chain security and efficiency, and drive strategic development along the Mediterranean and Baltic-Adriatic TEN-T corridors.
- TO Delta is a comprehensive logistics operator, connecting the Port of Trieste with Central Europe through integrated logistics chains.

5.1.3.2 Commitment, Conditions for Engagement and Relevant Information (interviews)

All interviewed stakeholders express a strong willingness to participate in future MODALSHIFT activities, including workshops, testing, and validation. Six out of seven respondents confirm their direct involvement, while one commits to collaboration.

To ensure active participation, stakeholders highlight the need for tangible outcomes, alignment with strategic goals, and regular updates tailored to their operational priorities.

- The University of Trieste seeks access to technical results from all Work Packages (WPs) and opportunities to involve PhD students in testing phases, ensuring academic integration and hands-on research experience.
- HHLA PLT Italy and TO Delta emphasize the importance of demonstrating a clear path to the 10% efficiency increase outlined in the project scope. They also require updates on how MODALSHIFT will address infrastructure constraints at Campo Marzio, ensuring the system's adaptability to evolving operational conditions.
- TMT prioritizes evidence of reduced reaction times during delays and detailed information on system interaction with the new Campo Marzio infrastructure, as these factors directly impact terminal productivity.
- Gruber Logistics is motivated by reductions in lead time and improved reliability of the Trieste rail node. They also request updates on interoperability between European corridors (WP6), as cross-border efficiency is critical for their logistics networks.
- The Port Network Authority stresses the need for alignment between MODALSHIFT outcomes and their Master Plan (Piano Regolatore di Sistema Portuale). They require regular technical briefings and progress reports on inter-actor communication protocols to ensure strategic coherence and operational integration.
- TMT demand quantifiable results, particularly a measurable reduction in idle times for rail tracks and shunting cycle times. Concrete proof of efficiency gains will solidify their long-term commitment to the project.

5.1.4 EXISTING TOOLS

- Only **partial availability of data on disruption and delays**, loading and unloading schedules, last-mile shunting slots, train departures and arrivals as well passenger train delays. Real-time visibility of train positions outside the port area remains a major gap.
- The Port Community System managed by the Port Authority of Trieste integrates customs and maritime data but **lacks full synchronization with rail operations**.
- Adriafer has its own software that feeds into the port system, a market software that has been customized by the company BINARY. Additionally, operators rely on RFI (national railway infrastructure manager) platforms (PIC – Integrated Circulation Platform) for national network tracking, but **these systems are fragmented and suboptimal for port-last mile integration**.

5.1.5 PROBLEM ADDRESSED

- **Low accessibility of (real-time) data** between railway and last mile managers - no integration / huge fragmentation link to a governance problem (data harmonization easy to solve)

- Access limitations on train-related data (high reliance on manual inputs and fragmented tracking tools).
- **Lack of data interoperability** between waterway, railway and last mile logistics operators. Important loss of time, friction and delay during shunting operations between different transportation modes leading to increased dwell times for wagons.
- **No forecasting of future scenarios** to prepare for different events or simulation of optimization scenarios. Inefficient decision-making due to a lack of information and high reaction times to unexpected delays.
- ***Compliance with EFTI*** *is one of the key challenges for ADRIAFER and terminal operators to achieve a paperless workflow.*

5.1.5.1 Operational Pain Points and Specific Daily Operational Challenges (interviews)

Friction and time loss during shunting, EFTI Compliance and high shunting time:

- For multipurpose terminals, shunting is the "heartbeat" of operations. Delays in technical inspections or wagon readiness cause standstills in quay operations, leading to cascading inefficiencies and increased costs.
- High-frequency shuttle train operators face a "domino effect" from even minor delays. A 30-minute disruption in shunting or inspections can result in missed rail slots on the national network and yard congestion.
- The rigidity of shunting schedules and manual wagon status updates prevent dynamic reprioritization, especially when vessel arrivals are delayed or advanced.

Low data interoperability, Limited real-time data availability

- The "last mile" remains a critical bottleneck. Manual synchronization between the national rail network and port terminals creates buffer times, wasting track capacity and reducing transparency.
- Visibility gaps force operators to allocate terminal resources—staff and machinery—inefficiently. Standstill times translate directly into lost productivity.
- Academic and research stakeholders struggle to access high-quality, real-time datasets from private operators to validate simulation models and predictive algorithms.

Limited cooperation between stakeholders, Ineffective decision-making

- The Trieste port node’s technical complexity, driven by its historical layout and ongoing infrastructure works at Campo Marzio, exacerbates these challenges. The "human factor" and manual processes limit the application of optimization algorithms and real-time decision-making.
- Terminal operators require faster reaction times—reducing delays by at least 15%—to maintain fluidity when vessels or trains are late.
- Lack of predictability affects the entire supply chain. Operators need precise information on trailer/container readiness post-train arrival and real-time updates on shunting delays to avoid missing vessel loading cut-offs.
- Ongoing infrastructure works at Campo Marzio demand adaptive systems to maintain efficiency despite temporary capacity reductions.

5.1.5.2 Operational Pain Points and Specific Daily Operational Challenges (kick off)

Friction and time loss during shunting, EFTI Compliance and high shunting time:

- **Critical bottleneck during shunting downtime:** HHLA highlighted that terminal operations stop whenever Adriafer is performing shunting and wagon inspection. When Adriafer carries out shunting plus inspection plus related checks, HHLA must wait before resuming loading operations. Today, wagon inspection requires approximately one hour, generating cumulative slowdowns. PNAEAS strongly agreed, reinforcing that automated wagon inspection represents an attainable and necessary innovation. RFI (not present at the debate) will also be a key subject for integration, particularly regarding shunting timing reduction and better connection of railway stations serving the port.
- Solutions to test:
    - Shared recognition of priority technological intervention
    - Automating or robotising wagon inspection procedures
    - Evaluation of AI-based recognition systems and/or drones for remote inspection activities
    - Combined reduction of shunting cycle duration.

Low data interoperability, Limited real-time data availability

- **Need for predictive operational visibility:** TMT confirmed similar issues related to waiting times due to shunting and wagon inspection windows._Proposal from TMT and shared across the table: Integrating data from Adriafer + terminal operators + RFI, developing real-time and predictive scheduling for reduced standstill periods, Late vessel arrivals are a known source of variability, but unpredictable shunting slots intensify the effect. Predictive planning emerges as a core MODALSHIFT development path.

Limited cooperation between stakeholders, Ineffective decision-making

- **Lack of Operational flexibility:** TO DELTA stressed that operational adaptability is essential: Adriafer resource allocation should become dynamic and forecast-based, using: PIC system data (RFI's software), terminal operator planning flows, expected arrival/departure forecasts. This would improve alignment with customer needs and reduce congestion.
- **Insufficient communication between railway undertakings:** Participants emphasized very limited communication among railway undertakings, attributed mainly to low trust and lack of shared data channels. MODALSHIFT can act as a neutral interoperability enabler, providing a structured environment for transparent information exchange, shared situational awareness and cooperative scheduling vs siloed planning

Note: All participants highlighted that Trieste Campo Marzio infrastructure works are ongoing and will significantly alter operating conditions in ~2 years. Any transformation piloted within MODALSHIFT must therefore be scalable and compatible with the post-works scenario.

5.1.6 OBJECTIVES & MAIN GOALS

- Enhance interoperability between waterway, rail, and last-mile logistics.
- Develop a collaborative platform integrating real-time data from port authorities, rail operators, and logistics companies.
- Use AI and digital twins to simulate and forecast traffic flows.

- Improve coordination of loading/unloading schedules, shunting slots, and train arrivals/departures.
- Evaluate the impact of passenger train delays on freight operations.

5.1.6.1 Core Challenge: Rail-Port Synchronization and Data Fragmentation

- The primary obstacle across all stakeholders is the lack of real-time data sharing and dynamic synchronization between sea-side and land-side operations. Manual communication—relying on phone calls, emails, and rigid schedules—creates inefficiencies, delays, and hidden costs.
- The absence of a shared data architecture prevents optimization of complex operations such as port shunting. This fragmentation directly impacts terminal productivity, dwell time, and the ability to scale rail capacity from 12,000 trains per year to future targets.
- The shift toward Industry 4.0 and **Green Logistics** is accelerating. Digital Twins and AI-driven solutions are increasingly used to monitor and reduce energy consumption in port operations. Stakeholders are prioritizing **digitalization** to eliminate inefficiencies, enhance flexibility, and meet carbon neutrality goals by 2040. Automated data exchange and real-time tracking are seen as essential to making rail as competitive as road transport. Trieste is evolving into a **"Smart Port,"** focusing on shore power, hydrogen use, and the creation of a Common European Mobility Data Space to improve port-hinterland connectivity.

5.1.6.2 Validation of MODALSHIFT Functionalities (interviews)

The **Multimodal Traffic Management (MTM)** system and dynamic adjustment of shunting schedules are universally recognized as the most valuable solutions. These functionalities directly address the core challenge of synchronizing sea-side and land-side operations, reducing delays, and improving efficiency. Shared situational awareness is equally critical, enabling real-time tracking of shunting engines, technical inspections, and crane deployments. This transparency is essential for optimizing terminal resources and managing customer expectations.

Stakeholders emphasize that achieving even a 10% increase in shunting efficiency through MTM would represent a strategic milestone for the port authority and private operators alike.

5.1.7 TECHNOLOGIES & DATA TYPES USED

- **Technologies**: AI, predictive analytics, cooperative dashboards, C-ITS, macroscopic fundamental diagrams (MFDs).
- **Data Types**: Shunting operations, train schedules, railway traffic data, integrated traffic platform data.

5.1.7.1 Data Availability and Sharing Conditions (interviews)

- Most operational data is private or commercially sensitive, but stakeholders express willingness to share under specific conditions to support the MODALSHIFT Living Lab and improve efficiency.
- The University of Trieste shares model results and academic papers publicly, while raw partner data remains under Non-Disclosure Agreements (NDAs).

- HHLA PLT Italy, TMT, Gruber Logistics, TO Delta, and TMT are open to sharing operational timestamps, rail-related data, or aggregated flow data under strict NDAs to enhance the Trieste node's efficiency.
- The Port Network Authority provides general statistics publicly, while operational data is shared within the port community under governance rules. For MODALSHIFT, data can be leveraged under Memorandums of Cooperation (MoCs).

5.1.7.2 Additional Suggested Functionalities (interviews)

To further enhance MODALSHIFT's impact, stakeholders propose the following additions:

- A **sandbox environment** for researchers to test optimization algorithms using real project data, without disrupting live operations.
- **AI-assisted or automated wagon inspection systems** to replace manual technical checks, significantly reducing inspection times and accelerating the shunting cycle.
- An **automated notification system** (Track & Trace) for the shunting phase, providing milestone updates—such as successful technical inspection completion—to all relevant parties.
- **Tools to enable cooperative scheduling** among private Multimodal Transport Operators (MTOs) and terminal operators, replacing the current siloed planning approach.
- An **integrated platform serving** as a "single source of truth" for wagon status, including technical inspection results, to eliminate delays caused by fragmented information.
- **An automated "ready-to-pull"** signal integrated into Terminal Operating Systems (TOS), providing real-time confirmation when a train is cleared for departure.

The possibility to develop these innovation or tools during the project will be studied shortly.

5.1.8 EXPECTED BENEFITS

The KPIs related to these benefits are described in the KPI section following this document.

The Trieste Use Case seeks to enhance the current transport situation by improving data availability and interoperability.

The project will implement and test solutions that enable stakeholders to integrate large volumes of real-time, aggregated data on disruptions, delays, and incidents affecting both freight and passenger railway and waterway operations. This includes access to simulated and forecasted data to better inform operational decisions.

The collected data, combined with forecasting and simulation tools, will be made available to the Trieste port managing authorities. These tools will help them optimize the planning of shunting activities and respond promptly to real-time operational challenges, such as friction and delays.

Although the project specifically targets the Trieste port ecosystem, the solutions developed can be adapted and replicated by other shunting and railway stakeholders facing similar challenges. This includes ports like Monfalcone, as well as Interporto di Fernetti and Cervignano, which are connected through the broader inland ports' network under the same Port Network Authority.

The project aims to achieve more effective transport and shunting operations, leading to a reduction in lead time and shunting cycle time. It will also foster greater interoperability between waterway, rail, and last-mile logistics through the use of real-time data. Additionally, it will promote common coordination strategies among stakeholders, reduce manual data entry errors, and enable more flexible and effective management of resources.

5.1.9 SUM-UP

Challenges	Tested solutions	Project Result Linked	Expected impact
Friction and time loss during shunting, EFTI Compliance and high shunting time	H: Transport planning, what-if & visualization tool leveraging on the already existing Sustainable Urban Mobility Plan (SUMP) J: Shunting operations optimization	PR6: Traffic forecasting algorithms PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services	More effective transport and shunting operations; reduction of lead time and shunting cycle time. Transition to paperless logistics and automated document exchange**.**
Low data interoperability, Limited real-time data availability	F: Multimodal, trust-by-design & secure data space	PR4: Trusted and secure mobility and freight data spaces	Enhanced overall interoperability between waterway, rail and last mile logistics thanks to real-time data Common coordination strategies
Limited cooperation between stakeholders, Ineffective decision-making	H: Transport planning, what-if & visualization tool D: Road & Rail traffic forecasting tool G: Agent-based transport modelling tool I: Cooperative Multimodal Traffic Management System	PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services PR6: Traffic forecasting algorithms PR7: Multi-objective decision-making algorithms for network and traffic management PR5: Multimodal transport network digital twins in case studies	Reduction of lead time and shunting cycle time, Reduction of manual data entry errors. More flexible and effective management of resources Optimized strategic decision and management

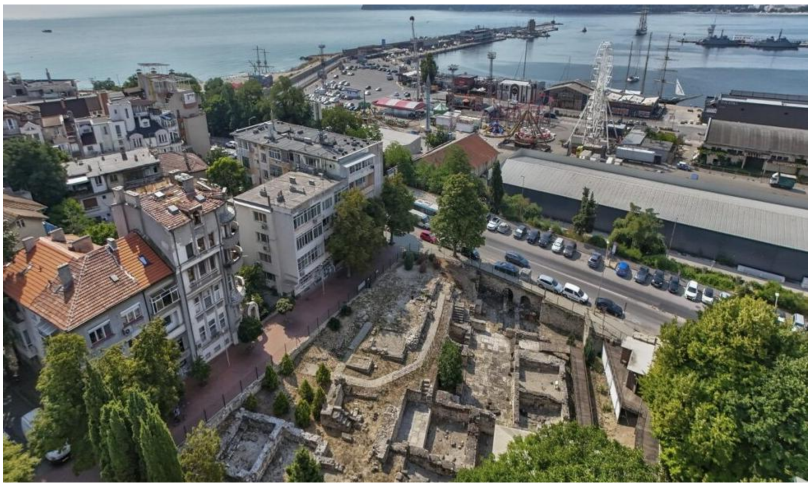
5.2 VARNA

The Varna municipality case study is going to test MODALSHIFT solutions in two different use cases. The first one will focus on providing innovative urban logistics by introducing cargo bikes. The second one will improve the overall traffic fluidity especially during peak tourism periods.

The testing phase will run from February 2027 (M21) to November 2028 (M42). Tests will be conducted across all seasons to ensure comprehensive evaluation.

The involved transport modes include public transport trains, buses and trolley buses, cargo bikes, (citizens' cars).

Note: interviews are still in progress – the deliverable (DL)will be updated when all are done. At the time, the results of 2 interviews have been integrated on the DL.



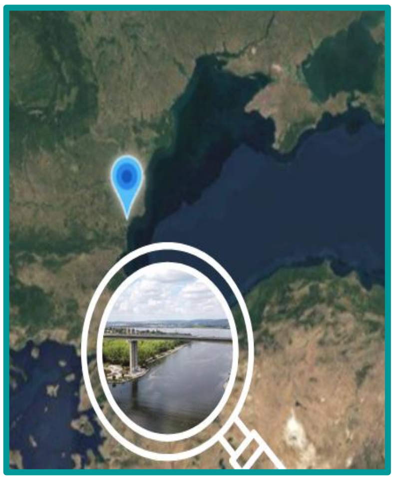


Figure 3 : VARNA

5.2.1 CONTEXT

Varna, Bulgaria's third-largest city with 323,000 inhabitants and a surface area of 254 km², is located on the Black Sea. It features a continental-Mediterranean climate and is a key tourist destination, with its population doubling during summer months. The city has a **pedestrianized city center and a well-established public transport network**, including trains, buses (60 electric), and trolleybuses. However, urban mobility faces challenges due to **seasonal demand peaks, limited urban planning, and inefficient traffic management, particularly when the Asparuhov Bridge is closed.** The Asparuhov Bridge connects the Asparuhovo district of Varna to the rest of the city by crossing the canal between the Black Sea and Lake Varna. This bridge is the only connection between these two parts of the city, and the closest other connection is the ferry in the town of Beloslav, which is located 19 km west of Varna. It happens sometimes that the Asparuhov Bridge is closed in case of heavy traffic congestion or reparation work meaning that connection between two city parts is unavailable. In that case, Varna traffic management gets even more critical.

Note: maritime shuttles have been removed from the case study because while Russia's military actions in Ukraine continue, maritime transport in the Black Sea is high-risk and therefore quite limited.

5.2.2 LEADER PARTNER

Municipality of Varna (Obshtina Varna) leads the pilot as a public authority. It coordinates local data collection, implements e-cargo bike logistics, and develops a digital twin for urban mobility planning.

Varna ensures data governance and integrates results into its Sustainable Urban Mobility Plan (SUMP) for long-term replication.

5.2.3 STAKEHOLDERS & END USERS

Important stakeholders in the two Varna municipality use cases can be divided into 4 groups:

- Varna municipality and connected bodies responsible for traffic management, urban planning and modelling (e.g. also managing the closing and opening of the Asparuhov bridge)
- Public and private transport operators responsible for passenger transport in buses, trains, maritime shuttles and ferries (such as the company Chensfild or the Bulgarian governmental railway company)
- Local business holders interested in transporting effectively their small goods
- End users (Varna citizens and tourists) using public transport and active mobility services
- *Recommended Contacts (interviews): OP TASRUD is suggested as another organization to involve.*

Commitment, Conditions for Engagement and Relevant Information (kick off)

- The representative of National Freight Forwarding Association insisted that in order to implement a multimodal connectivity project, it is necessary and important to attract the interest of the railway company.
- The representative of e-Motion life OOD commented that the regional library use a cargo bike as a mobile library and that contact could be sought with them to exchange experiences in the use of cargo bikes. He also recommended contacting Top Rent A Car, which offers regular electric bikes for rent.

5.2.4 EXISTING TOOLS

- Key infrastructure in place: pedestrian area in city center, well-established public transport network including trains, (electric) buses and trolley busses, extra maritime shuttle in tourist season
- City has designed a Sustainable Urban Mobility Plan (SUMP)
- Progress in electrification of public transport by previous European project *H2020 CityChanger CargoBik*e: Varna municipality has experience in using 6 locally produced e-cargo bikes –
- Geolocalization system of the busses is in place.

5.2.5 PROBLEM ADDRESSED & MAIN CHALLENGES

- Limited data accessibility due to low digitalization levels
- Limited visibility on passenger flows and behaviours
- No optimal urban planning and modelling
- Inefficient traffic management

- Congestion and traffic flow alteration problems, especially during the touristic summer months where population reaches its peak, during temporary closings of the Asparuhov bridge and during construction work

5.2.5.1 Operational Pain Points and Specific Daily Operational Challenges (kick off)

Very limited data accessibility and low digitalization

- The primary challenge faced is lack of connectivity. In daily operations, the absence of real-time data about the vehicle fleet is a significant hurdle. These gaps directly affect route planning, fleet management, and the broader goals of decarbonization and digitalization.
- During the discussion, stakeholder representatives agreed that the main challenges facing transport in Varna are poor infrastructure, insufficient data collection, and a low level of data digitalization.
- Gradski Transport EAD (public bus ant trolley transport company) representative insisted that there was a great need for a dispatch center to consolidate traffic data and better manage traffic.

5.2.6 OBJECTIVES & MAIN GOALS

- Use Case 1 - Low-Carbon Urban Freight:
  - Deploy sensors and a "pay-per-use" cargo-bike sharing system for local businesses.
  - Enable real-time tracking and booking via a dedicated digital tool.
  - Collect data to analyse traffic patterns and forecast demand.
- Use Case 2 - Intermodality & Active Mobility:
  - Improve train-bus intermodality at Varna's railway station.
  - Align public transport schedules with seasonal demand and future bike lanes.
  - Develop a digital twin and data space to enhance urban planning and traffic fluidity.

Validation of MODALSHIFT Functionalities (kick off)

- The planned activities of the MODALSHIFT are considered useful. Specifically, real-time data on the technical condition of vehicles, an accurate overview of bus operations by route, and support for duty and schedule planning are identified as especially valuable functionalities.
- Recent trends, particularly decarbonization and digitalization, highlight the need for a system that optimizes fleet operations. Such a system would enable more efficient route planning and resource utilization, aligning with sustainability and technological advancement goals.

5.2.7 TECHNOLOGIES & DATA TYPES USED

- Technologies: IoT sensors, AI-driven digital twin, real-time tracking systems, and collaborative platforms for data integration.
- Data Types: Mobility datasets (passenger flows, cargo-bike usage), traffic patterns, and public transport schedules.

Data Availability and Sharing Conditions (interviews)

- No external data from public or private sources is currently used.

- Personal data cannot be shared due to data protection regulations.
- There is a willingness to harmonize or standardize existing data to facilitate integration into the Modalshift data workflows.
- No additional datasets beyond those listed are identified as relevant.

5.2.8 EXPECTED BENEFITS

The KPIs related to these benefits are described in the KPI section following this document.

5.2.8.1 Specific benefits

- In **use case 1**, the tested solution will consist of the setup of a cargo-bike rental service for local businesses provided by the Varna municipality. The idea is to enable potential users to see full cargo-bike availability online and to offer an attractive service through the pay-for-use functionality. Targeted end users are small local businesses in need of a quick and simple solution for transportation of a limited amount of goods inside of the city of Varna on a sporadic base.
- In **use case 2**, the tested solution uses the growing available data and applies the MODALSHIFT transport planning tool to the Varna municipality context. The goal is to leverage on the stronger data coverage allowing for more awareness and transparency in traffic fluidity in order to improve traffic management decision-making. This solution targets the Municipality of Varna as the city's public management authority, Varna municipal public transport companies for traffic light control and public transport, the Bulgarian state railways.

5.2.8.2 General benefits

The project in Varna aims to promote modal shift and simulate various mobility management scenarios to reduce congestion and greenhouse gas emissions in the city center.

It seeks to empower small local businesses by offering innovative logistics services, including a flexible pay-per-use system and a digital cargo-bike reservation tool. This tool provides real-time availability information on the cargo-bike fleet, eliminating the need for upfront purchases and reducing maintenance burdens for businesses.

The project will also improve traffic management and enhance public transport fluidity by increasing data visibility across different transport modes. This includes better urban planning and modelling, leading to a general improvement in public transport management: stronger intermodality between trains and buses at the railway station, better alignment of public transport and active mobility schedules, and a contribution to the implementation of Varna's SUMP.

The project will enhance data availability and collection processes, enabling cooperative management among all stakeholders involved in the case study.

Ultimately, the goal is to facilitate overall traffic management in Varna, creating a better transport experience for both citizens and tourists. Citizen feedback will be gathered through surveys to assess the impact of these changes.

The recommendations and guidelines developed from this case study will demonstrate how similar multimodal solutions can be integrated into urban planning processes, making them replicable in other cities. For example, solutions tested in Varna could be adapted for Vienna, particularly around the traffic-critical Reichsbrücke, or in Venice, where the Ponte della Libertà connects key city nodes for car and railway traffic.

The project will deliver enhanced intermodality and real-time data for informed decision-making, while providing a framework for integrating multimodal solutions in other urban contexts. It will also offer cost-effective logistics for local businesses, reduce congestion, and optimize traffic management, especially during peak seasons, all while lowering emissions through the use of e-cargo bikes and improved public transport.

5.2.9 SUM-UP

Challenges	Tested solutions	Project Result (PR)	Expected impact
Traffic congestion especially during summer months and when city bridge is closed	B: T&T&M cargo-bike reservation tool C: Dynamic fleet management and drivers' traffic optimisation tool G: Agent-based transport modelling tool H: Transport planning, what-if & visualization tool leveraging on the already existing SUMP	PR9: Dynamic tools for daily transport service providers operations PR5: Multimodal transport network digital twins in case studies PR7: Multi-objective decision-making algorithms for network and traffic management PR10: Data and scenario visualisation platform for the planning of transport modes and services	Promotion of modal shift and simulation of different mobility management scenarios to reduce congestion and greenhouse gas emissions in the Varna city center Empowerment for small Varna businesses due to innovative logistics services with flexible pay-per-use system and digital cargo-bike reservation tool giving real-time availability information on the cargo-bike fleet Facilitated traffic management and improved public transport fluidity thanks to better data visibility on different transport modes
Inefficient urban planning and modelling	G: Agent-based transport modelling tool H: Transport planning, what-if & visualization tool leveraging on the already existing SUMP	PR5: Multimodal transport network digital twins in case studies PR7: Multi-objective decision-making algorithms for network and traffic management PR10: Data and scenario visualisation platform for the planning of transport modes and services	General improvement of public transport management through better urban planning and modelling Improved intermodality train-bus at the railway station Better aligned public transport and active mobility schedules Contribution to the application of the SUMP
Very limited data accessibility and low digitalization	F: Multimodal, trust-by-design & secure data space I: Cooperative Multimodal Traffic Management System	PR6: Traffic forecasting algorithms PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services	Improved data availability and data collection processes Facilitated cooperative management within the whole case study

5.3 MADRID

In the Estación Sur case study in Madrid, there will as well be two different focuses in testing and deploying activities. In one of the use cases, the overall Avanza network's efficiency will be improved. In the other use case, a new service of integrated passenger and freight transport is going to be tested.

The testing phase will run from February 2027 (M21) to November 2028 (M42). Tests will be conducted across all seasons to ensure comprehensive evaluation.

The involved transport modes include ppublic transport buses, suburban trains, long-distance trains, subways, private logistics trucks, cars for on-demand mobility services, private vehicles, Personal Mobility Devices (PMDs).

Figure 4 : MADRID

5.3.1 CONTEXT

Madrid, Spain's capital, spans 605.77 km² with a population of 3.3 million, expanding to 8,000 km² and 6.7 million in the metropolitan area. The city has a continentalized Mediterranean climate and a well-developed transport network, including buses, suburban and long-distance trains, subway, and private vehicles. Estación Sur is a multimodal goods' and passenger transport hub located at 83 Méndez Álvaro Street in Madrid (Arganzuela district), inside the M-30 ring road and barely 2 km from Atocha. The Méndez Álvaro axis, once an industrial-railway area, has been transformed into a high-density tertiary-residential corridor that includes landmarks such as the Repsol Campus, several state-of-the-art office complexes, and more than 5,000 new homes under development, reinforcing the station's role as the gateway to the new southern business and residential hub. Estación Sur is a multimodal hub connecting 1,500 national and 500 international destinations, with direct access to the M-30 and M-40 highways, Metro Line 6, and Cercanías Lines C-1, C-5, C-7, and C-10. However, the hub faces congestion, delays, and inefficiencies due to fragmented communication between stakeholders, lack of synchromodality, and insufficient freight capacity integration in public transport. This location, together with the extensive range of destinations and its road and rail connectivity, establishes Estación Sur as a strategic node for metropolitan and long-distance mobility, as well as a key platform for Avanza's innovation projects.

5.3.2 LEADER PARTNER

Avanza Spain SL (AVANZA) is the lead partner, operating within the Madrid Transport Consortium (CRTM). Avanza will develop a Digital Twin (DT) of Madrid's transport network and pilot multimodal passenger-freight services at Estación Sur. By enabling real-time data exchange, Avanza aims to reduce delays, optimize resources, and improve efficiency and punctuality across the network.

5.3.3 STAKEHOLDERS & END USERS

Important stakeholders in the two Estación Sur use cases can be divided into 7 groups:

- Logistics operators routing goods from other destinations to Estación Sur hub or public transport smart lockers (such as DHL Express Spain or Amazon Logistics Spain)
- Public transport operators transporting passengers and/or goods in trams and buses (such as AVANZA MOVILIDAD INTEGRAL or Metro de Madrid, S.A.)
- Estación Sur managing operator: managing internal passengers and goods flows' management, providing adapted services to all station users
- Connected mobility hubs receiving passengers and goods from Estación Sur hub (being located in Spain, wider Europe and Morocco)
- Public transport and services' end users (such as ~~Varna~~ Madrid citizens or tourists)
- Enabler entities giving valuable information to the Estación Sur multimodal hub (such as the Technical University of Madrid – Transport Group or the Goods Transport Confederation Madrid)
- Regulators setting regulation framework and controlling (such as the national administration, the regional government and the Urban mobility department of the Madrid City Council)

5.3.4 EXISTING TOOLS

Existing tools and services

- Well-integrated network of interurban buses, Metro, and *Cercanías* trains
- High availability of real-time data on ridership levels, service frequencies, vehicle occupancy, traffic incidents, weather conditions, and infrastructure status on Avanza services and grounds
- Flexible adjustment of supply according to demand and unexpected events. By leveraging Big Data and AI algorithms, dynamic display panels, and integrated management dashboards, CRTM and its operators
- Route optimization, effective resource allocations, and accurate passenger information delivery
- Lockers are in place only for parcel retrieval such as Amazon lockers for example

5.3.5 PROBLEM ADDRESSED & MAIN CHALLENGES

- Passenger overload with over 20 million passengers per year and a sustained growth of 7 % annually
  - Demand peaks during holiday departures
  - Long queues due to train line 6 closures, link currently to construction works, and Metro construction works.
- Chronic rush-hour congestion and increased travel times for intercity buses caused by
- roadway conflicts at Méndez Álvaro / M-30 (shared access between trucks and last-mile delivery vans)
- Insufficient passenger services
  - Limited real-time information when station is overloaded or during unplanned incidents
  - Insufficient storage solutions for users' demand: only luggage lockers and CityPaq parcel lockers are available able to accommodate only light shipments

    - Space issues between light shipments and passenger flows, no technical corridors or cargo areas that could be used by shipments to avoid the crowded passenger areas.
- Data gaps leading to planning difficulties (CRTM & Operators)
    - Data fragmentation due to a lack of a central platform bringing together all relevant network, schedule, regulatory and demand data, inefficient decision-making, slow intermodal coordination
    - Lack of visibility for the passenger on information due to low infrastructure digitalization creating operational inefficiencies and hampering the review and fine-tuning of mobility policies
    - Lack of data integration in real-time fleet and occupancy data, no integrated channels for sharing information with the CRTM

5.3.5.1 Operational Pain Points and Specific Daily Operational Challenges (kick off)

Opportunity to take advantage of the space and capacities available in the PT to move goods around

- Optimizing terminal space—both in urban and interurban areas—is essential to accommodate growing demand and improve operational efficiency. Increasing vehicle capacity utilization across urban, interurban, and medium-distance routes can reduce inefficiencies and lower costs. Strengthening logistics communication between urban centers and peripheral regions is also critical to ensure seamless connectivity and resource allocation.
- Space constraints, particularly in cities like Madrid, pose significant challenges to integrating new logistics models. Initiatives led by local authorities, such as the Madrid City Council, are crucial for developing feasible and sustainable solutions that respect urban limitations.

Insufficient public transport network capacity between Madrid city centre and outer skirts for high daily commuter numbers

- Intermodality remains a key challenge, requiring the transformation of stations into efficient, multi-functional hubs. Real-time information sharing and reduced transfer times are necessary to enhance intermodal connectivity. Freight management faces persistent traceability issues, while innovative solutions like vertiports and drones could revolutionize urban distribution. Passenger-freight integration demands new models that combine the transport of people and goods, with ongoing debates about centralized versus federated management approaches.
- An interactive session revealed critical pain points in last-mile logistics, including traffic congestion, storage limitations, parking shortages, absent recipients, digitalization gaps, delivery errors, scheduling issues, legislative barriers, and reverse logistics challenges. Conversely, passenger-goods integration presents opportunities for efficiency gains, optimization, economies of scope, reduced environmental impact, and cost savings.

5.3.6 OBJECTIVES & MAIN GOALS

- **Use Case 1** (Digital Twin for Transport Network):
    - Develop a virtual representation of Madrid's transport network using open mobility data.
    - Optimize bus schedules, resource allocation, and introduce on-demand mobility services to improve punctuality and reliability.

- **Use Case 2** (Integrated Passenger-Freight Transport):
  - Implement smart lockers and boxes in buses, trams, and Estación Sur for seamless freight transport.
  - Enable real-time data exchange for dynamic adjustments in routing, schedules, and shared infrastructure use.
  - Introduce Capacity-as-a-Service to integrate freight into public transport spaces.

5.3.7 TECHNOLOGIES & DATA TYPES USED

- Technologies: Digital Twin, AI algorithms, IoT sensors, smart lockers, and real-time tracking systems.
- Data Types: Traffic flow, public transport usage, incidents, weather conditions, and transport network structure.

Data Availability and Sharing Conditions (kick off)

- Dynamic data, such as real-time General Transit Feed Specification (GTFS) updates, significantly improves communication and user experience. However, adoption barriers persist, including friction in user interfaces, lack of comfort, and the need to demonstrate immediate usefulness to encourage widespread acceptance.
- Business-to-business (B2B) collaboration is hindered by reluctance to share data, highlighting the need for a neutral "trust entity" to facilitate secure and transparent information exchange. From the end-user perspective, citizens are open to data sharing if it guarantees reliability, transparency, and personalized services, underscoring the importance of building trust and demonstrating value.
- Data availability and sharing conditions must be clearly defined to ensure all parties can contribute to and benefit from shared information. Commitment and engagement conditions should outline the roles, responsibilities, and expectations of each stakeholder, fostering accountability and alignment. Validation of project functionalities is essential to ensure solutions meet operational needs, while additional suggested functionalities should be explored to address emerging challenges. Finally, understanding operational pain points and daily challenges is critical to designing practical, user-centred solutions.
- Zero-Knowledge Proofs (ZKP) offer a promising solution for verifying private data without exposing sensitive information. This technology could enable secure transactions and foster trust in data ecosystems, addressing privacy concerns while promoting collaboration.

5.3.8 EXPECTED BENEFITS

The KPIs related to these benefits are described in the KPI section following this document.

5.3.8.1 Specific benefits

- In **use case 1**, the aims at building a virtual version of the Madrid transportation network based on a digital twin to have a better in-detail knowledge about mobility flows and to improve bus schedules and overall resource use. This Use Case targets the *Consorcio Regional de Transportes de Madrid* (CRTM) as coordinator of Madrid’s public transport operations as well as *Avanza* as leading private transport operator inside CRTM network as users of the traffic management tools. The citizens of Madrid metropolitan area as end users of the transportation system are also going to benefit from the tested solutions.

- In **use case 2**, is going to combine passenger and freight transportation by integrating smart and connected parcel transportation lockers and boxes. Smart lockers will be placed inside buses and trams as well as inside the Estación Sur multimodal hub. Smart boxes will be placed inside the transport means' smart lockers and then transported towards the logistics end point at Estación Sur. Once transferred from the bus/tram into the station's smart lockers, the goods can be picked up by end users. Both smart boxes and lockers are equipped with sensors that record data whilst the freight is moved and stored in or collected from the lockers.

5.3.8.2 General benefits

The project delivers global benefits by improving both passenger and last-mile transport through dynamic adjustments. It provides detailed insights into Madrid's transport network, enabling better decision-making and reducing delays, costs, and congestion. This is achieved with Capacity-as-a-Service and smart logistics solutions.

The solutions are scalable and designed for Avanza's operations in cities like Zaragoza, Málaga, Elche, and Vigo. Commuters benefit from increased punctuality, reliability, and access to real-time information. The Capacity-as-a-Service solution also reduces costs and delays in goods transportation.

Real-time information on passenger transport and parcel delivery schedules optimizes logistics operations, primarily targeting private freight companies, consumers, and public transport operators. The project focuses on improving traffic management around Madrid's multimodal hub, Estación Sur, benefiting the local population with on-demand transport and improved public transit.

The strategies and best practices developed can be replicated by other cities and transport companies. Tailored travel experiences reduce customer friction and enhance satisfaction, while integrated logistics chains allow real-time package tracking and operational visibility.

The project optimizes resource use, improves inter-city bus schedules, and enhances coordination for seamless passenger mobility. It also deepens the understanding of Madrid's transport network for better urban planning, including smart locker capacity knowledge and optimized traffic management tools.

5.3.9 SUM-UP

Challenges / opportunities	Tested solutions	Project Result (PR)	Expected impact
Opportunity to take advantage of the space and capacities available in the PT to move goods around	E: Smart lockers & boxes Capacity-as-a-service G: Agent-based transport modelling tool I: Transport planning, what-if & visualization tool	PR3: Data collection and communication systems for infrastructures, vehicles, people and loads PR1: Capacity-as-a-service design and strategies for increasing the value of multimodal transport services PR7: Multi-objective decision-making algorithms for network and traffic management PR5: Multimodal transport network digital twins in case studies PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services	Optimization of resource use Reduction of costs and delays of goods' transportation through Capacity-as-a-service solution
Insufficient public transport network capacity between Madrid city centre and outer skirts for high daily commuter numbers	A: E-subscription device for public transport C: Dynamic fleet management and drivers' traffic optimisation tool D: Road & Rail traffic forecasting tool G: Agent-based transport modelling tool H: Transport planning, what-if & visualization tool leveraging on the already existing SUMP	PR3: Data collection and communication systems for infrastructures, vehicles, people and loads PR9: Dynamic tools for daily transport service providers operations PR6: Traffic forecasting algorithms PR7: Multi-objective decision-making algorithms for network and traffic management PR5: Multimodal transport network digital twins in case studies PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services	Better coordination and more seamless passenger mobility at Estación Sur Improved inter-city buses' schedules
Lack of information about transport network	D: Road & Rail traffic forecasting tool E: Smart lockers & boxes Capacity-as-a-service	PR6: Traffic forecasting algorithms PR4: Trusted and secure mobility and freight data spaces PR3: Data collection and communication systems for infrastructures, vehicles, people and loads PR1: Capacity-as-a-service design and strategies for increasing the value of multimodal transport services	Better overall and in detail understanding of Madrid's transport network for better urban planning decisions Including capacity knowledge from smart lockers

	F: Multimodal, trust-by-design & secure data space I: Cooperative Multimodal Traffic Management System	PR8: Collaborative platform for multisource multistakeholder traffic and network management PR10: Data and scenario visualisation platform for the planning of transport modes and services	Optimized traffic management tools for dynamic adjustment in passenger and last-mile transport

6 DEVELOPED SOLUTIONS AND SERVICES

In the following part of this document, there will be a detailed description of the different solutions and services developed and tested within the MODALSHIFT project. All in all, there will be 11 different solutions and services, some of them deployed together or integrated in a common tool, some dedicated to being deployed separately.

For the development and extension of Digital Twins, new generation algorithms and transport optimisation models will be used. The Cooperative Multimodal Traffic Management System will leverage on this Digital Twin technology as well as on the Transport planning, What-If & Visualization Tool, the Road and Rail Traffic Forecasting Tool, the Agent-based Transport Modelling Tool and the Secure Data Space.

To further define the services and subservices within the MODALSHIFT project, a structured and iterative methodology was employed. The initial list of services was reviewed collectively by the project partners to ensure a common understanding, improve clarity, and optimize the service lettering for ease of reference. This process included the evaluation of each service's scope and objectives, followed by discussions to refine their content and relevance. As a result, certain modifications were made, including the removal of the "Business Model" service and the addition of "Shunting Operations" and "Anonymisation" as new services to better reflect operational priorities and project objectives.

In the MODALSHIFT context, a distinction is made between services and subservices. While a **subservice** can be considered a technological building block capable of functioning independently, it is typically accessed by end-users only through a higher-level **service**, which integrates one or more subservices into a coherent, user-facing offering. This approach allows the project to leverage modular technical components while ensuring that the solutions provided to mobility stakeholders remain practical, seamless, and directly aligned with their operational needs.

6.1 A: E-SUBSCRIPTION DEVICE FOR PUBLIC TRANSPORT

6.1.1 INITIAL VERSION

MODALSHIFT aims to provide an e-subscription device for vulnerable citizens using public transport. The device is going to facilitate their access to public transport to monitor their trips and provide added value information to guide them in their intermodal journeys. The device is going to help users ~~–~~and by communicating with buses and the surrounding vehicles improving the security of vulnerable users with alerts to nearby connected car users. This e-subscription and tracking device will be developed by **NGS** using Bluetooth Low Energy technology and based on the tracking platform offered by **GGI**. It is going to manage user-based data collection through the OBU. Therefore, **NGS** will customize their IoT scalable sensor to integrate the relevant payment and connectivity functionalities. From the operator perspective, by integrating the IoT data into the Data Space (S6) and including it the MTM tool (S10) this service can also be explored as a source of live demand data with associated benefits.

Will be tested in: Estación Sur Case Study

6.1.2 FEEDBACK AND ADAPTATIONS

Description of the service

The E-subscription device for public transport is a user-facing service providing safety, wellbeing, and occupancy monitoring for Vulnerable Road Users (VRUs) through a personal Bluetooth Beacon with a compact, credit-card-sized form factor.

When a passenger boards a vehicle, the on-board OBU/Gateway automatically detects the beacon and activates a **Be-In/Be-Out** mechanism, enabling automated journey tracking without user interaction. The system logs trips, counts bus stops, and supports passenger flow analysis.

During the journey, onboard environmental conditions (temperature and humidity) are continuously monitored to ensure passenger comfort and wellbeing. When a passenger approaches the vehicle doors to alight, proximity transceivers trigger a **V2X (C-ITS) safety alert** to nearby vehicles, creating a safety zone during the disembarking phase.

The service operates as a hardware-based alternative to MaaS applications, designed with privacy-by-design principles and interoperability through ITS-Station and GS1 EPCIS standards.

Targeted users and customers

- **Users:** Vulnerable citizens using public or private transport, including elderly passengers and persons with reduced mobility.
- **Customers:**
  - Public and private passenger transport operators
  - Municipalities and transport authorities responsible for public mobility coordination

Explanation: Users directly benefit from improved safety, autonomy, and wellbeing during their journeys, while customers deploy and manage the service to enhance transport quality, safety, and operational insight.

Related Project Result (PR)

- **PR3:** Data collection and communication systems

Expected impact regarding modal shift

- Improves perceived and actual safety of public transport for vulnerable users, increasing trust and willingness to use collective transport modes.
- Enhances comfort and accessibility, supporting inclusive mobility strategies.
- Provides operators with precise data on passenger flows and vehicle occupancy, enabling service optimization and improved quality of service, which indirectly supports a shift from private car use to public transport.

6.1.3 TESTING METHODOLOGY

6.1.3.1 Technical / Functional Validation

The technical validation aims to verify that the e-subscription device and the associated backend services reliably support automated journey detection (Be-In/Be-Out), environmental monitoring, and V2X safety alerting for Vulnerable Road Users (VRUs). The validation focuses on hardware–software integration between Bluetooth beacons, OBU/Gateway, proximity transceivers, and the GGI tracking platform, as well as on data interoperability with the project Data Space (S6).

Method

Technical validation will be carried out during development and pre-pilot phases through:

- Internal unit and integration tests on Bluetooth Low Energy (BLE) beacon detection, transceiver sensing near vehicle doors, and OBU/Gateway data transmission.
- On-board functional tests, primarily planned on selected buses operating in Madrid case study, to calibrate BLE detection ranges and positioning accuracy.
- End-to-end tests validating data flows from the IoT devices to the GGI platform and their ingestion into the Data Space, using anonymised datasets where applicable.

While Madrid represents the main reference environment for technical validation, additional or alternative testing modalities are currently being assessed. These may be used to complement, or temporarily replace, on-board vehicle testing in case external constraints (e.g. operational, regulatory, or scheduling limitations) prevent full execution within the use-case vehicles.

Technical KPIs and objectives

- Beacon detection success rate at boarding/alighting: ≥ 90% of events correctly detected under real operational conditions
- Accuracy of Be-In/Be-Out journey detection: ≥ 85% of trips correctly identified end-to-end
- Latency of V2X alert generation after alighting detection: ≤ 2–3 seconds in nominal network conditions
- Environmental data availability during trips (temperature, humidity): ≥ 90% of journey duration

6.1.3.2 User / Adoption Validation

WHY – Purpose of the test

The purpose of the test is to verify the coherence between the functionalities initially planned for the E-subscription device for public transport and the service version effectively developed and deployed at pilot level. The test contributes to the validation of the PR3 – Data collection and communication system.

In particular, the test aims to:

- validate the core functionalities of automated journey detection and passive user interaction as defined in the project objectives.
- assess whether the service effectively supports proactive safety during boarding and alighting phases.
- identify potential deviations from the initial plan caused by technical, operational, or regulatory constraints.

Where certain planned features cannot be fully tested in real vehicles, the test is also used to understand the limiting factors and to document alternative validation approaches adopted.

WHAT – Scope of the test

The scope of the test covers the core elements of the e-subscription service, with a focus on functionalities directly impacting VRU safety and user experience. These include:

- automated Be-In/Be-Out journey detection based on Bluetooth Low Energy (BLE);
- proximity-based detection of boarding and alighting events;
- generation of safety-related alerts associated with passenger disembarkation;
- collection of basic environmental data supporting passenger wellbeing.

Testing is performed at both system integration level (interaction between user device, on-board components, and backend platform) and user-facing service level. Advanced or non-critical features are excluded from the test scope where their validation would require conditions not achievable within the pilot constraints.

HOW – Test methodology

The test is conducted through a combination of technical and user-oriented validation activities.

The methodology includes:

- unit and integration tests to verify correct operation of BLE detection, proximity sensing, and data transmission;
- functional tests executed in pre-pilot and pilot environments to assess end-to-end service behaviour;
- user sessions involving a limited group of vulnerable passengers to evaluate usability, perceived safety, and overall service acceptance.

WHO – Actors involved

The test involves multiple stakeholder groups with distinct roles:

- Public transport operator: supporting access to vehicles and operational coordination.
- Public authorities / transport stakeholders: overseeing compliance and alignment with local mobility policies.
- End-users: vulnerable passengers participating as test subjects in user/adoption validation activities.

HOW MANY – Scale of the test

The scale of the test is deliberately limited and progressive. Technical validation involves a predefined number of test cases and scenarios executed during development and pre-pilot phases. User validation involves a small group of selected vulnerable users (indicatively a few tens of participants), each participating in one or more monitored journeys. The duration of individual tests corresponds to a standard public transport trip.

WHERE – Test environment

The primary reference environment for testing is the Madrid case study, using selected bus lines operating under real conditions.

Where full on-board testing is not feasible, complementary validation activities may take place in controlled or semi-controlled technical environments, such as test vehicles, laboratory setups, or simulation-supported platforms.

WHEN – Timing

Testing activities are carried out during the development, pre-pilot, and pilot phases of the project, in alignment with the implementation timeline defined in the project Gantt charts (D1.3). The detailed testing timeline is further agreed in coordination with the Municipality and the relevant local stakeholders to ensure operational feasibility and regulatory compliance.

ADDED VALUE – Capacity building and learning effects

The testing activities support capacity building for transport operators and public authorities by increasing familiarity with safety-oriented digital services for vulnerable users. For end-users, the pilot contributes to greater awareness and confidence in the use of inclusive public transport solutions, supporting long-term adoption and transferability to other urban contexts.

6.2 B: T&T&M CARGO-BIKE RESERVATION TOOL

6.2.1 INITIAL VERSION

For the development of the shared municipality-owned cargo-bike service in the VARNA case study, MODALSHIFT will connect the T&T&M technology for data collection into an app, giving visibility to local companies on how many shared bikes are currently in use or allowing them to book a time slot, using **NGS**'s 5G battery-less device. For privacy reasons, the bikes' position is not available when in use by other stakeholders. The data transmitted by the IoT devices provided by **NGS** and from the environment will be converted into the GS1 EPCIS 2.0 standard by **NGS** and made available to **GGI**, which will process and display them within its platform. **GGI** will improve its T&T&M portal with functionalities to meet the requirements of the VARNA CS for city-owned cargo-bike fleet management, with self-registration of local businesses, and overview of the municipality about the users. Registered users can see cargo-bike availability and location, reserve them, and track their usage by operators. No location is shown when the vehicles are in use by other business or put offline by the city for servicing. The municipality can extract anonymized information about the locations, and have a report on the utilisation of vehicles, payment and potential misuses (e.g. late return, damages). This data shall also be available via the Data Space (S6) and support analytics and patterns via the MTM tool (S10).

Will be tested in: Varna Municipality Case Study

6.2.2 FEEDBACK AND ADAPTATIONS

Description of the service

The T&T&M cargo-bike reservation tool is a digital service enabling local companies to access and use municipality-owned cargo bikes through a self-service model. Via a dedicated app and software platform, businesses can register, book available cargo bikes, select time slots, and manage payments autonomously.

IoT tracking devices installed on the cargo bikes enable real-time monitoring of usage, operational status, and maintenance needs. To ensure privacy-by-design, the real-time position of bikes is not visible to other stakeholders while they are in use.

In parallel, the municipality accesses a fleet management interface providing anonymized insights on bike utilization, availability, payments, and potential misuse (e.g. late returns or damages). These insights support operational oversight and strategic planning of the shared cargo-bike service.

Targeted users and customers

- **Targeted users** are local businesses and SMEs that require flexible, low-emission last-mile logistics solutions, as well as municipal cargo-bike fleet managers overseeing daily operations.
- **Targeted customers** are municipalities and local public authorities, which own or manage the cargo-bike fleets, and small and medium-sized enterprises that directly use the service. The distinction reflects the dual nature of the service: municipalities act as service enablers and coordinators, while businesses are the primary end users generating operational demand.

Related Project Result (PR)

The service contributes primarily to **PR9 – Dynamic tools**, by delivering an operational digital platform for managing shared mobility assets. It also supports cross-cutting project results related to data interoperability and digital mobility services through the integration of IoT-generated data into common data standards.

Expected impact regarding modal shift

By enabling professional and commercial use of shared cargo bikes, the service directly supports a shift from motorized delivery vehicles to zero-emission alternatives for urban logistics. This contributes to reduced local GHG emissions, lower congestion, and improved air quality, while making sustainable logistics economically and operationally viable for small local businesses.

6.2.3 TESTING METHODOLOGY

6.2.3.1 Technical / Functional Validation

Purpose and scope

Two main parts are tested for this service: the vehicle trackers ability to record and transmit bikes' location and the platform's capability to effectively manage shared vehicles without data-leak between different users.

Method

Before releasing the service to the actual customers, some test rides are performed by NGS or VARNA to generate data used to tune the trackers, configure the servers and ensuring that data is not visible outside the intended audience.

Technical KPIs and objectives

- Data availability: ≥ 99% of relevant recorded positions are used to update GGI's platform.
- Service uptime: the service is available ≥ 99% of the time. Planned maintenance is considered as uptime.
- Real-time updates: the bikes location is updated within 90 seconds from when it's recorded by the tracking device.
- Data privacy: no data is leaked to unintended parties.

6.2.3.2 User / Adoption Validation

WHY – Purpose of the test

After the technical tests are passed, some user tests will be performed to assess that the customers can actually use the shared bike service, and the municipality of VARNA can effectively manage the vehicles.

WHAT – Scope of the test

The validation focuses on:

- Usability of the interface for reserving and tracking the vehicles
- Impact of system use on the VARNA's traffic with focus on the city centre and pedestrian areas
- Impact of system use on local business

HOW – Test methodology

User tests are conducted with support from VARNA and the external stakeholders that accept to be involved in this pilot.

- Local shops perform deliveries using the cargo bikes, reserving the vehicles through the platform and returning it in the designated spots after usage.
- VARNA monitors the status of the vehicles performing the required maintenance when needed.
- VARNA monitors the number of freight vehicles that requests access to pedestrian areas.

WHO – Actors involved

VARNA’s mobility team, external stakeholders that uses the service, NGS and GGI monitoring the service.

HOW MANY – Scale of the test

The duration of the test, the number of vehicles, users, and test sessions will be jointly defined with the Municipality of Varna, based on the availability of cargo bikes, the engagement of service providers, and the involvement of local merchants.

WHERE – Test environment

City of VARNA, NGS and GGI’s servers.

WHEN – Timing

Testing is conducted during operational periods aligned with the work package schedule and system readiness.

ADDED VALUE – Capacity building and learning effects

Data collected in the test stage, should demonstrate the benefits of the last-mile delivery with cargo-bikes on both social and economic level. The social aspect consists in lighter traffic in the city centre and that means lower GHG and more usable pedestrian areas.

6.3 C: DYNAMIC FLEET MANAGEMENT AND DRIVERS' TRAFFIC OPTIMISATION TOOL

6.3.1 INITIAL VERSION

Among the number of devices connected to the multimodal collaborative traffic and network management platform, there will be a dynamic fleet management and drivers' app based on real-time optimisation algorithms for freight delivery. The mobile app for logistics fleet management developed by **GGI** will be further improved since for now it is limited to the management of the fleet of a single user for cargo bike urban deliveries. MODALSHIFT aims at designing a tool suitable for efficient and sustainable urban parcel distribution, based on the **GGI** app in deliveries. The app allows the tracking of the shared vehicles by the registered companies when in use, while focusing on the privacy requirements to avoid a company tracking competitors. These privacy requirements are equally implemented in the Data Space (S.F) and MTM Tool (S.I).

Will be tested in: Varna Municipality Case Study, Estación Sur Case Study

6.3.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Dynamic fleet management and drivers' traffic optimisation tool is an integrated software solution combining an app, backend software, and optimization algorithms. It enables efficient and sustainable urban parcel distribution by allowing logistics operators to track shared vehicles (cars, trucks, cargo bikes equipped with NGS trackers) in real time while preserving data privacy and preventing competitor monitoring. The tool leverages operational, shipment, routing, and urban infrastructure data to optimize tours, load consolidation, and last-mile delivery processes, ensuring reliable and timely deliveries even under restrictive urban regulations.

Targeted users and customers

Targeted users include logistics operators and carriers (planning tours, optimizing loads, managing incidents), infrastructure managers (operating hubs, depots, and microhubs), and last-mile delivery staff (drivers, couriers, cargo-bike riders) who directly interact with the system to improve daily operations.

Targeted customers are shippers, including retailers, e-commerce companies, and manufacturers, who seek reliable, sustainable, and cost-efficient urban freight solutions. Users and customers differ because users operate the system to execute operational tasks, while customers benefit strategically from improved delivery reliability, efficiency, and sustainability.

Related Project Result (PR)

The service contributes primarily to PR7 – Multi-objective Decision-making algorithms for network and traffic management and is also integrated within PR9 – Dynamic tools for daily transport service providers operations, supporting advanced fleet optimization and multimodal delivery operations.

Expected impact regarding modal shift

By enabling smarter, real-time vehicle allocation, optimized routing, and load consolidation, the tool reduces empty runs, improves vehicle and staff utilization, and minimizes congestion and emissions in urban areas. Expected impacts include enhanced delivery reliability, lower environmental footprint, better urban space management, and stronger adoption of shared and low-emission vehicles, promoting a modal shift from single-user or road-dedicated freight transport to optimized, multimodal urban logistics.

6.3.3 TESTING METHODOLOGY

6.3.3.1 Technical / Functional Validation

Purpose and scope

The functional validation aims to ensure that the algorithms developed by KEDGE and the app developed by GGI can produce useful hints to assist logistics operators optimising their operations in planning the delivery tours, operating facilities and performing deliveries.

Method

Validation is performed using data from external stakeholders if available or synthetic data to assess both the integration between the app and the optimisation algorithms and the ability to provide optimised and reliable information.

For a more robust test, uncertainties will be introduced in the model to see how to provide the best solution depending on different scenarios.

Technical KPIs and objectives

- The models are adapted to 3 use cases
- The algorithm is multiplatform and interoperable
- Performance and scalability of the algorithm will be tested against the state-of-the-art
- Vehicle load factor: increased ≥ 10% compared to baseline
- Service time: number of deliveries performed in the expected time window increased ≥ 15% compared to baseline
- Delays: reduction of late deliveries (> 30' outside the time window) and missed deliveries ≤ 15% compared to baseline

6.3.3.2 User / Adoption Validation

WHY – Purpose of the test

The user test has the purpose of validating whether logistics operator can improve deliveries reducing time, distance travelled offering a better service without increasing the number of vehicles in their fleet.

WHAT – Scope of the test

- Usability of the user interface for logistics operator
- Reduction of travel time and distance per parcel delivered
- Increased load factor in the vehicles
- Improved service offered to the customers

HOW – Test methodology

- User tests are performed involving external stakeholders that use the service.

- Historical data from the stakeholder involved is collected to act as baseline.
- System outputs and user decisions are logged for comparison with historical data or expert evaluation
- Feedback is collected on ease of use, trust in system recommendations, and perceived operational improvements
- Analysis is performed to quantify the impact of system recommendations on efficiency and vehicle usage

WHO – Actors involved

External stakeholders that take part in the pilot.

HOW MANY – Scale of the test

The system is monitored for at least 8 months with at least 2 logistics operators using it.

WHERE – Test environment

At least one of the CS cities involved in last-mile logistics, if possible both VARNA and Madrid.

WHEN – Timing

Testing is conducted during operational periods aligned with the work package schedule and system readiness.

6.4 D: ROAD & RAIL TRAFFIC FORECASTING TOOL

6.4.1 INITIAL VERSION

IMEC has developed expertise on route travel time prediction models capable of improving the accuracy of traffic state forecasting through additional components like road / time features or weather information applicable on both public transport and logistics traffic as well as prediction on road network, particularly on segments where induction loops, cameras, and/or map-matched vehicle trajectories are available. These predictive models are also capable of forecasting the freight demand (e.g., volume of incoming cargo) and capacity (e.g., workforce capacity by men hours) at logistics hubs useful for optimization of transport routing. MODALSHIFT will further develop the current network state forecasting and extend it to rail network application for the Italian CS. Through specific transfer learning techniques and preprocessing strategies, a sound use of AI in a multimodal framework and the identification of relevant machine learning based techniques lack of data will be reduced and exploitation of multi-source data will be improved. The Road & Rail traffic forecasting tool is meant to improve the accuracy of traffic forecast and improve the capacities of anomaly detection algorithms to compare forecasts and on-ground situation. This tool will be accessible via the MTM Tool (Service I) where live data and forecasts can be explored, used for alerts and combined with other data sources and visualizations.

Will be tested in: Port of Trieste Case Study, Estación Sur Case Study

6.4.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Road & Rail traffic forecasting tool is a software subservice designed to improve the accuracy of traffic state predictions and enhance anomaly detection algorithms by comparing forecasts with on-ground traffic conditions. Predictions generated by the tool are shared with project partners to improve simulations, scenario planning, and integration into client-facing services such as dashboards.

- Applicable to both road and rail networks.
- Capable of real-time forecasting, using historical and live data from loop detectors, floating car data, public transport buses, and rail network measurements.
- Supports multimodal transport management and enables better decision-making for traffic operations.

Targeted users and customers

- **Users:** Traffic managers, public transport authorities, event organizers, and logistics companies.
- **Customers:** Same as users; these stakeholders directly benefit from improved forecasting and anomaly detection for operational decisions.

Explanation: In this case, users and customers largely overlap because the software outputs are consumed directly by the entities responsible for traffic and transport operations.

Related Project Result (PR)

- **PR6:** Traffic forecasting algorithms

Expected impact regarding modal shift

- More accurate and resilient traffic forecasts enable smoother multimodal traffic management.
- Improved anomaly detection supports rapid response to disruptions, reducing delays for low-carbon and shared transport modes.
- Forecasts contribute to better planning and integration of rail services within multimodal logistics chains, indirectly supporting modal shift from road to rail.

6.4.3 TESTING METHODOLOGY

6.4.3.1 Technical / Functional Validation

Purpose and scope:

- Verify forecasting accuracy for both road and rail networks.
- Assess robustness of models against missing data and sensor failures.

- Confirm anomaly detection capabilities under real-world conditions.

Method:

- Simulate performance using the final segments of historical datasets to evaluate accuracy metrics.
- Conduct on-site tests during real events at Madrid Estación Sur and Trieste using existing traffic management systems.
- Compare forecast outputs against live data to measure predictive performance and anomaly detection reliability.

Technical KPIs and objectives:

- Forecasting accuracy: 10–15% improvement over current state of the art.
- Anomaly detection: 10–15% increase in detection rate.
- Resilience to missing data: 30% reduction in negative impact from gaps in sensor or vehicle data.
- Extension to rail network: full functionality integrated for Italian case study.

6.4.3.2 User / Adoption and Integration Validation

WHY – Purpose of the test:

- Assess whether traffic managers and other stakeholders can effectively interpret and act on forecasts.
- Evaluate real-time integration into operational systems for decision support.

WHAT – Scope of the test:

- Accuracy and timeliness of predictions.
- Usability of dashboards and interfaces.
- Reliability of anomaly alerts.
- Contribution to operational decisions and integration with other MODALSHIFT services (e.g., MTM Tool).

HOW – Test methodology:

- Test models on historical data to validate forecasting performance.
- Deploy forecasts in real-time operations at pilot sites for live testing.
- Log and compare predicted vs. actual traffic states.
- Collect feedback from end-users on usability, trust, and effectiveness.

User and adoption KPIs and objectives:

- Task completion and response to real-time anomalies: ≥ 80%.
- Reduction in average travel delay: measured against baseline conditions.

WHO – Actors involved:

- IMEC technical staff, traffic managers, public transport authorities, event organizers, and project partners supervising integration.

HOW MANY – Scale of the test:

- Tests cover multiple road and rail segments at each pilot site, with several forecasting cycles over representative periods of traffic conditions.

WHERE – Test environment:

- Madrid Estación Sur and Trieste traffic management systems; connected to real-time traffic and rail network data streams.

WHEN – Timing:

- Testing aligned with pilot site operational schedules and WP development milestones.

ADDED VALUE:

- Provides a common forecasting tool for road and rail traffic management.
- Enhances real-time decision-making for multimodal logistics and transport authorities.
- Contributes to improved performance of other MODALSHIFT services relying on accurate traffic forecasts.

6.5 E: SMART LOCKERS & BOXES CAPACITY-AS-A-SERVICE

6.5.1 INITIAL VERSION

The concept of a smart box will be adapted to Capacity-as-a-Service applications through the building of a prototype smart locker, containing several smart boxes that can be swiftly loaded/unloaded between the transport mean and the stop. The smart box acts as a service for logistic unit consolidation and characterisation, enabling the buying of a shipment and collecting data, with Track&Trace&Monitoring (T&T&M). The idea is that smart boxes, once filled by couriers, are loaded into the smart locker installed inside the public transport vehicle. When the vehicle reaches the designated stop where a second smart locker is installed, the system will automatically transfer the smart box—using, for example, a robotic arm—from the locker inside the vehicle to the locker at the stop. The smart box exchange will be scheduled and managed at the dynamic logistics fleet management scale with synchromodality strategies to maintain the public transport network performance. Parcel retrieval is done with an NFC connection. **NGS** develops prototypes of the smart boxes and the smart lockers following ISO sizing standards. The Logistics-as-a-Service approach will embed services like logistics units' characterisation (weight, size, number of items), T&T&M, and the possibility of buying a shipment. Designing this smart box enabling Capacity-as-a-service is a solution for reducing traffic, through the use of public transport for logistics, while adding a new data source helping V2X operations and traffic forecasting. This new data source will be made available in the Data Space (S6) and, through the MTM Tool (S10), will be explored in terms of synchromodal optimisation potential.

Will be tested in: Estación Sur Case Study

6.5.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Smart lockers & boxes Capacity-as-a-Service (CaaS) service enables the use of public transport capacity for urban logistics through modular, automated smart lockers and standardized smart boxes. The service is based on a prototype smart locker containing multiple smart boxes, designed to be rapidly loaded and unloaded between public transport vehicles and designated stops. The smart box acts as a logistics service unit, enabling shipment purchasing, logistics unit characterization (weight, size, number of items), and Track, Trace & Monitoring (T&T&M). All exchanges are scheduled and orchestrated at fleet-management level using synchromodality strategies to ensure that logistics operations do not affect public transport performance. The service follows a Logistics-as-a-Service approach, embedding digital, traceability, and transactional services into public transport operations.

During the current validation phase, the service is implemented through a targeted pilot configuration designed to assess the operational feasibility of automated and semi-automated freight exchange. Specifically, the validation setup foresees the installation of one smart locker at Estación Sur and one smart locker on board a public transport vehicle. This configuration allows the project to test loading, unloading, transfer, and collection processes, as well as the integration of mechanised handling solutions within real operational workflows.

Targeted users and customers

Targeted users are citizens and end recipients of goods, who benefit from more sustainable, less congested urban deliveries, as well as logistics operators handling shipments through the system.

Targeted customers include public transport operators, logistics and courier companies, and small local businesses and retailers. Public transport operators provide and manage vehicle capacity, while logistics actors and local businesses use the service to move goods efficiently and sustainably. The separation reflects the infrastructure-provider role of transport operators versus the operational and commercial role of logistics stakeholders.

Related Project Result (PR)

The service directly contributes to **PR1 – Capacity-as-a-Service (CaaS) models**, by demonstrating how unused or underutilized public transport capacity can be monetized and operationalized for logistics purposes. It also supports **PR3 – Standardised connectors and APIs**, through the integration of smart locker and smart box data into interoperable digital systems.

Expected impact regarding modal shift

By enabling logistics flows to be partially shifted from dedicated delivery vehicles to public transport, the service supports a modal shift towards more efficient and low-emission urban freight transport. This results in reduced traffic congestion, lower local GHG emissions, and improved use of existing transport infrastructure, while supporting small local businesses with access to sustainable logistics services.

6.5.3 TESTING METHODOLOGY

6.5.3.1 Technical / Functional Validation (ultra-short)

Purpose and scope

The validation aims to verify the core technical functionalities of the prototype, specifically the Track&Trace&Monitoring (T&T&M) capabilities, the electronic locking mechanisms, and the API integration with the GGI platform. The validation aims also to ensure that the system effectively enables the Capacity-as-a-Service (CaaS) model, allowing for real-time visibility, dynamic allocation, and remote booking of locker storage space according to a "Logistics-as-a-Service" approach at a TRL 5/6 maturity level.

Method

Validation will follow a multi-stage approach. First, Unit Testing of the IoT sensors and NFC modules within the Smart Boxes will be conducted to ensure signal stability. This is followed by Integration Testing, where the NGS hardware communicates with the GGI platform using the GS1 EPCIS 2.0 standard. Finally, the system will undergo **E**nvironment Testing designed to replicate real-world transport conditions.

Technical KPIs and objectives

- Simulation execution success rate: ≥ 85 % of runs completed without critical errors Unlocking and Access Latency: ≤10 seconds. The maximum time elapsed between user authentication via smartphone and the physical release of the locker compartment.
- Real-time Data Availability**:** ≥98%. The percentage of time the Smart Box system successfully transmits status updates (location, integrity, or environmental data) during transit and storage phases.
- Standard Compliance**:** 100% conformity with the GS1 EPCIS 2.0 standard and defined Data Space (S6) schemas for all outbound messages from the Smart Locker and Boxes.
- System Stability: Zero blocking issues or critical bugs at delivery milestones, ensuring the safety and continuity of the Estación Sur pilot operations.

6.5.3.2 User / Adoption Validation

WHY – Purpose of the test

his test verifies that the PR1 (Capacity-as-a-Service models) and **PR3 (Standardised Connectors and APIs)** are operationally viable.

WHAT – Scope of the test

The validation scope is designed to verify the alignment between the experimental development and the project's strategic objectives, specifically focusing on **PR1 (Capacity-as-a-Service models)** and **PR3 (Standardised Connectors and APIs)**. The test aims to confirm that the "Capacity as-a-Service" approach is technically functional and operationally efficient through the integration of three core components: smart locker prototype, smart box unit and end-to end data flow.

HOW – Test methodology

Phase 1: Technical Deployment & Onboarding**.** Setup of the locker prototype and connection to the GGI portal, followed by the recruitment of a commercial carrier to test the CaaS interface.

Phase 2: Environment-Simulated Operational Testing. A monitored period where "test parcels" are cycled through the system. Observers will track mechanical performance and data latency under conditions that mimic the complexity of a public transport stop.

WHO – Actors involved

NGS & GGI: Technical leads responsible for hardware development (Smart Boxes and Lockers), software platform integration, and standard compliance.

Estación Sur Case Study (Madrid): The primary pilot site management and local technical staff hosting the validation activities.

Target Users (Carriers & Logistics Operators): Professional logistics staff from SMEs or large couriers who will test the loading/unloading workflows and the "buying of a shipment" (Capacity-as-a-Service) model.

Local Businesses (Retailers & SMEs): End-users interacting with the lockers for goods consolidation and "click & collect" services.

Facilitators & Observers: Mobility planners from the municipality and researchers monitoring the impact on urban traffic.

HOW MANY – Scale of the test

The final scale of the test will depend on the project's timeline, the specific availability of the involved stakeholders, and the professional profiles identified for the pilot. The exact number of participants and test sessions will be calibrated in coordination with the municipality and the technical partners to ensure a statistically relevant validation within the operational constraints of the site.

WHERE – Test environment

Primary Site (Choice 1): The Madrid Estación Sur case study is the priority environment for real-world validation, providing the necessary operational complexity.

Secondary/Alternative Sites: Should administrative or technical constraints arise in Madrid, the project is proactively scouting for auxiliary pilot sites or other environments that can provide similar operational data to ensure the testing schedule remains on track.

Last Resort (Contingency**):** As a final fallback measure, validation will be conducted within NGS internal facilities. In this scenario, the labs will be configured as a controlled "operational sandbox" to simulate the Estación Sur environment with high fidelity, ensuring that the TRL 5/6 demonstration can be completed even if external site access is unfeasible.

WHEN – Timing

The testing schedule will be strictly aligned with the overall MODALSHIFT project timeline and milestones. The specific phases and operational windows will be decided in coordination with the municipality of Madrid and the involved stakeholders to ensure the Tdemonstration is completed within the planned work package duration.

ADDED VALUE – Capacity building and learning effects

- **Synchromodal Logistics Proficiency:** The test will demonstrate the feasibility of integrating freight into public transport networks, providing stakeholders with practical knowledge on how to optimize urban logistics.
- **Digital Empowerment for SMEs:** Local businesses will gain expertise in using digital CaaS (Capacity-as-a-Service) tools, improving their ability to manage last-mile deliveries dynamically.

- **Environmental Impact:** The pilot serves as a learning case for reducing local GHG emissions and mitigating traffic congestion through delivery consolidation.
- **Standardization Awareness:** Stakeholders will benefit from the implementation of international standards (GS1 EPCIS 2.0), facilitating future interoperability with other European data spaces.

6.6 F: MULTIMODAL, TRUST-BY-DESIGN & SECURE DATA SPACE

6.6.1 INITIAL VERSION

To tackle current data standard and format harmonisation problems and foster data space security in the logistics and mobility sector through a multimodal perspective, MODALSHIFT will design and implement a new data space architecture for the 3 Case Studies integrating mobility, logistics and transport infrastructures. Based on the learnings of ITA gathered in HE GEMINI (2023 – 2026) and best practices from EMDS, Digital Transport and Logistics Forum and EU data strategy (e.g. supported data harmonisation, addressing the requirements of various data types, minimising redundancies by streamlining knowledge exchange, etc.), the project ambitions to convert data in open REST APIs into the Data Spaces, in line with the EU Directive on open data and the re-use of public sector information. In this process, FIWARE Data Spaces is the proposed Data Space Connector and framework intended for implementation. The aim is to make the data spaces completely compatible with GDPR with the anonymised access to datasets from private actors, while ensuring the alignment with stakeholders' own formats and maturity levels. Moreover, MODALSHIFT will develop standard-based connectors for shared access in the data space for each category of transport stakeholder, facilitating the adoption and customisation to the specificities of stakeholders' data, and integrating trust-by-design with the anonymisation processes. Moreover, these anonymization processes can also be used to desensitize data that do not contain personal but industrial data. The aim of desensitization is to modify information that could potentially reveal strategic or commercial insights about a company. By complementing the possibilities offered by anonymization, desensitization can thus also contribute to encouraging local stakeholders to share their data. **NGS** will support this architecture by providing a GS1 EPCIS-compliant repository and a blockchain-enabled cloud gateway to ensure secure and standardised logistics data exchange. MODALSHIFT will propose practical guidelines for the 3 national/local contexts of Case Studies to support evolutions of data regulations, building on the key directions identified by the MTM cluster (e.g. mandatory open data access) and test phase in these CS.

Will be tested in: Port of Trieste Case Study, Varna Municipality Case Study, Estación Sur Case Study

6.6.2 FEEDBACK AND ADAPTATIONS

Description of the service

This service provides a secure, multimodal data space for the logistics and mobility sector, addressing current challenges in data standardization, format harmonization, and privacy. It integrates mobility, logistics, and transport infrastructure data across the three MODALSHIFT case studies. The platform converts incoming data into standardized formats (REST APIs) and enables anonymization or desensitization, allowing stakeholders to safely share and, where permitted, access aggregated or anonymized data. The architecture also embeds GS1 EPCIS 2.0 compliance and blockchain-enabled mechanisms to ensure trusted, tamper-proof data exchange.

Targeted users and customers

Targeted users include data providers, data owners, and service providers who will upload, query, or manage datasets within the secure data space.

Targeted customers are municipalities, public authorities, transport and logistics operators, and transport/logistics clusters who benefit from standardized, interoperable, and trusted data integration. Users and customers differ because users actively manage or contribute data, while customers leverage the platform to optimize operations, support decision-making, and enhance service coordination across mobility and logistics networks.

Related Project Result (PR)

The service contributes to **PR4 – Data Spaces** by implementing a cross-domain, interoperable data architecture and **PR8 – Collaborative for multisource multistakeholder traffic and network management Platform** by enabling secure, standardized, and privacy-compliant data sharing among multiple stakeholders.

Expected impact regarding modal shift

By enabling secure sharing and integration of multimodal mobility and logistics data, the service supports better-informed planning and coordination of transport operations. It encourages collaboration among stakeholders, improves operational efficiency, and indirectly facilitates modal shift by optimizing logistics flows and reducing delays, congestion, and inefficiencies in urban and regional transport systems.

6.6.3 TESTING METHODOLOGY

6.6.3.1 Technical / Functional Validation

Purpose and scope

This section describes the methodology used to evaluate the performance, usability, economic sustainability, and perceived value of a data space implemented using FIWARE technologies. The methodology is designed to support both **pilot-scale validation** and **operational evaluation**, and it combines quantitative measurements with qualitative assessment to provide a comprehensive view of data space maturity.

The evaluation framework addresses the following dimensions:

- Technical and governance KPIs
- User interaction and usability
- API usage and data exchange behaviour
- Infrastructure and operational costs
- Perceived costs and value for participating organizations

Method

The first evaluation dimension focuses on the objective measurement of the technical performance and governance mechanisms of the data space. Key Performance Indicators (KPIs) are defined to assess reliability, scalability, and trustworthiness.

Technical KPIs and objectives

Technical KPIs are used to evaluate the correct operation of the core FIWARE components and supporting services.

The main indicators include:

- Service availability of context brokers, connectors, and supporting services
- Average and percentile response times of exposed APIs
- Data propagation latency from publication to consumption
- Error rates, including failed API calls and transaction errors
- System behaviour under increasing load conditions

These KPIs are measured through automated monitoring, synthetic workload testing, and log analysis.

Data governance KPIs assess whether data sharing rules are consistently applied and enforced across the data space. Relevant indicators include:

- Proportion of datasets associated with explicit usage policies
- Success rate of access control and contract enforcement mechanisms
- Authentication and identity federation success rate
- Completeness and traceability of access and usage logs

This evaluation ensures that trust mechanisms operate as expected and support secure data sharing between participants

6.6.3.2 User / Adoption Validation

WHY – Purpose of the test

The purpose of the user and adoption validation is to assess whether the FIWARE-based Data Space operates effectively, efficiently, and sustainably, and whether it delivers tangible value to stakeholders. In particular, the test aims to:

- Verify the reliability, scalability, and performance of the data space infrastructure
- Validate data governance, access control, and trust mechanisms
- Evaluate real data exchange and API usage
- Assess operational and infrastructure costs
- Understand the perceived costs and benefits for data providers and data consumers

WHAT – Scope of the test

The evaluation covers both technical and socio-economic aspects of the data space. It includes:

- Core FIWARE components (context brokers, connectors, IAM, APIs)
- User-facing functionalities (data publication, discovery, access, consumption)
- Data governance mechanisms (policies, contracts, access enforcement)
- Infrastructure and operational aspects (availability, cost, scalability)
- User and organizational perception of value and adoption barriers

HOW – Test methodology

The testing methodology combines quantitative measurement, qualitative assessment, and user-centred evaluation, guided by the following principles:

- Tests are performed using realistic datasets and representative use cases
- Quantitative indicators are collected via automated monitoring and logging
- Qualitative feedback is gathered through structured observation, surveys, and interviews
- Standardized scenarios are executed for all participants to ensure comparability
- Test results are documented using consistent templates for KPIs, API usage, and user journeys

Main outputs include:

- KPI tables covering performance, availability, and governance metrics
- API usage logs and aggregated statistics
- User journey execution reports (dataset publication, discovery, access, consumption)
- Infrastructure cost breakdown tables
- Summaries of surveys and interviews capturing user perception

Usability indicators include:

- Time required to complete key user journeys
- Number of steps and manual interventions per journey
- Time to first successful data exchange
- User-reported satisfaction and perceived complexity
- Analysis of anomalies, such as unpublished datasets, inactive consumers, API errors, or documentation gaps

WHO – Actors involved

- Data space operator: Deploys and maintains infrastructure, collects technical metrics
- Data providers: Publish datasets, define usage policies, participate in usability tests
- Data consumers: Discover, access, and consume data; provide feedback on usability and value
- Technical evaluators: Execute performance and security tests, analyse system logs and API usage
- Project coordination and evaluation team: Consolidates results, identifies improvements

HOW MANY – Scale of the test

- 3–5 data providers
- 5–10 data consumers
- 10–30 datasets
- Thousands to tens of thousands of API requests over the test period

WHERE – Test environment

Controlled but realistic staging or pilot deployment of the data space

Cloud-based infrastructure reflecting expected production conditions

Secure network and identity management configuration

Separation from development environments to ensure stability

WHEN – Timing

The testing cycle is structured in phases:

- Preparation: Configure test environment and templates
- Execution: Perform technical tests, user journeys, and collect data
- Analysis: Consolidate, interpret results, and compute KPIs
- Feedback: Discuss findings with stakeholders and identify improvements

Full cycle duration: 4–8 weeks depending on participant number and complexity

ADDED VALUE – Capacity building and learning effects

Beyond validation, testing strengthens capacity and knowledge among participants:

- Increased technical competence in FIWARE and data space concepts
- Improved understanding of data governance and trusted data sharing
- Identification of organizational and technical best practices
- Enhanced readiness for scaling and adoption of the data space

6.7 G: AGENT-BASED TRANSPORT MODELLING TOOL

6.7.1 INITIAL VERSION

To integrate the stakeholders' and end users' perspective in traffic forecasting and optimisation, as well as introduce detailed data on e.g. users' choices and freight flows, MODALSHIFT is going to introduce agent-based modelling (ABM) into multi-objective decision-making algorithms. Hence, **AIT** will use separate models to produce homogenous user groups using mobility information types (Dangschat & Millonig, 2023) and build on the available data shared through data spaces. AIT will apply a lightweight activity-based modelling (ABM-light) approach for multimodal mobility demand analysis, mainly developed within the project KNOWING (2022-2026). This approach is implemented in a Python-based modelling framework rooted in the classical four-step travel demand model, while extending it to better capture temporal and behavioural aspects of individual mobility. By integrating selected features of activity-based microscopic models, such as individual trip chaining, time-of-day sensitivity, and mode choice dynamics, without the full computational complexity of large-scale ABM platforms, the framework enables efficient scenario analysis and policy evaluation at metropolitan scale. Where higher behavioural resolution or network dynamics are required, AIT can also perform full-scale agent-based modelling using MATSim. Depending on the use case, results from the lightweight demand model, MATSim simulations, and data-driven user segmentation can be combined or cross-validated, enabling a flexible modelling pipeline that balances computational efficiency with behavioural realism.

TELLAE has developed an open-source and flexible agent-based simulator dedicated to transportation issues called Starling in the BPI DIVD Rennes Metropole COMOB project (2020-2021), initially used for shared mobility (carsharing, on-demand PT and bike sharing services). Through MODALSHIFT, **TELLAE** will improve the Starling open-source core framework, and community extensions, and will further develop this agent-based model to cover more realistic UCs integrating traffic flow congestion, optimisation of regulatory operations, timetable updates, demand models. Additional mobility services like on-demand mobility and several variants that matches needs of vulnerable populations are going to make the UCs even closer to the reality of the transportation ecosystem and improve the ABM accuracy with positive impacts in strategic and management decisions. MODALSHIFT also aims to measure and improve how the design of services actually answers the citizen needs. Relevant results can be integrated in S10 to be available in combination with the full set of available data.

ITA's digital twin will be based on Multi Agent Virtual Models (AnyLogic) and fed by the data space datasets and synthetic populations. Tailored user-friendly interfaces will interact with the digital twins, allowing stakeholders with varying technical backgrounds to evaluate different scenarios and utilize the insights generated by the digital twin. The digital twin will consider features like scenario definition, visualization tools, and clear reports for effective decision-making. The methodology will follow these steps: (i) collect data from various sources, including sensors (T2.2) and network data for both freight and passenger transport; (ii) develop simulation models to test scenarios like new routes or infrastructure; (iii) ensure reliable data flow, verify quality, and address gaps; (iv) balance model detail with computational efficiency to reach an optimum of detail; (v) continuously calibrate the digital twin with real data, establishing procedures for data integration and validation; (vi) finalize the digital twin for each CS, incorporating feedback from pre-tests.

Will be tested in: Port of Trieste Case Study, Varna Municipality Case Study, Madrid Case Study

6.7.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Agent-based transport modelling tool provides access to simulation models developed in WP3, integrated into the project's digital twin. It enables evaluation of "What-If" scenarios defined by the user, supporting assessment of new mobility services, transport policies, or other interventions.

- For each scenario, key performance indicators (KPIs) and geospatial visualizations are generated.
- Through integration with service H, simulations can be accessed and executed in a user-friendly interface, allowing further visualizations and scenario analysis.
- The tool supports multimodality, individual behaviour changes, and testing of transport system adjustments at agent level.

Targeted users and customers

- **Users:** Technical teams working on transport modelling.
- **Customers:** Transport authorities, transport operators, and consulting companies.

Explanation: Users operate the modelling tool directly, while customers benefit from optimized transport management insights and scenario evaluations.

Related Project Result (PR)

- **PR5:** Multimodal Transport Network digital twin
- **PR7:** Decision-making algorithms

Expected impact regarding modal shift

- Provides evidence-based insights to measure how the design of transport services meets authorities' objectives.

- Supports optimization of transport management for operators.
- Enhances strategic and operational decision-making by simulating individual behaviours, multimodality, and new mobility services, indirectly supporting modal shift through better-informed planning and service design.
- Provide more robust and reliable decisions seeing possible deviations and agent-based modelling tools.

6.7.3 TESTING METHODOLOGY

6.7.3.1 Technical / Functional Validation

Purpose and scope:

- Calibrate the agent-based models using existing data.
- Evaluate the accuracy and reliability of scenario simulations.
- Assess the tool's ability to model multimodal transport systems and behavioural responses.

Method:

- Initial validation by calibrating models with historical and operational datasets.
- Sensitivity tests to evaluate robustness and simulator behaviour under different input conditions.
- Execution of multiple mobility scenarios per use case to assess performance and outcomes.
- Comparison of model outputs with expert opinions and literature to validate results.

Technical KPIs and objectives:

- Accuracy of simulation outputs: validated against historical data and expert judgment.
- Robustness and realistic sensitivity of scenarios
- Inputs and outputs clarity and understandability

6.7.3.2 User / Adoption and Integration Validation

WHY – Purpose of the test:

- Assess whether transport modelers and stakeholders can efficiently use the tool.
- Evaluate the impact of scenario simulations on decision-making and transport management.

WHAT – Scope of the test:

- Usability of interfaces for scenario definition and execution.
- Accuracy and relevance of simulation results.

HOW – Test methodology:

- Users run defined scenarios for each pilot case study (Trieste, Varna, Madrid).
- Collect feedback on usability, clarity, and trust in simulation outputs.
- Compare model results against reference datasets, operational observations, and expert assessment.

User and adoption KPIs and objectives:

- Simulation calibration KPIs with a maximum of 20% deviation from historical data
- Sensitivity scenarios with a maximum of 20% deviation from expert opinions or literature
- Inputs and outputs files are clear and understandable enough: ≥ 80% of cases

WHO – Actors involved:

- AIT, TELLAE, ITA technical staff, transport authorities, and project partners supervising integration.

HOW MANY – Scale of the test:

- Multiple scenarios per case study, covering passenger flows, public transport, and goods movement.

WHERE – Test environment:

- Pilot sites in Trieste, Varna, and Madrid, on relevant simulation use case.

WHEN – Timing:

- Testing conducted during WP3 development phases and aligned with scenario definition and data availability.

ADDED VALUE:

- Supports realistic agent-level transport simulations, improving evaluation of new mobility services and policy interventions.
- Enhances multimodal planning, operational management, and strategic decision-making.
- Provides a flexible tool to analyse behavioural changes and optimize transport networks, supporting modal shift indirectly through better-informed service design.

6.8 H: TRANSPORT PLANNING, WHAT-IF & VISUALIZATION TOOL

6.8.1 INITIAL VERSION

TELLAE has developed KITE as a platform bringing complete tools for transport planners to enhance decision-making: from data analysis to what-if simulation, giving access to easy-to-use ABM simulation, simplified and more sophisticated simulation results. MODALSHIFT will enhance the functionalities of the KITE tool through combining data visualisation of raw observed data, enhanced data like synthetic data of population and trips, agent-based simulation results, and adding simplified simulation tools in order to bring together all data around public transport and shared mobility, allowing easy analysis and data visualization. New data connectors to open data platform will be developed to support the adaptation to the three CS countries targeted. As the volumetry of data will increase (OpenStreetMap, etc.), data management processes will be adapted, depending on the fit of various architectures, and strengthening algorithms will be added, as open data often suffer from a lack of quality or too much inconsistencies, notably OpenStreetMap (lack of consistency between open contributions) and public transport data (often with errors). New algorithms for cross analysis between data will be developed with python functions and API services to make available KPIs for territory analysis. In the KITE front end, MODALSHIFT will focus on the simulation integration. Besides Starling, other simulators will be connected to KITE with new widgets in order to change the public transport routes, evaluate demand, etc.

Will be tested in: Port of Trieste Case Study, Varna Municipality Case Study, Estación Sur Case Study

6.8.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Planning Tool provides a comprehensive platform for transport planners to support decision-making through data analysis, what-if scenario simulations, and visualization. Building on TELLAE's KITE platform, MODALSHIFT enhances the tool by integrating raw observed data, synthetic population and trip datasets, and agent-based simulation results. The platform allows users to explore simplified and advanced simulations, evaluate public transport routes, and analyse mobility patterns across multiple datasets. Front-end widgets and new data connectors to open data platforms facilitate easy interaction with simulations and seamless adaptation to the three case study countries. Adaptive data management processes and quality-strengthening algorithms ensure reliable outputs despite inconsistencies in open-source or public transport data. Cross-analysis functions and API-based KPI generation enable territory-level insights for more informed transport planning.

Targeted users and customers

- **Targeted users:** Technical teams responsible for mobility planning, GIS analysis, and scenario modelling. These are the professionals who directly operate the tool, run simulations, and interpret results.
- **Targeted customers:** Transport authorities, transport operators, and consulting companies. Customers may not use the tool directly but rely on its outputs for planning, decision-making, or service design.

Related Project Result (PR)

PR10: Data and scenario visualisation platform for the planning of transport modes and services.

Expected impact regarding modal shift

By enabling clear visualization of mobility patterns, simplified scenario testing, and integrated analysis of public transport and shared mobility, the Planning Tool supports more effective planning decisions that encourage modal shift toward sustainable transport modes. Expected impacts include improved allocation of transport resources, better integration of shared mobility options, and informed interventions to reduce car dependency in the three case study regions.

6.8.3 TESTING METHODOLOGY

6.8.3.1 A. Technical / Functional Validation

Purpose and scope

The technical validation verifies that the Planning Tool delivers the core functionalities defined in the project and that data processing and simulation workflows operate reliably and reproducibly.

Method

Validation is performed during development work packages through unit and integration tests, combined with the execution of predefined simulation scenarios using anonymised (e.g. Octopize-processed) and/or open datasets.

Technical KPIs and objectives

- Easiness and intuitiveness of the tool interface

- Understanding of Planning tool KPIs and simulation results
- Usefulness of Planning tool KPIs and visualisation for decision-making

6.8.3.2 B. User / Adoption Validation

WHY – Purpose of the test

The user and adoption validation assesses whether the Planning Tool can be effectively used by transport planners to support planning and decision-making processes, in line with project objectives. It evaluates usability, comprehension of simulation results, and perceived added value, while identifying adoption barriers and training needs.

WHAT – Scope of the test

The test focuses on user interaction with the interface, ability to configure and run what-if simulations, understanding and interpretation of simulation outputs, and relevance of results for local mobility planning objectives.

HOW – Test methodology

User tests are organised as structured hands-on sessions. Core functionalities are tested without prior training to assess intuitiveness, while advanced functionalities may be tested after a short introduction. Users perform predefined tasks aligned with project objectives, such as testing scenarios involving a target number of cargo bikes or modal shift assumptions. Developers may be present as observers but do not intervene. Feedback is collected through screen recordings, observation grids, or structured questionnaires.

User and adoption KPIs and objectives

- Task completion rate: ≥ 80% of predefined tasks completed without assistance
- User satisfaction score: ≥ 3.5 / 5
- Understanding of the Planning tool KPIs and simulation results: ≥ 70% of users report “good” or “very good” understanding
- Perceived usefulness for decision-making of the Planning tool KPIs and visualisations: ≥ 70% of users report “good” or “very good” usefulness

WHO – Actors involved

Mobility and transport planning professionals from each pilot site (e.g. the city of Varna), supported by project partners facilitating and observing the tests.

HOW MANY – Scale of the test

Ideally three users, each participating in a one-hour testing session.

WHERE – Test environment

Pilot site linked to the use case, within a defined geographical perimeter if required.

WHEN – Timing

Tests are conducted once the service reaches sufficient maturity and in alignment with pilot planning schedules. The first tests might be carried out starting in month 20.

ADDED VALUE

Beyond validation, the tests contribute to capacity building for local stakeholders, notably in Varna and Trieste, supporting skills development and increasing readiness for the adoption of simulation-based planning tools.

6.9 I: COOPERATIVE MULTIMODAL TRAFFIC MANAGEMENT SYSTEM

6.9.1 INITIAL VERSION

One key aspect of the MODALSHIFT project is to overcome existing limitations and vertical segmentation of management (and data) in multimodal infrastructures. To directly address this aspect, **ATOBE** will build on one of the main results of the TANGENT Horizon 2020 Funded project, the TANGENT Dashboard. This Dashboard relies on a configurable data visualisation engine for multimodal transport management, coupled with planning and incident management, with a great focus on multi-entity cooperation built in.

The MTM tool to be developed under MODALSHIFT will integrate results from WP3, providing combined visualisation and planning, namely of the digital twins resulting from T3.1 “Development and calibration of Digital Twins modelling freight, mobility and network”. For T3.2 Network and traffic forecasting, by integrating S.D as part of the core tool, making forecast data a first-class citizen of the tool. For T3.3 “Agent-based modelling for identifying ‘socially optimal’ multimodal framework” mostly by integrating data from S7S.G. For T3.4 “Dynamic network optimisation coupling predictive and prescriptive analytics” by integrating data from S.B and the broader results of T3.4 (not covered in S.B). Finally, for T3.5 “Synchromodality for logistics-mobility integrated services in intermodal nodes” either by integrating the data through the digital twins in T3.1 and/or by integrating T3.5 results into the MTM Tool Planner.

By building on top of the WP2 Data Space and natively allowing the configuration of dashboards using live and forecast data and providing cooperative planning and management tools supported by the results of WP3 and other WP4 modules, the MTM Tool will be able to tackle several limitations such as a lack of information about the transport network, the limited cooperation between stakeholders, lack of a single system with all relevant real-time data, or inefficient planning and modelling of the infrastructure.

The MTM Tool is meant as a horizontal platform covering the visualisation and cooperative management needs of the multiple stakeholders involved in the CS. In MODALSHIFT this platform is also combined with a set of tools that cover vertical aspects (namely S.A, S.B and S.E), providing more domain specific tools and covering innovative operational aspects of the CS.

Will be tested in: Port of Trieste Case Study, Varna Municipality Case Study, Estación Sur Case Study.

6.9.2 FEEDBACK AND ADAPTATIONS

The MTM Tool enables enhanced traffic and transport management and operations through an intuitive integrated multimodal live visualisation environment, embedded forecasting, cooperative features, and scenario-based incident management. It provides live and forecasted situational awareness across all Case Studies and incorporates cooperative functionalities such as chat and coordinated incident management, allowing stakeholders to interactively prepare and activate optimisation plans in close coordination with the Optimisation Layer. These live and forecast views also support continuous monitoring and assessment of the outcomes of activated plans, improving operational responsiveness. Overall, the delivered MTM Tool overcomes key limitations of current commercial solutions, including insufficient visibility of network status, limited cooperation among multimodal stakeholders, and the absence of a single unified Realtime system capable of supporting coordinated decision making.

Targeted users and customers

· Targeted users: Technical teams responsible for the day-to-day operation in different transport operators and in authority control centers (e.g., police, municipal departments, other authorities); These are the professionals who directly operate the traffic and transit management systems and/or manage the movement of people and goods, monitoring the transport network, managing large and small events and resolving incidents.

· Targeted customers: Transport authorities and managers, municipalities and regional authorities and transport operators. The MTM tool will support their tactical and strategic planning, alongside the operational aspects benefiting their technical teams.

Related Project Result (PR)

PR8: Collaborative platform for multisource multistakeholder traffic **and network** management

Expected impact regarding modal shift

The targeted users and customers, in their daily operations, employ state of the art vertical solutions that tackle a specific mode and operation type. By providing a unified tool that brings these verticals together, and by enabling cooperation between different entities and modes, this tool allows live situational awareness of the full transport network and real multi-modal, multi-stakeholder operation. Multimodal management is key for the efficient optimization of the transport ecosystem as a hole and is pivotal for the promotion of modal shifts towards a more sustainable mobility.

6.9.3 TESTING METHODOLOGY

6.9.3.1 Technical / Functional Validation (ultra-short)

Purpose and scope

The functional validation will assess whether the MTM Tool effectively delivers the core capabilities defined for MODALSHIFT. The technical testing will focus on ensuring that the interactions across the functional architectural layers—Data, Optimisation and Applications—operate seamlessly as an integrated workflow and that interlink correctly with the other partners' modules covering vertical services. This includes verifying that live data streams are correctly processed and represented, and that forecasting outputs and optimisation recommendations produced within the wider architecture can be ingested and displayed whenever available. Emphasis will be placed on validating the end-to-end workflows that rely on these components to support the platform's user facing features, namely intuitive multimodal visualisation, predictive insights, cooperative operational tools, and scenario-based incident management views. **Method**

Early-stage technical and functional testing will be conducted continuously during Task T4.1 (M10–M20), accompanying the development of the MTM Tool. This phase will begin with low-sensitivity datasets—such as open data, anonymized data or augmented datasets produced in WP2—and will progressively incorporate additional datasets emerging from WP2 and WP3. Testing activities will include unit tests, integration tests, acceptance tests, and other targeted validation procedures to verify both functional behavior and non-functional requirements. Performance aspects (system behavior under high data volumes and processing loads) will be assessed, while security testing will ensure early detection and mitigation of potential vulnerabilities. Task T4.5 (M16–M24) will serve as the dedicated integration-testing phase, ensuring end-to-end verification of the complete project architecture and covering the widest possible set of system functionalities. Given its central role, integration testing will start even when some modules are not yet available; in such cases, mock components will be introduced to enable continuous system-level validation and to ensure that the interactions between components are thoroughly exercised throughout the development cycle.

Technical KPIs and objectives

- Provide an intuitive and easy-to-use interface, supported by configurable dashboards tailored to different users
- Enable seamless and reliable cooperation features, allowing users to quickly share insights across dashboards
- Guarantee access to multimodal data with real-time updates, subject to the availability of external data sources.
- Support the overlay of heterogeneous data layers, including real-time information, forecasts, and indicators from different modes
- Deliver dedicated, adapted, and configurable user interfaces for each of the three Case Study pilots, supporting multiple user roles with differentiated permission levels

6.9.3.2 User / Adoption Validation

WHY – Purpose of the test

The user and adoption validation assesses whether the MTM Tool can be effectively used by operational transport stakeholders to support live multimodal monitoring, decision-making, and coordinated incident management. It verifies usability, clarity of life and forecasted information, and the perceived added value of cooperative features in real operational workflows. The tests will also help identify potential adoption barriers, integration needs with existing control-room practices, and any required user training. This typology of tests aims to confirm whether the MTM Tool effectively supports multimodal operational decision-making and enhances cross-stakeholder cooperation.

WHAT – Scope of the test

The tests focus on user interaction with the live/forecast visualisation dashboards, use of cooperative functionalities (e.g., chat and coordinated workflows) and the relevance of the MTM Tool's outputs for operational decision-making and cross-agency coordination. Particular attention is to be given to integration with the Optimisation Layer for plan preparation/activation and to the clarity/actionability of alerts and KPIs.

HOW – Test methodology

Testing will be conducted through hands-on sessions, preceded by short online or on-site introductory workshops that explain the tool's functionalities and ensure a common baseline among participants. These hands-on sessions will take place throughout the continuous improvement process of WP5, following an iterative approach in which user feedback contributes directly to successive refinements.

Different testing scenarios will be considered to ensure a comprehensive evaluation of the MTM Tool:

- Day-to-day operational usage, covering as many operational contexts as possible (e.g., holidays vs. business periods, winter/summer, weekdays/weekends).

- Simulated events, used for structured training and focused evaluation of coordination workflows and incident-handling capabilities.
- Real events, whenever feasible, involving different typologies such as large, planned events or unplanned incidents, to observe tool performance in real operational conditions.

The final stage of the testing cycle will consist of an assessment carried out through stakeholder interviews or questionnaires to collect their concluding feedback.

User and adoption KPIs and objectives

The validation focuses on how operators and control-room staff interact with the MTM interface and whether the tool meets their operational needs. In particular, it evaluates:

- usability, clarity, and reliability of dashboards and functionalities;
- accuracy and coherence of real-time and forecasted information;
- navigation and configuration of live, forecasted, and multimodal dashboards;
- use of cooperation tools including shared annotations, chat, and coordinated incident workflows;
- understanding and interpretation of real-time and forecasted situational awareness elements;
- relevance of the tool for incident detection, coordinated response, and network-wide operational monitoring.

WHO – Actors involved

Control-room staff from transport operators on each pilot site, supported by project partners facilitating and observing the tests; where applicable, representatives of transport authorities and municipalities for high-level validation (as final customers).

HOW MANY – Scale of the test

Per Case Study, 3–5 operational users—either from different transport modes or, depending on the characteristics of the Case Study, from different operators within the same mode—will participate in testing sessions ranging from 15 minutes to 1 hour, conducted throughout the continuous improvement process. Group sessions will also be organised to validate the cooperation features.

WHERE – Test environment

Operational environments linked to the Case Studies pilot site(s) (either control rooms or realistic test settings), with pre-defined perimeters, depending on the use cases chosen for testing.

WHEN – Timing

User validation tests will start once the MTM Tool and its Optimisation Layer integration reach sufficient maturity and align with pilot schedules. Preliminary tests may begin from M20 and continue in iterative rounds as features and data integrations are refined, with increased activity from M25 onward, when T5.3 (Validation of results and continuous improvement) starts.

ADDED VALUE – Capacity building and learning effects (optional but recommended)

The tests strengthen operational readiness beyond validation, by:

- Building capacity in multimodal, forecast-informed operations and coordinated incident response.
- Institutionalizing shared procedures via cooperative features and role-based workflows.

- Demonstrating the added value of a unified, real-time system for coordinated decision-making across stakeholders in all Case Studies.

6.10 J: SHUNTING OPERATION

6.10.1 INITIAL VERSION

This service was not originally described in the strategic document, as its development resulted from a collaborative co-design process involving ADF and the technical partners GGI and NGS. The initiative followed the local kick-off meeting and was informed by the presentation delivered within the framework of Task T1.5 to the case study, ensuring that the service addresses specific local requirements and complements the project's overall objectives.

6.10.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Dynamic Rolling Stocks Management System is a software service that supports and optimizes shunting operations in multimodal freight logistics. It provides shunting operators with enhanced visibility and control over rolling stock, particularly shunting locomotives, by combining ADF operational data with relevant open data sources. On the essential premise that Adriafer provides its locomotives for active monitoring, NGS can provide the IoT tracking infrastructure that can be installed on locomotives to collect high-frequency, real-time positional and operational data. This data is continuously transmitted, converted by NGS into the GS1 EPCIS 2.0 standard, and fed into the GGI platform to support system processing and analysis. The system identifies locomotives likely to be idle or underutilized and highlights locations or time periods with high operational workload. By doing so, it enables operators to plan locomotive movements more efficiently, reduce bottlenecks, and improve the overall management of freight transport operations.

Targeted users and customers

Targeted users: ADF operational managers responsible for shunting operations. These users directly interact with the software to monitor locomotive status, make decisions on repositioning rolling stock, and manage daily operations.

Targeted customers: ADF as the transport operator. While the customers may not use the system directly, they benefit from the improved efficiency, better resource utilization, and enhanced multimodal logistics enabled by the tool.

Explanation: Users and customers are different because the system is operated by internal staff (users), while the strategic benefits are realized at the organizational level (customers).

Related Project Results (PR)

PR1: Capacity-as-a-service design and strategies for increasing the value of multimodal transport services

PR10: Data and scenario visualisation platform for the planning of transport modes and services

Expected impact regarding modal shift

- By enabling dynamic management of rolling stock and faster, more efficient shunting operations, the system supports better integration of rail freight within multimodal logistics chains. Expected impacts include:
- Reduced delays in railway services
- Improved multimodal logistics efficiency
- Ability to manage more trains without increasing the number of locomotives
- Strengthened rail's attractiveness as a reliable and timely freight mode, supporting modal shift from road to rail

6.10.3 TESTING METHODOLOGY

6.10.3.1 Technical / Functional Validation

Purpose and scope

The technical validation aims to verify that the Dynamic Rolling Stocks Management System correctly identifies underutilized locomotives- and generates actionable insights for shunting operations.

Method

Validation is performed through automated and scenario-based tests using historical ADF operational data combined with selected open data sources. The system's outputs are checked for accuracy, consistency, and timeliness. Given the aforementioned premise, the validation can also include field testing of NGS hardware on ADF locomotives. This process verifies the reliability of real-time data transmission, signal stability within the complex railway environment, and high-precision data capture. It also validates the system's end-to-end capability to autonomously transform raw operational metrics into the standardized GS1 EPCIS 2.0 format and continuously feed them into the GGI platform.

Technical KPIs and objectives

- Accuracy of locomotive utilization detection: ≥ 95% of identified idle/underutilized locomotives match operational records
- Detection of bottlenecks and high workload periods: ≥ 90% alignment with historical operational peaks
- System uptime and response time: ≥ 99% availability, < predefined threshold for response to operational queries
- Error rate in planned repositioning suggestions: ≤ 5% of cases

6.10.3.2 User / Adoption and Integration Validation

WHY – Purpose of the test

The user and adoption validation assesses whether ADF operational managers can effectively use the se the real-time data continuously provided by the IoT devices, standardized into interoperable formats, and fed into the existing system, together with the high integrable data format to optimize shunting operations and whether the system's recommendations improve operational efficiency. It also evaluates the organizational impact on multimodal logistics planning and resource management.

WHAT – Scope of the test

The validation focuses on:

- Usability of the interface for monitoring and decision-making
- Accuracy and relevance of operational alerts and locomotive repositioning suggestions

- Integration with existing workflows and other data sources
- Impact of system use on shunting operation efficiency and multimodal logistics performance

HOW – Test methodology

User tests are conducted in collaboration with ADF operational teams:
- Operational managers perform standard shunting tasks using the system over defined testing periods
- Key operational scenarios (high workload, unexpected delays, locomotive unavailability) are tracked and simulated if the tests require more scenarios than the ones that actually happen
- System outputs and user decisions are logged for comparison with historical data or expert evaluation
- Feedback is collected on ease of use, trust in system recommendations, and perceived operational improvements
- Analysis is performed to quantify the impact of system recommendations on efficiency, locomotive utilization, and throughput
  Real -time data flows from NGS IoT devices to the system are monitored to assess continuity, latency, and completeness during operational use

User and adoption KPIs and objectives

- Task completion rate for operational scenarios: ≥ 80% successfully managed using the system
- Reduction in idle locomotive time: ≥ 10% compared to baseline
- Decrease in shunting-related delays: ≥ 15% during test periods
- User satisfaction score: ≥ 3.5 / 5
- Number of operational decisions improved or accelerated by system insights: ≥ 70% of logged cases
- Integration success: ≥ 90% of tested workflows show seamless adoption without major issues
  Availability of real-time operational data for decision support:

WHO – Actors involved

ADF operational managers (users), ADF technical staff, and project partners monitoring system integration.

HOW MANY – Scale of the test

Tests cover multiple shunting scenarios and locomotives, with at least one week of continuous operational trials per pilot site.

WHERE – Test environment

ADF operational sites and associated control systems; connected to live operational data streams originating from multiple operational systems, including NGS IoT devices and selected open data sources.

WHEN – Timing

Testing is conducted during operational periods aligned with the work package schedule and system readiness.

ADDED VALUE

Beyond technical validation, testing demonstrates the system's contribution to improved efficiency, enhanced integration of rail freight into multimodal logistics, and supports the broader objective of modal shift from road to rail. It also helps train ADF staff on dynamic planning tools and data-driven decision-making. It also helps train ADF staff on dynamic planning tools, real-time

6.11 K: ANONYMISATION

6.11.1 INITIAL VERSION

This subservice was designed to enable secure and GDPR-compliant anonymization of datasets within the Modalshift project. Its development is led by Octopize, leveraging the Avatar software and specialized anonymization services for complex data types. The subservice was identified as necessary to broaden the availability and usability of diverse datasets across project services, ensuring compliance with privacy regulations while supporting multimodal logistics analysis and optimization.

6.11.2 FEEDBACK AND ADAPTATIONS

Description of the service

The Anonymization subservice applies a GDPR-compliant anonymization process to datasets or databases, enabling their use beyond the original collection scope. This allows more datasets to be included in the Modalshift project, supporting other services and subservices.

- Structured data (tabular, time series, geolocation) is anonymized through the **Avatar software**.
- Complex data types, such as geolocation traces, may be anonymized as a service by Octopize.
- Output data is safe to share, ensuring compliance while maintaining analytical value for downstream services.

Targeted users and customers

- **Users:** Technical and non-technical users accessing anonymization via Python or web interfaces, including data owners, data scientists, and Data Protection Officers.
- **Customers:** Data providers (who anonymize their datasets before sharing) and Modalshift members (who use anonymized datasets in the protected project environment).

Explanation: Users directly operate the tool, while customers benefit indirectly from compliant and usable datasets.

Related Project Result (PR)

- **PR4:** Trusted and secure mobility and freight data spaces

Expected impact regarding modal shift

- Increases the availability of datasets that enable multimodal logistics analysis and optimization.
- Strengthens the ethical and legal framework of data handling in the project.
- Supports the integration and improved performance of services that rely on anonymized datasets, indirectly facilitating modal shift by improving data-driven decision-making in transport logistics.

6.11.3 TESTING METHODOLOGY

6.11.3.1 Technical / Functional Validation

Purpose and scope: Verify that anonymization outputs respect GDPR compliance, ensure data utility for downstream services, and confirm compatibility across data types and Modalshift pipelines.

Method:

- Conduct tests using sample datasets in CSV and Parquet formats.
- Evaluate utility and privacy/sensitivity metrics with Avatar tools.
- For complex data types (e.g., geolocation traces), assess anonymization via service-based workflow.
- Monitor compatibility with downstream services by comparing performance using original vs. anonymized data.

Technical KPIs and objectives:

- Privacy compliance: 100% adherence to GDPR criteria.
- Data utility: Minimal loss of statistical or analytical value.
- System interoperability: ≥ 90% of datasets successfully integrated with Modalshift services.
- Automation and scalability: Ability to process large datasets without failure.

6.11.3.2 User / Adoption and Integration Validation

WHY – Purpose of the test: Assess whether end-users can apply anonymization efficiently and evaluate the impact of anonymized datasets on service performance and operational decisions.

WHAT – Scope of the test:

- Usability of software interfaces (Python and web)
- Accuracy and relevance of anonymization outputs
- Integration with other Modalshift modules and workflows
- Impact on services using anonymized datasets (e.g., forecasting, logistics optimization)

HOW – Test methodology:

- Users perform anonymization on representative datasets over defined periods.
- Compare performance of services using anonymized vs. original datasets.
- Collect user feedback on ease of use, trust in anonymization, and perceived effectiveness.
- Quantify changes in data utility and service outcomes.

User and adoption KPIs and objectives:

- Task completion rate: ≥ 80% of anonymization tasks completed without errors.
- Preservation of data utility: ≤ 10% degradation in analytical performance.
- User satisfaction: ≥ 3.5 / 5.
- Integration success: ≥ 90% of workflows adopt anonymized datasets seamlessly.

WHO – Actors involved: Octopize technical staff, Modalshift data users, and project partners supervising integration.

HOW MANY – Scale of the test: Multiple datasets representing all types relevant to Modalshift; at least one anonymization cycle per dataset per pilot service.

WHERE – Test environment: Modalshift protected environment and connected project pipelines; includes both Avatar interfaces and on-demand services.

WHEN – Timing: Testing conducted in line with project schedule, aligned with WP development and dataset availability.

ADDED VALUE: Expands dataset availability for Modalshift services, strengthens privacy, trust, and ethical standards in project data handling, and improves interoperability between anonymization and other project tools.

Table 5: Use case testings

Project Result	Solution/ service	Port of Trieste	Varna Municipality	Estación Sur Madrid
PR3 Data collection and communication systems	A E-SUBSCRIPTION			X
PR9 Dynamic tools	B CARGO BIKE		X	
PR7 Decision-making algorithms & PR9 Dynamic tools	C OPTIMISATION		X	X
PR6 Traffic forecasting algorithms	D FORECASTING	X		X
PR1 Capacity-as-a-Service (CaaS) models & PR3 Standardised Connectors and APIs	E LOCKERS			X
PR4 Data Spaces / PR8 Collaborative Platform	F DATA SPACE	X	X	X
PR7 Decision-making algorithms & PR5 transport network digital twins	G MODELLING TOOL	X	X	X
PR10 Visualization Platform	H PLANNING TOOL	X	X	X
PR8 Collaborative Platform	I MANAGEMENT SYSTEM	X	X	X

7 RELEVANT KPI

This table shows the link between:

- Project results and KPIs coming from the proposal / DoA
- Services that will be developed during the project and the relevant partners.

The objective of the table is to explain the relevance of the services tested by each use-case towards the results the project is aiming for.

Measures and baseline for each KPIs will be further defined in WP6. So far, the table lists the KPIs regardless to the fact that they are simulation-based or operational. The difference will be clearly established later on.

	Project result	Services	Partner	KPI
PR1	Capacity-as-a-service design and strategies for increasing the value of multimodal transport services	E - Lockers; J - Shunting operations	ID4M, ADF, PNAEAS + KEDGE	VARNA: • Reduce the estimated average interconnection time by 20% • A fleet of at least 2 cargo-bikes, owned by the municipality, will be managed in a shared renting approach between 5 local commercial activities. TRIESTE: • Aims at a 10% increase in efficiency in the shunting operations, towards an improved use of railway with a reduction of 15% of the reaction time MADRID: • Reduction of passenger connection time by 20% thanks to seamless transfers • 20 Capacity-as-a-service travels on buses/trams in mobility-freight multimodal hubs (Spain & Bulgaria–TRL6) and evaluate their potential for reducing traffic flows.
PR2	Governance schemes, dynamic incentives and business models		AIT, ATOBE	• Public transport customer satisfaction rate increased by 20% on these vulnerable population segments in Spain and Bulgaria. • Modal shift from individual cars to shared/active modes among 25% of citizens; • Targeting a “global” cost savings of 5% over all transport services/actors in CS (including side benefits like health) in simulation, and >1% operational savings at individual actor scale; • Reach 30% of CS stakeholders adopting more sustainable business models; • Dynamic perspective with 1 policy white paper and 2 workshops per CS, • One engagement scenario and action plan will be defined and implemented for each of the CS; • Onboard 8 stakeholders per CS that are active over at least 1 year and providing good quality data, • Governance and decision support tool and results • Identify 50% of urban road space that could be reallocated to other uses
PR3	Data collection and communication systems for infrastructures, vehicles, people and loads	A – E-subscription; E - Lockers	NGS	• reduce to below 100ms the V2X communication latency and to less than 1-minute trusted communications latence • provide an e-subscription device based on Bluetooth Low Energy technology (TRL6) to facilitate the access of vulnerable users in public transport, to monitor their trips and provide added value information to guide them in their intermodal journeys.

PR4	Trusted and secure mobility and freight data spaces	F - Data Space ; K – Anonymization	ITA, OCTO	• Level of accuracy (max 2% variation) between models trained on the anonymized data versus “normal” data; • design and implement data space architecture for the 3 CS integrating mobility, logistics and transport infrastructures; • make the data spaces completely compatible with GDPR with the anonymised access to datasets from private actors; • At least 10 datasets will be accessible per Case Study through the data space, • 3 national/local contexts of CS to support evolutions of data regulations
PR5	Multimodal transport network digital twins in case studies	G - Modelling Tool	ITA, GGI	• build a modular digital twin framework where individual components represent specific transportation and logistics modes, fitted with the diversity of CS • integrate a range of 100-1000 vehicles in the model depending on the Case Studies, with the basis of regular transit vehicles (buses, trams) and on-demand, logistics (trucks/vans/cargo bikes).
PR6	Traffic forecasting algorithms	D - Forecasting	IMEC	• 30% reduction in the negative impact of missing data. • Improve the accuracy of traffic forecast compared to the state-of-the-art by 10-15%. • Enhance anomaly detection rate by 10-15%.
PR7	Multi-objective decision-making algorithms for network and traffic management	G - Modelling Tool; C - Optimisation	KEDGE, ITA, IMEC, AIT, TELLAE	• improvement of the ABM accuracy between simulations and observations by 20%; • reduction of average travel delay for low-carbon options of passengers and freight transport by 30% with digital twin based simulation; improvement by 15% of the generalised accessibility of points of interest • reduction of the average daily travel miles by 40%, a reduced capacity violation and number of failures of the system facing with uncertainties of 25% with safeguards and a reduced decision-making time by the algorithms of 70% in average thanks to the implementation of efficient computational techniques and predictive analytics.
PR8	Collaborative platform for multisource multistakeholder traffic and network management	I - Management System	ATOBE	
PR9	Dynamic tools for daily transport service providers operations	B - Cargo bike; C - Optimisation	GGI, KEDGE	
PR10	Data and scenario visualisation platform for the planning of	H - Planning tool;	TELLAE, AIT	• connect at least 4 various Agent-based models/simulation engines • 10 main scenarios for the 3 Case Studies, with as many cross analyses between collected data and simulation.

	transport modes and services			

8 CONCLUSION

The completion of this deliverable marks a critical transition from the initial strategic vision of the MODALSHIFT project to a concrete, stakeholder-validated operational framework. Through an intensive engagement process involving interviews and kick-off meetings in Trieste, Varna, and Madrid, we have refined the 11 planned technical solutions to address documented "pain points".

The most significant takeaway is that successful modal shift depends less on isolated technology and more on data synchronization and trust-based collaboration. We identified that the primary barriers are data fragmentation (notably between port and rail in Trieste), low digitalization levels affecting seasonal traffic management (Varna), and the need for physical and digital integration of passenger and freight flows via the Capacity-as-a-Service (CaaS) concept (Madrid).

The project is now moving into the technical development and integration phase, followed by large-scale demonstrations. Key upcoming actions include:

- Technical Development (M10 – M24): Finalizing the architecture of the secure, multimodal data space and refining AI-based forecasting and optimization algorithms.
- Operational Pilot Phase (February 2027 – November 2028): Deploying the solutions across the three case studies to test them under real-world conditions across all seasons.
- Continued Stakeholder Engagement: Finalizing pending interviews and signing necessary data-sharing agreements (NDAs/MoCs) to ensure the models are fed with high-quality, real-time datasets.

The findings in this deliverable serve as a strategic roadmap for future transport projects and policy improvements:

- For Transport Authorities: The "What-If" simulation and planning tools will enable policymakers to simulate the impact of new regulations or infrastructure changes before implementation, reducing investment risks.
- For Operators: The dynamic management tools (such as shunting optimization in Trieste or fleet management in Varna) provide immediate levers to improve operational efficiency and reduce interconnection delays by a targeted 15% to 25%.
- For Strategic Planning: The project demonstrates how a neutral, trust-by-design data space can overcome the reluctance of private actors to share data, facilitating more inclusive and low-carbon urban logistics.

In conclusion, D1.2 establishes a shared foundation that ensures the project's technical outputs are not mere prototypes but scalable tools. By aligning innovation with the practical needs of local stakeholders, MODALSHIFT is positioned to move directly from information to action, delivering measurable improvements in European multimodal transport networks.

9 REFERENCES

None

10 ANNEX(ES)

10.1 TRIESTE

10.1.1 KICK OFF

The session focused on operational bottlenecks, data-sharing opportunities, and concrete areas where MODALSHIFT solutions could bring measurable benefit.

10.1.1.1 HHLA PLT – Critical bottleneck during shunting downtime:

- HHLA highlighted that terminal operations stop whenever Adriafer is performing shunting and wagon inspection. When Adriafer carries out shunting plus inspection plus related checks, HHLA must wait before resuming loading operations.
- ➤ Today, wagon inspection requires approximately one hour, generating cumulative slowdowns.
- Outcome: shared recognition of priority technological intervention
- Automating or robotising wagon inspection procedures
- Evaluation of AI-based recognition systems and/or drones for remote inspection activities
- Combined reduction of shunting cycle duration
- PNAEAS strongly agreed, reinforcing that automated wagon inspection represents an attainable and necessary innovation. RFI (not present at the debate) will also be a key subject for integration, particularly regarding shunting timing reduction and better connection of railway stations serving the port.

10.1.1.2 TMT – Need for predictive operational visibility:

- TMT confirmed similar issues related to waiting times due to shunting and wagon inspection windows. Proposal from TMT and shared across the table:
- Integrating data from Adriafer + terminal operators + RFI
- Developing real-time and predictive scheduling for reduced standstill periods
- Late vessel arrivals are a known source of variability, but unpredictable shunting slots intensify the effect. Predictive planning emerges as a core MODALSHIFT development path.

10.1.1.3 TO DELTA – Operational flexibility must increase

- TO DELTA stressed that operational adaptability is essential: Adriafer resource allocation should become dynamic and forecast-based, using:
    - PIC system data (RFI's software)
- terminal operator planning flows
- expected arrival/departure forecasts
- This would improve alignment with customer needs and reduce congestion.

10.1.1.4 Cross-stakeholder: insufficient communication between railway undertakings

- Participants emphasized very limited communication among railway undertakings, attributed mainly to low trust and lack of shared data channels.
- MODALSHIFT can act as a neutral interoperability enabler, providing a structured environment for transparent information exchange, shared situational awareness and cooperative scheduling vs siloed planning

- Campo Marzio works – evolving future state: All participants highlighted that Trieste Campo Marzio infrastructure works are ongoing and will significantly alter operating conditions in ~2 years. Any transformation piloted within MODALSHIFT must therefore be scalable and compatible with the post-works scenario.
- The meeting successfully initiated the MODALSHIFT stakeholder process in Trieste. Consensus was reached on key operational challenges and potential technological interventions—particularly regarding shunting efficiency, automated wagon inspection, and predictive synchronization across operators.

10.1.2 INTERVIEW

10.1.2.1 Stakeholders' Roles and Relevance in the Local Transport Ecosystem

The interviews represent a diverse range of public and private actors, each contributing distinct expertise to the port and logistics sector in the North Adriatic region.

- The University of Trieste leads academic research and innovation, specializing in maritime and rail transport modelling, digitalization, and sustainability within the port sector.
- HHLA PLT Italy operates as a multipurpose terminal in the Port of Trieste, serving as a critical southern hub for HHLA's European logistics network. Their focus is on intermodal sea-rail connectivity.
- TMT functions as the primary gateway for containerized traffic in the North Adriatic. They handle ultra-large container vessels and manage one of the region's most efficient rail hubs, linking global maritime routes with Central and Eastern European markets such as Austria, Germany, Hungary, and Slovakia.
- Gruber Logistics acts as a bridge between shippers and infrastructure, organizing goods flow across the TEN-T corridors.
- The Port Network Authority, a public body, oversees the planning, coordination, and promotion of port operations in Trieste and Monfalcone. They manage public domain assets, ensure logistics chain security and efficiency, and drive strategic development along the Mediterranean and Baltic-Adriatic TEN-T corridors.
- TO Delta is a comprehensive logistics operator, connecting the Port of Trieste with Central Europe through integrated logistics chains.

10.1.2.2 Diversity of Profiles for a Comprehensive Vision

The interviewees include:

- Researchers and academics focused on port and logistics innovation
- CEOs and senior managers in operations, rail, and intermodal logistics
- Project managers for logistics and infrastructure
- Strategic development and logistics coordinators

This diversity ensures a broad perspective, covering both public institutions (University of Trieste, Port Network Authority) and private companies (TO Delta, Gruber Logistics, TMT, HHLA PLT).

10.1.2.3 Strong Engagement with Adriafer and Local Initiatives

Stakeholders are actively involved with Adriafer. TMT participated as a primary stakeholder and terminal operator during the Trieste Local Kick-off meeting, representing the "demand side" of port-rail services. The Port Network Authority collaborates closely with Adriafer, reinforcing institutional partnerships and project implementation.

10.1.2.4 Core Challenge: Rail-Port Synchronization and Data Fragmentation

- The primary obstacle across all stakeholders is the lack of real-time data sharing and dynamic synchronization between sea-side and land-side operations. Manual communication—relying on phone calls, emails, and rigid schedules—creates inefficiencies, delays, and hidden costs.

- The absence of a shared data architecture prevents optimization of complex operations such as port shunting. This fragmentation directly impacts terminal productivity, dwell time, and the ability to scale rail capacity from 12,000 trains per year to future targets.

10.1.2.5 Operational Pain Points and Specific Daily Operational Challenges

- The Trieste port node's technical complexity, driven by its historical layout and ongoing infrastructure works at Campo Marzio, exacerbates these challenges. The "human factor" and manual processes limit the application of optimization algorithms and real-time decision-making.
- For multipurpose terminals, shunting is the "heartbeat" of operations. Delays in technical inspections or wagon readiness cause standstills in quay operations, leading to cascading inefficiencies and increased costs.
- High-frequency shuttle train operators face a "domino effect" from even minor delays. A 30-minute disruption in shunting or inspections can result in missed rail slots on the national network and yard congestion.
- The "last mile" remains a critical bottleneck. Manual synchronization between the national rail network and port terminals creates buffer times, wasting track capacity and reducing transparency.
- Visibility gaps force operators to allocate terminal resources—staff and machinery—inefficiently. Standstill times translate directly into lost productivity.
- Academic and research stakeholders struggle to access high-quality, real-time datasets from private operators to validate simulation models and predictive algorithms.
- Terminal operators require faster reaction times—reducing delays by at least 15%—to maintain fluidity when vessels or trains are late.
- The rigidity of shunting schedules and manual wagon status updates prevent dynamic reprioritization, especially when vessel arrivals are delayed or advanced.
- Lack of predictability affects the entire supply chain. Operators need precise information on trailer/container readiness post-train arrival and real-time updates on shunting delays to avoid missing vessel loading cut-offs.
- Ongoing infrastructure works at Campo Marzio demand adaptive systems to maintain efficiency despite temporary capacity reductions.

10.1.2.6 Emerging Trends: Digitalization and Decarbonization

- The shift toward Industry 4.0 and Green Logistics is accelerating. Digital Twins and AI-driven solutions are increasingly used to monitor and reduce energy consumption in port operations.
- Stakeholders are prioritizing digitalization to eliminate inefficiencies, enhance flexibility, and meet carbon neutrality goals by 2040. Automated data exchange and real-time tracking are seen as essential to making rail as competitive as road transport.
- Trieste is evolving into a "Smart Port," focusing on shore power, hydrogen use, and the creation of a Common European Mobility Data Space to improve port-hinterland connectivity.
- Sustainability is a key driver. Clients demand Green Logistics, pushing operators to optimize rail use and reduce the carbon footprint of the "last mile" and hinterland connections. Digitalization is no longer optional but a prerequisite for competitiveness and sustainability.

10.1.2.7 Validation of MODALSHIFT Functionalities

- The Multimodal Traffic Management (MTM) system and dynamic adjustment of shunting schedules are universally recognized as the most valuable solutions. These functionalities directly address the core challenge of synchronizing sea-side and land-side operations, reducing delays, and improving efficiency.

- Shared situational awareness is equally critical, enabling real-time tracking of shunting engines, technical inspections, and crane deployments. This transparency is essential for optimizing terminal resources and managing customer expectations.
- Stakeholders emphasize that achieving even a 10% increase in shunting efficiency through MTM would represent a strategic milestone for the port authority and private operators alike.

10.1.2.8 Additional Suggested Functionalities

To further enhance MODALSHIFT's impact, stakeholders propose the following additions:

- A sandbox environment for researchers to test optimization algorithms using real project data, without disrupting live operations.
- AI-assisted or automated wagon inspection systems to replace manual technical checks, significantly reducing inspection times and accelerating the shunting cycle.
- An automated notification system (Track & Trace) for the shunting phase, providing milestone updates—such as successful technical inspection completion—to all relevant parties.
- Tools to enable cooperative scheduling among private Multimodal Transport Operators (MTOs) and terminal operators, replacing the current siloed planning approach.
- An integrated platform serving as a "single source of truth" for wagon status, including technical inspection results, to eliminate delays caused by fragmented information.
- An automated "ready-to-pull" signal integrated into Terminal Operating Systems (TOS), providing real-time confirmation when a train is cleared for departure.

10.1.2.9 Technical Compatibility Requirements

Seamless integration with existing systems is a priority. MODALSHIFT must ensure:

- Open-source standards or interoperable APIs to facilitate integration with academic simulation software, digital gate systems, and proprietary TMS platforms.
- Standardized data formats (e.g., JSON/API) to enable direct data exchange with transport management systems, Terminal Operating Systems (TOS), and Port Community Systems like Sinfomar.
- Automated data flow into operational dashboards, eliminating the need for manual data entry or multiple separate screens.
- Compatibility with proprietary systems (e.g., TOS, TMS) to ensure MODALSHIFT solutions complement, rather than complicate, existing workflows.

10.1.2.10 Types of Data Currently Collected

Stakeholders collect a wide range of operational and logistical data, tailored to their roles in the transport ecosystem.

- The University of Trieste accesses historical datasets from partners and public statistical data on port traffic, primarily for research and modelling purposes.
- HHLA PLT Italy gathers gate throughput data, rail loading lists, container/Ro-Ro volumes, and vessel Estimated Times of Arrival (ETAs) to optimize terminal operations.
- TMT utilizes a Terminal Operating System (TOS) and Sinfomar, capturing real-time data on container movements, yard occupancy, vessel ETAs, and rail loading lists.
- Gruber Logistics tracks GPS data from trailers and trucks, along with electronic loading lists and booking data, to manage fleet and customer logistics.
- The Port Network Authority leverages Sinfomar for comprehensive datasets, including vessel calls, customs statuses, rail loading lists, and general cargo volumes.
- TO Delta collects cargo volumes, gate movements, loading/unloading timestamps, and warehouse occupancy data to streamline logistics chains.

10.1.2.11 Current Data Storage Systems

Data storage and management systems vary by organization, reflecting their operational and analytical needs.

- The University of Trieste employs advanced simulation software (MATLAB, Python-based models, GIS tools) and university server infrastructures to store and analyse research data.
- HHLA PLT Italy and TMT rely on Terminal Operating Systems (TOS) and Info.era/Circle Group solutions, ensuring integration with Sinfomar for seamless data flow.
- Gruber Logistics uses an internal Transport Management System (TMS) and fleet management platforms to centralize logistics data.
- The Port Network Authority and TO Delta depend on Sinfomar—the Port Community System (PCS)—as their digital backbone, alongside internal terminal management systems.

10.1.2.12 Data Availability and Sharing Conditions

- Most operational data is private or commercially sensitive, but stakeholders express willingness to share under specific conditions to support the MODALSHIFT Living Lab and improve efficiency.
- The University of Trieste shares model results and academic papers publicly, while raw partner data remains under Non-Disclosure Agreements (NDAs).
- HHLA PLT Italy, TMT, Gruber Logistics, TO Delta, and TMT are open to sharing operational timestamps, rail-related data, or aggregated flow data under strict NDAs to enhance the Trieste node's efficiency.
- The Port Network Authority provides general statistics publicly, while operational data is shared within the port community under governance rules. For MODALSHIFT, data can be leveraged under Memorandums of Cooperation (MoCs).

10.1.2.13 External Data Sources

Stakeholders supplement their datasets with external public and private sources, though real-time integration and quality remain challenges.

- The University of Trieste uses European data (Eurostat, TEN-T reports) and local open data for research.
- HHLA PLT Italy, TMT, Gruber Logistics, TO Delta, and the Port Network Authority rely on Sinfomar for customs, maritime, and port status data. They also use RFI (Italian Rail Network) platforms for train tracking, though real-time visibility outside the port area is limited.
- The Port Network Authority highlights the need for improved real-time data quality from RFI, maritime agencies, and customs to enhance coordination.

Fragmentation between national rail tracking and port shunting systems is a recurring issue, underscoring the need for better integration.

10.1.2.14 Commitment to Future MODALSHIFT Activities

All interviewed stakeholders express a strong willingness to participate in future MODALSHIFT activities, including workshops, testing, and validation. Six out of seven respondents confirm their direct involvement, while one commits to collaboration.

10.1.2.15 Conditions for Engagement and Relevant Information

To ensure active participation, stakeholders highlight the need for tangible outcomes, alignment with strategic goals, and regular updates tailored to their operational priorities.

- The University of Trieste seeks access to technical results from all Work Packages (WPs) and opportunities to involve PhD students in testing phases, ensuring academic integration and hands-on research experience.

- HHLA PLT Italy and TO Delta emphasize the importance of demonstrating a clear path to the 10% efficiency increase outlined in the project scope. They also require updates on how MODALSHIFT will address infrastructure constraints at Campo Marzio, ensuring the system's adaptability to evolving operational conditions.
- TMT prioritizes evidence of reduced reaction times during delays and detailed information on system interaction with the new Campo Marzio infrastructure, as these factors directly impact terminal productivity.
- Gruber Logistics is motivated by reductions in lead time and improved reliability of the Trieste rail node. They also request updates on interoperability between European corridors (WP6), as cross-border efficiency is critical for their logistics networks.
- The Port Network Authority stresses the need for alignment between MODALSHIFT outcomes and their Master Plan (Piano Regolatore di Sistema Portuale). They require regular technical briefings and progress reports on inter-actor communication protocols to ensure strategic coherence and operational integration.
- TMT demand quantifiable results, particularly a measurable reduction in idle times for rail tracks and shunting cycle times. Concrete proof of efficiency gains will solidify their long-term commitment to the project.

10.2 VARNA

10.2.1 KICK OFF

- During the discussion, stakeholder representatives agreed that the main challenges facing transport in Varna are poor infrastructure, insufficient data collection, and a low level of data digitalization.
- Gradski Transport EAD (public bus ant trolley transport company) representative insisted that there was a great need for a dispatch center to consolidate traffic data and better manage traffic.
- The representative of National Freight Forwarding Association insisted that in order to implement a multimodal connectivity project, it is necessary and important to attract the interest of the railway company.
- The representative of e-Motion life OOD commented that the regional library uses a cargo bike as a mobile library and that contact could be sought with them to exchange experiences in the use of cargo bikes. He also recommended contacting Top Rent A Car, which offers regular electric bikes for rent.

10.2.2 INTERVIEWS

- The primary challenge faced is lack of connectivity. In daily operations, the absence of real-time data about the vehicle fleet is a significant hurdle. These gaps directly affect route planning, fleet management, and the broader goals of decarbonization and digitalization.
- Recent trends, particularly decarbonization and digitalization, highlight the need for a system that optimizes fleet operations. Such a system would enable more efficient route planning and resource utilization, aligning with sustainability and technological advancement goals.
- The planned activities of the PROJECT are considered useful. Specifically, real-time data on the technical condition of vehicles, an accurate overview of bus operations by route, and support for duty and schedule planning are identified as especially valuable functionalities.

10.2.2.1 Technical, Data Availability and Sharing Conditions

- Compatibility: No technical compatibility issues are anticipated with existing tools or systems.
- Device Installation: Installation of external devices (e.g., OBUs, trackers, gateways) is possible on 135 vehicles, but 60 electric buses (still under warranty) require permission.

- Power Supply: A stable 24V power supply can be ensured for PROJECT devices.
- V2X Systems: Currently, there are no systems capable of receiving or processing V2X messages.
- Data Ownership: Vehicle data is owned by the Municipality of Varna and OP TASRUD, but there is no existing platform or access point for this data.
- External Data: No external data from public or private sources is currently used.
- Data Restrictions: Personal data cannot be shared due to data protection regulations.
- Data Harmonization: There is a willingness to harmonize or standardize existing data to facilitate integration into the PROJECT's data workflows.
- Additional Datasets: No additional datasets beyond those listed are identified as relevant.

10.2.2.2 Conditions for Engagement and Relevant Information

- Future Participation: There is strong interest in participating in future PROJECT activities, including workshops, testing, and validation.
- Level of Involvement: The organization is open to information sharing, consultation, involvement, and collaboration.
- Resource Support: Project funding would help allocate the necessary time and resources for participation.
- Engagement Updates: Any type of information or updates would be useful to stay engaged throughout the project.
- Recommended Contacts: OP TASRUD is suggested as another organization to involve.

10.3 MADRID

10.3.1 KICK OFF

The workshop emphasized the need for collaboration, data transparency, and innovation to tackle Madrid's mobility and logistics challenges. The MODALSHIFT project is well-positioned to drive intermodality, efficiency, and sustainability through pilot projects and active stakeholder engagement. For further details, refer to the Technological Institute of Aragón's report.

10.3.1.1 Operational Pain Points and Specific Daily Operational Challenges

- Optimizing terminal space—both in urban and interurban areas—is essential to accommodate growing demand and improve operational efficiency. Increasing vehicle capacity utilization across urban, interurban, and medium-distance routes can reduce inefficiencies and lower costs. Strengthening logistics communication between urban centers and peripheral regions is also critical to ensure seamless connectivity and resource allocation.
- Space constraints, particularly in cities like Madrid, pose significant challenges to integrating new logistics models. Initiatives led by local authorities, such as the Madrid City Council, are crucial for developing feasible and sustainable solutions that respect urban limitations.
- Intermodality remains a key challenge, requiring the transformation of stations into efficient, multi-functional hubs. Real-time information sharing and reduced transfer times are necessary to enhance intermodal connectivity. Freight management faces persistent traceability issues, while innovative solutions like vertiports and drones could revolutionize urban distribution. Passenger-freight integration demands new models that combine the transport of people and goods, with ongoing debates about centralized versus federated management approaches.

10.3.1.2 Expected Benefits

- Tailored travel experiences are proven to reduce customer friction and enhance satisfaction. Concession-based models must be designed with user needs in mind, ensuring they align with expectations for convenience, efficiency, and personalization.
- An integrated logistics chain could allow customers to track packages in real-time, whether in lockers, buses, or during deliveries. Achieving operational visibility—where all stakeholders have access to capacity data—would streamline decision-making and resource allocation. The last-mile sector stands to benefit from advanced traceability and optimization, such as digital pouches integrated into bus transport systems.

10.3.1.3 Data Availability and Sharing Conditions

- Dynamic data, such as real-time General Transit Feed Specification (GTFS) updates, significantly improves communication and user experience. However, adoption barriers persist, including friction in user interfaces, lack of comfort, and the need to demonstrate immediate usefulness to encourage widespread acceptance.
- Business-to-business (B2B) collaboration is hindered by reluctance to share data, highlighting the need for a neutral "trust entity" to facilitate secure and transparent information exchange. From the end-user perspective, citizens are open to data sharing if it guarantees reliability, transparency, and personalized services, underscoring the importance of building trust and demonstrating value.
- Data availability and sharing conditions must be clearly defined to ensure all parties can contribute to and benefit from shared information. Commitment and engagement conditions should outline the roles, responsibilities, and expectations of each stakeholder, fostering accountability and alignment. Validation of project functionalities is essential to ensure solutions meet operational needs, while additional suggested functionalities should be explored to address emerging challenges. Finally, understanding operational pain points and daily challenges is critical to designing practical, user-centred solutions.
- Zero-Knowledge Proofs (ZKP) offer a promising solution for verifying private data without exposing sensitive information. This technology could enable secure transactions and foster trust in data ecosystems, addressing privacy concerns while promoting collaboration.

10.3.1.4 Interactive session

- An interactive session revealed critical pain points in last-mile logistics, including traffic congestion, storage limitations, parking shortages, absent recipients, digitalization gaps, delivery errors, scheduling issues, legislative barriers, and reverse logistics challenges. Conversely, passenger-goods integration presents opportunities for efficiency gains, optimization, economies of scope, reduced environmental impact, and cost savings. Public transport users show openness to sharing space with parcels, with 8 out of 12 users expressing willingness.
- Digital maturity for a secure data space varies, with 5 stakeholders rated as high, 2 as medium, and 3 as low. Regarding pilot synergy potential, 5 out of 9 stakeholders see clear opportunities, while 2 remain uncertain. There is also support for evolving tariff models, with 7 out of 11 stakeholders backing adjustments if public transport generates logistics revenue. The scalability of solutions beyond Estación Sur is rated as viable, with a 4 out of 5 agreement score.