SMARTMOBAIR project

Work package: WP2

Deliverable title: Technical specification of SMARTMOBAIR intelligent transport system technologies

Expected date: June 2025

Partner responsible for the deliverable: ICMF

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Dissemination level: Public

Type of deliverable: Document

Status: Final

Version: 1.0

Date: 30.06.2025

This has been produced with the financial assistance of the European Union. The content of the document is the sole responsibility of ICMF and can under no circumstances be regarded as reflecting the position of the European Union and/or IPA ADRION programme authorities.
This project is co-funded by the European Union through the Interreg IPA ADRION Programme

Deliverable Quality Checklist

Deliverable nr	Deliverable title	Use of correct template	Alignment with AF deliverable description	Fulfillment of the goal(s) of the deliverable as defined in the AF	Public level dissemination requirements fulfilled	Target group reached	Reviewer
D2.1.1	Technical specification of SMARTMOBAIR intelligent transport system technologies	YES	YES	YES	YES	YES	F. Tomasi (AREA) and B. Monaco (AREA)

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List of abbreviations and terms

AIR	Adriatic Ionian Region
API	Application Programming Interface
CCPA	California Consumer Privacy Act
DATEX	DATa EXchange between traffic and travel information centers
ETSI	European Telecommunications Standards Institute
EU	Europion Union
GDPR	The general data protection regulation
GIS	Geographic Information System
GPRS	General Packet Radio Service
GPS	Global Positioning System
GTFS	General Transit Feed Specification
ICT	Information and Comunicagtion Technology
IoT	Internet of Things
IP	Institucional Partner
IR-PCS	Infrared Passenger Counting System
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
MaaS	Mobility-as-a-Service
NeTEx	Network Timetable Exchange
NFC	Near Field communication
PII	Personally Identifiable Information
SWG	Stakeholder Working Group
SWG	Stakeholder Working Group
TP	Technical Partner

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Executive Summary

This report presents the collection of technical specifications of identified ICT solutions that are to be tested in pilot territories.

The Deliverable D.2.1.1 – Technical specification of SMARTMOBAIR intelligent transport system technologies has a twofold objective. On the one hand, it aims at selecting and tailoring the identified solution to the peculiarities of pilot territories, and on the other hand, it ensures the standardisation of pilot implementation and their comparability in terms of achieved outcomes.

The D.2.1.1 builds upon the outcomes of D1.4.1 Technology gap assessment upon earlier project deliverables and preparatory activities, and D1.4.2 Factsheets on adoptable smart mobility technologies. Moreover, the selection and tailoring process of technologies to be applied in SMARTMOBAIR pilots strongly relies on the stakeholders' collaboration and inputs from the SWGs.

The cross-territorial analysis, presented in D1.4.1 Technology gap assessment upon earlier project deliverables and preparatory activities, confirms that while early digitalisation initiatives are underway, systemic smart mobility readiness — involving dynamic traffic control, integrated fare management, multimodal planning, and predictive analytics — remains fragmented. Similarly, the maturity of cross-cutting enablers such as interoperability, scalability, sustainability impact assessment, and user acceptance is low, with most territories operating below real-world deployment thresholds. Overall, the assessment shows that the SMARTMOBAIR territories are entering a critical transition phase. Initial investments and pilot deployments have laid important foundations, but achieving a fully integrated, resilient, and citizen-centred smart mobility ecosystem will require coordinated scaling, enhanced institutional capacity, and a stronger emphasis on systemic enablers.

Therefore, the selection of technologies was a critical step. The selected technology should have the capacity to remove the mobility problem identified in pilot territories, and thus contribute to the existing mobility and transportation goals at the same time, responding to environmental, social and economic goals. The solution should be accepted as a generator of public value with an impact on long-term plans for smart mobility deployment.

Technologies and solutions to be tested in pilot territories have undergone a tailoring process, where technical solutions are adapted to national and local legislative and organisational requirements, licensing & permits, accessibility & inclusiveness standards, and environmental standards. Moreover, the tailoring process addresses data collection issues, integration & interoperability with other systems (existing and new ones), as well as the security & privacy concerns. Consolidating foundational technologies, ensuring the stability and integration of existing operational systems related to data collection, security, and real-time information services, is a critical step in this process.

The findings of this report will serve as prerequisites for a realistic and smooth solution procurement phase, carried out in A. 2.2. Procurement, implementation and monitoring of SMARTMOBAIR pilot actions.

1 Introduction

Smart and sustainable mobility is a key enabler of Europe's development. Transforming urban mobility is essential to address growing urban challenges through inclusive, digital, and low-emission solutions. The Urban Mobility Framework supports this transition by promoting smart, safe, accessible, and sustainable transport across the EU. The SMARTMOBAIR project addresses the common challenge of traffic congestion and air pollution in the Adriatic-Ionian region, hindering the achievement of climate neutrality goals. Recognizing the need for targeted and scalable solutions, the Interreg IPA ADRION programme supports joint action among countries to bridge capacity gaps, strengthen institutional cooperation, and foster innovation. Through a transnational approach, the project aims to enhance sustainable and smart urban mobility by strengthening territorial collaboration to support the deployment of intelligent transport system solutions in 6 pilot territories and foster their uptake in other Adriatic Ionian cities and territories.

The main barriers to a large-scale deployment of intelligent transport technologies and systems and the launch of new smart mobility services lie on a lack of knowledge and understanding of the new technologies and the implications of their introduction both on the mobility system and on the mobility management systems. Another issue is that these technologies have been usually studied and tested in contexts quite different from the Adriatic Ionian Region (AIR) and their introduction in this area requires a process of adaptation and testing. The overall objective is to overcome these barriers and establish a joint approach for identification, implementation, monitoring and evaluation of ICT solutions able to respond to specific territorial mobility needs.

To investigate the current context and state of the art of solutions/technologies to be applied, improved or scaled up in partner territories this report (Deliverable 1.4.2) elaborate a set off Factsheets on recognized adoptable smart mobility technologies planned within pilot implementation on six pilot territories included in the SMARTMOBAIR project. It focuses on supporting pilot territories in selecting the best solution to meet identified territorial mobility-related needs. The deliverable highlights the main characteristics of potentially adoptable technologies in terms of product application, data collection, integration and interoperability, security and privacy, expected impacts.

The assessment builds on previous work within the SMARTMOBAIR project, including the review of available data and the analysis of regional drivers and barriers (Deliverables D.1.1.2 and D.1.1.3 under Activity 1.1 and Deliverables D.1.4.1 under Activity 1.4). It also lays the groundwork for the upcoming exploration of emerging technologies (Activity 1.5) and the design and implementation of pilot interventions (Work Package 2). Throughout the process, the work has been supported by inputs from the Stakeholder Working Groups (Activity 1.2), which contribute local knowledge and multi-actor perspectives across all phases of the project.

This report is structured into four main chapters. Following the introduction, the second chapter presents the methodological framework for the development of smart mobility technologies' specifications. This chapter provides clear and precise technical specification for each identified technology solution, acknowledged as prerequisites for a realistic and smooth solution procurement phase (Activity 2.2). The chapter is divided into six subsections, one for each of the pilots. The report concludes with a final chapter that outlines key observations and recommendations, and points toward the next steps of the project, which will build on the findings and insights provided in this deliverable.

2 Methodology

The development of each smart mobility technology technical specification follows a structured and consistent methodology designed to ensure clarity, comparability, and practical relevance.

Table 2.1 Timeline of Methodology Development for the Technical Specifications

Source: The Authors

STEP	DATE
Preparation of the methodology	May 2025
Conceptual approach presented	5th June2025
Template and supporting material shared	7th June 2025
Data collection end	27th June2005
Draft Report shared with PPs for review	30th June2005

The methodology has two steps. The main inputs to this process are D1.4.2 Factsheets on adoptable smart mobility technologies. The main technologies per pilot site, presented in D1.4.2, are selected and specified in detail in this document.

Once a technology is selected, desk research is conducted to gather detailed specification from a wide range of authoritative sources. These include peer-reviewed academic literature, industry and government reports, technical standards (e.g., ISO, ETSI), and vendor documentation.

The next step in the methodology is customisation of the selected technologies. The tailoring process of technologies to be applied in SMARTMOBAIR pilots strongly relies on the stakeholders' collaboration and inputs from the SWGs. SWGs' members are asked to fill in the next table to address the aspects of selected technology which need to be adjusted to the local context. One table is filled per each technology.

Table 2.1 Input table for tailoring the selected technologies to the local context

TAILORING SELECTED TEHNOLOGY TO FIT LOCAL LEVEL		
Aspect	**Yes / No**	**Description**
National and Local Laws		
Licensing & Permits		
Accessibility & Inclusiveness Standards		
Environmental Standards		
Data Collection		
Integration & Interoperability		
Security & Privacy		

Anticipated areas of customization are: National and Local laws; Licensing and Permits; Accessibility and inclusiveness Standards; Environmental Standards; Data Collection; Integration and interoperability; and Security and privacy.

3 Technical Specification of the Selected Technologies by Pilot Territory

This chapter presents the technical specifications for pilot territories. Each chapter starts with the description of the territorial context of the pilot, which is followed by technical specifications.

3.1 Province of Gorizia (Turriaco e Sagrado, Italy)

3.1.1 Territorial context

Turriaco and Sagrado are both located in the Friuli Venezia Giulia region in Italy and near the Slovenian border. These municipalities are part of the Province of Gorizia and jointly form a modestly sized territorial unit, covering a combined area of approximately 20 km^2. The total population is around 5,000 inhabitants, with 2,460 residing in Turriaco and 2,048 in Sagrado.

The area is primarily urban, although less densely built compared to larger cities. Mobility infrastructure is influenced by the compact settlement patterns and the role of the territory as a peri-urban node within the broader cross-border mobility system. While the local transport offer is relatively limited, bus services are available, and some commuter connections exist to nearby urban centers.

Public transport usage is monitored daily, primarily via internal systems, but there is no systematic data collection on traffic flows, pedestrian movement, or multimodal accessibility. Some public transport-related data are gathered by local service providers, although not openly accessible.

The region benefits from the deployment of several digital solutions, including an Automatic Vehicle Monitoring (AVM) system that provides real-time bus location and operational data accessible on buses, at stops, and online. Public transport services are provided by TPL-FVG, with buses as the main mode; no metro or tram systems exist. The modal split data is not available in percentage terms but suggests a high reliance on private vehicles and modest use of public transport. The area does not face high levels of congestion, with peak traffic periods occurring between 7:30–8:00 AM and 17:00–17:30.

The TPL-FVG customer app enables passengers to plan routes, purchase tickets, and access real-time service information. In parallel, a dedicated driver app supports daily operations by managing shifts and enabling internal communication. Additionally, a Mobility-as-a-Service (MaaS) solution is under development for the wider Province of Gorizia and is expected to be fully operational by February 2025.

The area is characterized by the absence of a dedicated public transport strategy, inadequate frequency and coordination of services, and insufficient active mobility infrastructure. Safety issues, particularly for pedestrians and cyclists, and lack of enforcement of traffic rules were also raised. Mobility issues tend to peak during school holidays and summer tourist periods. The territory does not have an adopted Sustainable Urban Mobility Plan (SUMP), nor are there dedicated zoning regulations explicitly targeting mobility infrastructure. The lack of structured mobility planning frameworks poses a constraint on the integration of sustainable transport objectives into urban development policy.

In terms of institutional and technical capacity, the territory faces constraints related to funding, outdated regulations, and lack of stakeholder cooperation. Despite these limitations, the municipalities expressed interest in exploring smart mobility concepts. Key drivers include reducing congestion, improving public transport access, and aligning with environmental goals.

There is currently no real-time traffic monitoring system, and while general digital infrastructure is available, smart mobility technologies remain limited. Public transport data is collected daily but is not publicly accessible, and pedestrian counts or traffic flow data are not systematically gathered. Data analysis tools rely on custom applications rather than standardized platforms like GIS. No Sustainable Urban Mobility Plan (SUMP) exists at the municipal level. The main mobility-related problems include the lack of public transport prioritization, insufficient multimodal integration, and an underdeveloped cycling infrastructure.

As part of the SMARTMOBAIR project, the pilot in Gorizia—covering the municipalities of Turriaco and Sagrado—focuses on enhancing the efficiency, reliability, and digitalization of public transport services.

The pilot intervention focuses on strengthening key ITS and MaaS-ready technologies. For the **trip booking and payment customer's app**, the main objective is to **scale up** the existing solution to broaden its reach and enhance its functionality. In parallel, the **bookings management and trip planning software** will be **scaled up** to improve operational efficiency and service coordination. Regarding the **driver's communication on-board equipment**, the intervention aims to **improve** the current communication tools to ensure more effective interaction between drivers and the control center. Finally, for **MaaS integration (once fully operational),** the pilot plans to **improve** the integration framework to facilitate seamless multimodal travel and unified access to services.

The **geospatial coverage** of the pilot is focused on intra-municipal routes and key public transport corridors within Turriaco and Sagrado, particularly those with commuter relevance and potential for intermodal integration.

Trieste Trasporti's on-demand service has been identified as an exemplar for its innovative approach to flexible public transport, offering responsive, user-oriented mobility solutions that complement traditional scheduled services.[1]

Expected benefits of the pilot include enhanced real-time visibility of services, increased operational efficiency, improved public trust in public transport, and a foundational step toward regional MaaS integration.

3.1.2 TECH-GO1 Trip booking and payment customer's APP

The **Trip Booking and Payment App** is a modular, user-centric mobile application designed to improve passenger experience and operational efficiency for flexible public transport services in the Province of Gorizia, with a specific focus on **Turriaco and Sagrado**. Given the small, semi-urban nature of these municipalities, **the app must be tailored to address low population density, limited fixed-route services, and modest digital literacy among users**. These factors have influenced both the interface design and the booking logic of the application.

[1] https://www.triestetrasporti.it/it/notturno-tsondemand

Passenger-Centric Modules and Screens

The application is composed of several core modules, each corresponding to a screen or function designed to facilitate seamless use and real-time information access:

- **Home Screen**: Displays an interactive map showing the user's location and nearby service zones or active transport options. Includes search fields for pickup/drop-off addresses.
- **Trip Booking Screen**: Allows users to input travel details (origin, destination, desired time), check ride availability, and confirm bookings. Route suggestions consider availability, estimated time of arrival (ETA), and detour limits.
- **Trip Tracking Screen**: Real-time tracking of the assigned vehicle with dynamic ETA updates, live map position, driver identification, and vehicle details.
- **User Profile and Preferences**: Stores user data, preferred routes, and accessibility needs (e.g., PRM features). Allows setting communication preferences and saving favorite locations.
- **Ticketing & Payments Module**: Enables digital ticket purchases using integrated payment methods (credit/debit cards, NFC), including QR code generation for validation.
- **Notifications Module**: Sends real-time push alerts regarding delays, service disruptions, driver arrival, and trip completion.
- **Feedback and Support**: Embedded support chat and reporting system to collect user feedback, enable customer service communication, and report service issues.

Technology Tailoring for Local Context

Due to limited public transport frequency and fragmented routes, the application includes:

- **Dynamic time windows** to accommodate wide variation in trip requests.
- **Multilingual interface** (Italian, Slovenian, English) for cross-border and tourist use.
- **Low-bandwidth mode** to ensure usability in areas with limited 4G/5G connectivity.

Integration and Interoperability

The app is **interoperable** with:

- **TECH-GO2**: booking management and planning software to access real-time availability, trip matching, and capacity data.
- **TECH-GO3**: on-board driver systems for synchronizing ETA updates and passenger notifications.

Modular APIs ensure seamless data exchange and support integration with Mobility-as-a-Service (MaaS) aggregators. Key interfaces include:

- RESTful APIs for booking and payment processing
- Secure data channels (TLS encryption)
- Standardized GTFS-RT feeds for route updates and vehicle positions

3.1.2.1 Privacy and Data Protection

The system is fully compliant with GDPR (EU Regulation 2016/679). Data such as addresses, trip history, GPS coordinates, and preferences are encrypted and securely stored. Users have full data control (access, modify, delete). Aggregated data is anonymized for analysis, improving service quality without compromising privacy. ISO/IEC 27001 compliance and full auditability are ensured.

3.1.2.2 Infrastructure Required

Component	Specification / Description	Purpose / Notes	Tailored specifics for APT Pilot Action
Backend Server Infrastructure	Cloud-hosted or on-premises with autoscaling	Ensures scalability and reliability	Designed to support limited but highly dynamic booking volumes and low server latency
Database	Encrypted SQL/NoSQL, GDPR + ISO compliant	Securely stores personal and trip data	Data structure adapted to include specific accessibility needs (e.g., PRM)
API Gateway	RESTful APIs with secure authentication	Enables system interoperability	Custom endpoints created for MaaS integration in the Gorizia context
Payment Gateway Integration	PCI-DSS-compliant providers	Enables digital ticketing	Integrated with local fare schemes and supports Italian banking systems (e.g., PagoPA)
CRM / User Support Platform	Web-based helpdesk, in-app feedback	Enhances customer service	Supports multilingual tickets (Italian/Slovenian) for cross-border travelers
Analytics and Monitoring Dashboards	Business intelligence tools	Monitor usage and satisfaction	Focused on low-frequency/high-value insights (e.g., school holiday peaks)
Security Layer	TLS encryption, GDPR-compliant access	Protects user data	Tailored for low-barrier user registration (email + mobile only)
Push Notification Service	FCM and APNS	Real-time updates to passengers	Configured for local peak-time alerts (commuter and school hours)

3.1.3 TECH-GO2 Booking Management Software and Trip Planning Software

The Booking Management and Trip Planning Software represents the **operational core** of on-demand mobility services. In the Gorizia pilot, its role is to adapt to **variable demand, low-density areas**, and **limited coordination among existing operators**, requiring robust flexibility and real-time intelligence.

Booking Management Software

- **Functionality**:
  - Handles incoming user requests (via mobile or web app)
  - Assigns bookings based on geofencing, fleet availability, and priority rules (e.g., PRM, students, seniors)
  - Manages fleet load balancing and cancellation handling
- **Tailoring Needs**:
  - Zonal management to match rural boundaries
  - Configurable time buffers to compensate for limited vehicles and longer distances
  - Prioritization engine to manage peak school and tourist periods

Trip Planning Software

- **Functionality**:
  - Real-time routing and scheduling based on GPS, traffic APIs (e.g., TomTom, HERE)

    - Dynamic optimization using constraints like road closures, regulatory zones, and fleet availability
    - Navigation instructions for drivers (sent to TECH-GO3 devices)
- **Tailoring Needs**:
    - Must tolerate poor connectivity (failsafe re-routing)
    - Local road constraints and bridge limits incorporated into routing logic
    - Time-adjusted scheduling to account for traffic near border crossings

System Requirements and Constraints

- **Cloud or hybrid hosting** with edge processing for rural resilience
- Modular architecture to scale based on municipality size
- Support for vehicle types ranging from vans to minibuses
- Configurable detour thresholds (max 20–25%) and user wait-time thresholds
- GDPR-compliant data handling for passenger profiling and trip logs

APIs and Integration Interfaces

- Open APIs for:
    - Fare collection and ticketing platforms (e.g., TPL-FVG)
    - Real-time public transport feeds (GTFS/GTFS-RT)
    - Customer app data exchange
- Webhooks for service alerts and booking confirmation
- Middleware support for MaaS platforms (to be integrated in 2025)

Integration and Interoperability

- Connects with **TECH-GO1** for real-time booking display and user feedback
- Interfaces with **TECH-GO3** for live vehicle location, navigation updates, and operational status
- Synchronizes shift schedules and route plans across driver devices

Infrastructure Required

- SaaS/cloud environment with high availability
- Web-based operator dashboard with real-time KPIs
- Real-time routing engine (traffic-integrated)
- Fleet tracking and dispatch platform
- Secure GPS units installed in vehicles
- Dashboard for service metrics, user behavior, and reporting

3.1.3.1 Infrastructure Required

Component	Specification / Description	Purpose / Notes	Tailored specifics for APT Pilot Action
Hosting Environment	Cloud/hybrid with EU data compliance	Ensures scalability and resilience	Modular instance scaled for two small municipalities with shared backend
Booking Interface	Operator web panel + API endpoints	Centralized booking management	Designed to support human-assisted bookings for elderly/non-digital users

Component	Specification / Description	Purpose / Notes	Tailored specifics for APT Pilot Action
Routing Engine	Real-time engine with traffic APIs	Calculates efficient routes	Configured with regional road constraints and known bottlenecks (e.g., railway crossings)
Fleet Management Dashboard	Real-time control panel for operators	Tracks dispatch, vehicle status	Simplified to reflect small fleet (≤10 vehicles) and local routes
Secure GPS Units	Installed on all operational vehicles	Enables accurate tracking	GPS logic adjusted for semi-rural positioning errors and weak signal zones
User Profile & Trip History DB	Stores travel preferences and logs	Enables personalization	Prioritizes PRM and recurring commuter profiles (e.g., students, workers)
Rule Engine	Custom trip allocation logic	Adapts to operational constraints	Supports low-density booking logic, flexible service windows
Notification System	Multi-channel alert system	Real-time trip and ops notifications	Uses SMS fallback in case of app push failure (critical in rural context)
System Redundancy & Failover	Backup services and database mirroring	Ensures uptime	Lightweight replication model to reduce infrastructure costs
Integration APIs	REST APIs for all external systems	Interoperability backbone	Pre-integrated with TPL-FVG ticketing system and MaaS aggregator specs

3.1.4 TECH-GO3 Driver's On-Board Communication Equipment

The **Driver Communication and On-Board Equipment** is the enabling technology that allows frontline operational coordination across the system. It facilitates the **link between real-time planning, service execution, and user communication**, especially in an area like Turriaco-Sagrado where fleet sizes are small and services are dispersed.

Minimum Equipment Specifications

- **Device**: Rugged tablet or smartphone
  - Screen size: ≥8 inches
  - Operating system: Android (preferred for cost-effectiveness)
  - Battery: 8+ hours backup or vehicle-powered
  - Connectivity: 4G/5G, GPS-enabled
  - Storage: ≥64GB, expandable
- **Mounting and Power**: Secure dashboard mounting, 12V power supply with inverter or hardwired option
- **Router (optional)**: Mobile Wi-Fi router with external antenna for areas with low coverage
- **Communication**:
  - Bluetooth-enabled hands-free headset
  - Real-time voice or message exchange with control center

Core Functionalities via Driver App

- View assigned trips and real-time navigation
- Receive updates and alerts on cancellations or detours
- Shift management and digital log-in/out
- Navigation with turn-by-turn assistance

Existing System Integration

Most regional public transport vehicles already include:

- **Automatic Passenger Counting (APC)**
- **Electronic Ticket Validators** (NFC, QR)
- **CCTV Surveillance Systems**
- **CAN-BUS Telematics Interface**

Integration and Interoperability

- **With TECH-GO2**: receives trip and route plans, updates real-time location, and reports operational status.
- **With TECH-GO1**: provides ETA and arrival alerts to users, enabling real-time tracking.
- APIs and middleware bridge communication between the driver app and:
  - Booking systems
  - Telematics (CAN-BUS) for vehicle diagnostics and performance monitoring
  - Fare validators for confirming check-ins/check-outs

Infrastructure Required

- Rugged mobile device (≥8" Android tablet/smartphone)
- Dashboard mounting with power connection
- 4G/5G SIM cards with appropriate data plans
- Optional mobile router with antenna
- Bluetooth audio for hands-free use
- Driver app (preconfigured, OTA updatable)
- API/middleware layer for integration with APC, ticketing, CCTV, and telematics

3.1.4.1 Infrastructure Required

Component	Specification / Description	Purpose / Notes	Tailored specifics for APT Pilot Action
Driver Mobile Device	≥8" rugged Android tablet or smartphone	Runs driver app and nav	Selected for durability and compatibility with limited 4G coverage areas
Vehicle Mounting System	Anti-vibration dashboard cradle	Device safety and usability	Universal mount chosen to match mixed fleet (vans, minibuses)
Power Supply Integration	12V wired or inverter connection	Provides continuous power	Adapted for older vehicles in local fleet without USB/power ports
Mobile Connectivity	4G/5G SIM with ~10GB/month plan	Real-time communication	Selected regional carrier with best coverage in Gorizia province
External Mobile Router (Optional)	In-vehicle Wi-Fi with antenna	Improves connection stability	Included only in longer rural routes or weak-signal zones
Hands-Free Audio System	Bluetooth headset or fixed mic system	Voice communication	Simplified interface to avoid driver distraction
Driver App	Configured for real-time ops	Displays trip and shift data	App localized for Italian language and PRM trip tagging
On-Board Integration Layer	Interfaces with APC, fare, CCTV, CAN-BUS	Enables advanced monitoring	Middleware developed to match legacy fare systems from TPL-FVG fleet

Cross-Technology Integration Highlights

Technology	Interoperability Links
TECH-GO1 App	Interacts with TECH-GO2 (trip planning, booking data), and TECH-GO3 (ETA updates from driver device)
TECH-GO2 Software	Central hub for booking, routing, and real-time fleet data; connects to user app (TECH-GO1) and driver systems (TECH-GO3)
TECH-GO3 Equipment	Sends real-time location, shift updates, and operational status to TECH-GO2; indirectly supports user experience in TECH-GO1

3.2 Municipality of Koper (Slovenia)

3.2.1 Territorial context

MESTNA OBČINA KOPER
COMUNE CITTA DI CAPODISTRIA

The Municipality of Koper, located on the Slovenian coast, includes a compact historical core—referred to as the old city—which serves as the pilot territory within SMARTMOBAIR. This area is marked by a dense medieval street network, narrow alleyways, and significant architectural heritage, reflecting Venetian urban influences. The old city is bordered by modern urban developments and a coastal promenade, offering a combination of residential, commercial, and tourist functions.

Due to its compact and walkable layout, the population density in this area is relatively high, with an estimated 4,000–5,000 inhabitants per km², higher than the municipality-wide average. While the total area of the historical center is approximately 1 km², the overall Municipality of Koper spans a more diverse urban and rural mix. Traffic peaks typically occur in the morning (7:00–10:00) and afternoon (14:00–17:00), reflecting commuter and freight movement patterns.

The city center is organized into seven regulatory zones that govern access and traffic flows. These include fully pedestrian areas, zones allowing limited or permitted vehicular access, paid and reserved parking zones, and calm traffic areas with regulated speeds. Delivery access is time-restricted and subject to designated loading zones. These zoning measures are designed to balance the preservation of the urban heritage with the functional requirements of daily mobility.

Public transportation is available, with buses serving both urban and inter-urban needs. Traffic congestion is considered moderate and is concentrated during morning and afternoon rush hours, particularly during the tourist season and around the Port of Koper, which generates substantial freight traffic.

The city is currently in the process of updating its Sustainable Urban Mobility Plan (SUMP), building on the existing strategy from 2017. Land use and mobility policies are integrated through this planning instrument, which includes measures for pedestrian and vertical mobility connections. Challenges include funding, technological gaps, and coordination issues among stakeholders.

As part of the SMARTMOBAIR project, the pilot in Koper aims to enhance smart mobility solutions for traffic flows monitoring and data-driven planning through improved regulation of stationary traffic and vehicle access. The core intervention includes the installation of **retractable bollards equipped with automatic license plate recognition (ALPR)** systems at key entry points to control and monitor access in real time. This technology is designed to address misuse of remote access systems and contribute to a more enforceable and transparent access control regime.

The pilot integrates a **geofencing framework**, enabling **restricted access control** based on digital vehicle recognition, and is complemented by an **urban mobility management platform** for monitoring and reporting. These two technologies—**geofencing and access control** and **urban mobility management systems**—form the core of the deployment. According to the pilot design, these technologies are marked to be **scaled up**, within the SMARTMOBAIR framework.

The **geospatial coverage** of the pilot will start with the historic city center, specifically around Kosovel Square, where pedestrian safety, vehicle access, and parking pressures converge. This will be followed by the model for further implementation in the city functional urban area.

The solution builds upon an existing technology developed by "Palisada sistemi"[2], which has been successfully deployed in Slovenia and is now adapted for the specific needs and regulatory environment of Koper.

Expected benefits include decreased crowding and traffic in the core zone, a reduction in uncontrolled parking, and an improved regulatory environment for stationary traffic. Access will be granted exclusively to residents and business entities with premises in the designated area. By digitizing access control, the pilot is expected to contribute to enhanced compliance, better traffic flow, and more sustainable urban mobility management in heritage-sensitive zones.

3.2.2. TECH-KO1 Geofancing and Restricted Access Control

Geofencing and restricted access control technologies are increasingly used in the management of traffic and mobility within urban environments, particularly in heritage-sensitive or congested zones like the historic center of Koper.

Geofencing relies on geospatial technologies such as **Global Navigation Satellite Systems (GNSS)**, **cellular triangulation**, or **Wi-Fi fingerprinting** to define dynamic or static virtual perimeters. These perimeters are digitally mapped and used to **trigger predefined logic-based responses** when an authorized or unauthorized vehicle enters or exits a zone. Integration with **real-time vehicle tracking** systems ensures the enforcement of access rules based on temporal, spatial, and categorical criteria (e.g., only electric vehicles allowed during peak hours).

Restricted Access Control, in this context, is implemented through a combination of **physical deterrents** (retractable bollards), **sensor technologies**, and **data-driven decision systems**. It allows only pre-authorized vehicles to enter the controlled area, based on a digital permit registry managed via a centralized platform. This approach significantly improves compliance, reduces human error, and ensures transparency and auditability.

The **fusion of geofencing with Automatic Number Plate Recognition (ANPR)** enables the system to dynamically adapt access permissions based on contextual rules (e.g., time of day, vehicle category, pollution level). This smart enforcement ensures the regulation of access in a non-intrusive, scalable, and sustainable way.

[2] https://palisada-sistemi.si/promet/avtomatski-potopni-stebricek

Geofencing and restricted vehicular access control are the technological backbone of Koper's pilot within SMARTMOBAIR, serving to regulate mobility in the highly sensitive heritage zone of the historic city center. The deployment in Koper has been **customized at multiple levels**—hardware, software, and integration logic—to ensure **full compatibility with existing infrastructure**, **legal frameworks**, and **urban governance practices**.

A. Tailoring to Local Context and Integration with Existing Systems

The geofencing and access control solution in Koper has been specifically adapted to:

- **Integrate natively with existing Palisada sistemi hardware and control software**, already in use for parking and bollard regulation in other parts of the city.
- Use **interoperable APIs** (e.g., RESTful JSON, MQTT over TLS) that allow seamless communication with Palisada's legacy control units, avoiding duplication and ensuring operational continuity.
- Support **multi-node deployment**, enabling synchronized control of multiple access points based on real-time vehicle detection and permit validation.
- Ensure **firmware-level compatibility** with bollard controllers already installed under earlier municipal initiatives, thus reducing upgrade costs and deployment time.

The access management backend will include a **middleware layer** for data normalization and cross-system interoperability, allowing:

- Real-time synchronization with the municipal permit registry.
- Bi-directional communication with Palisada's local edge servers (for bollard control logic and failover operations).
- Optional integration with Koper's urban IoT platform (FIWARE-compatible), traffic monitoring network, and environmental sensors (air quality, noise).

B. Localization and Language Requirements

All system interfaces—public and administrative—are **fully localized**:

- Web portals, user dashboards, and mobile apps will be available in **Slovene (primary), Italian, and English**, aligning with Koper's multicultural and tourist-heavy demographic.
- Bollard signage and LED messaging will support **multi-language dynamic instructions** (e.g., "Access Granted", "Unauthorized Vehicle", "Zone Closed") based on user profile or time-of-day.
- System-generated alerts, automated notifications (SMS/email), and monthly reports will be formatted in the **user's preferred language**, defined in the registry.

C. Advanced Analytics and Reporting Requirements

Koper's pilot includes a dedicated **mobility analytics engine** focused on actionable, policy-relevant insights. Key features include:

1. **Access Event Logging & Visualization**:

  - Real-time dashboards displaying vehicle entries/exits by zone, time, and user category.
  - Heatmaps of access demand over time and spatially across gates.
2. **Policy Compliance & Infraction Detection**:
  - Automated alerts for unauthorized access attempts.
  - Tracking of expired or misused digital permits.
  - Identification of vehicles repeatedly violating rules.
3. **Temporal Traffic Flow Analysis**:
  - Comparative analysis of peak traffic periods pre-/post-intervention.
  - Delivery and service vehicle access density during allowed hours.
4. **Environmental Impact Projection (optional)**:
  - Linking access patterns with local air quality sensors to estimate emission reduction effects.
  - Integration with noise sensors for heritage-area livability assessments.
5. **Administrative & Regulatory Reports**:
  - Monthly compliance reports for municipal mobility departments.
  - GDPR logbooks detailing system access, data handling events, and anonymization protocols.

All data exports are available in **open formats (CSV, XML, JSON, PDF)** and compatible with municipal archiving tools and regulatory documentation standards.

D. Environmental & Urban Adaptation

- All components meet **IP65+ and IK10** standards for outdoor operation in marine environments.
- Camera enclosures are equipped with **anti-fog and anti-condensation heating elements** for reliable OCR during humidity peaks.
- Equipment is designed to operate in **-20°C to +50°C**, ensuring year-round functionality, including peak summer tourist periods.
- **Cable routing and hardware installation** follow strict heritage preservation guidelines: all core components are non-invasive, reversible, and compliant with conservation authority standards.

E. Data Security and GDPR Compliance

The system is engineered with full compliance to EU cybersecurity and privacy standards:

- **End-to-end encryption** with TLS 1.3 for all data in transit.
- **Encrypted storage** with role-based access control (RBAC) and 2FA for backend system users.

- **On-device anonymization** or pseudonymization of license plate data where possible (e.g., for statistical reporting).
- **Immutable audit trails** for all admin interactions and access rule changes, stored according to GDPR retention policies.
- Citizen-facing interfaces include **clear opt-in/out options**, data access request mechanisms, and public transparency notices.

3.2.2.1 Infrastructure required

A robust geofencing-based access control system in a complex urban setting such as Koper requires a **synergistic integration of hardware and software components**, outlined as follows:

Component	Technical Specifications	Tailored specifics for Koper
Retractable Bollards	Steel/composite, electromechanical, response time < 4 sec. Integrated status and emergency override.	Reinforced anti-corrosion coating (salt-resistant), IK10 vandal-proof.
Inductive Loops	In-ground vehicle detection, 24V operation, embedded microcontroller for signal conditioning.	Calibrated for narrow medieval streets; sensitivity adjusted for cobblestone vibration.
ANPR Cameras	Dual-sensor (visible + IR), IP67, OCR > 98%, night vision, 60 fps real-time.	Integrated with Slovene national vehicle database; tuned to recognize Slovenian and Italian plate formats.
Traffic Lights & LED Signage	RGB full matrix displays; status indicators (red/green/orange), integrated with bollard control logic.	Custom language sequences and multilingual fallback for tourists.
Control Units (PLCs)	Redundant industrial-grade PLCs with CANbus and Ethernet ports. Onboard watchdog timers and UPS support.	Configured for remote diagnostics; over-the-air (OTA) firmware updates via secure channel.
Communications Backbone	Dual-channel (Ethernet + 4G/5G), TLS 1.3 encryption, MQTT + HTTP REST API support.	Redundant cellular fallback due to historic center's limited cabling options.
Mobility Management Platform	Cloud-native (or on-premise) backend, role-based access, analytics dashboard, GDPR-compliant storage.	Deployed in Slovene, with admin interface and logs adhering to national transparency regulations.

3.2.2.2 Security and privacy model

The system's design must be **cybersecurity-resilient** and **privacy-compliant**, especially under the **General Data Protection Regulation (GDPR)**, which governs personal data handling within the EU.

Security Objectives and Technical Measures:

- **Confidentiality**:
  - End-to-end encryption (e.g., TLS 1.3) for data in transit.

- Role-based access control (RBAC) and two-factor authentication (2FA) for system administrators.
- Data anonymization or pseudonymization for storage or analysis when possible.

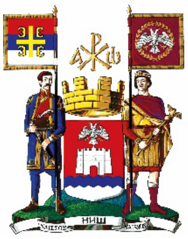
- **Integrity**:
  - Cryptographic hash functions to ensure that access logs and configuration files are tamper-evident.
  - Version control and secure audit trails for system changes and access rule modifications.
- **Availability**:
  - Use of redundant hardware (e.g., hot-swappable servers, dual network interfaces).
  - Intrusion detection systems (IDS) and cybersecurity monitoring to protect against denial-of-service (DoS) attacks or unauthorized access attempts.
  - Maintenance of service continuity through fallback procedures and remote diagnostics.
- **Access Control**:
  - Only authorized personnel (municipal staff, system integrators, emergency services) should have backend access.
  - All backend interfaces (e.g., admin dashboards) secured via VPN or private IP ranges.
- **Accountability**:
  - Logging of all user interactions (e.g., login attempts, configuration changes, manual overrides).
  - Logs must be immutable and stored for a defined retention period in compliance with GDPR.

Privacy Considerations:

- **Minimization**:
  - Collect only data strictly necessary for access control (e.g., license plate number, timestamp).
  - Avoid secondary data collection (e.g., driver identity) unless justified.
- **User Rights**:
  - Residents and businesses must be informed about data processing activities.
  - Mechanisms must be provided for data access, correction, or deletion requests.
- **Transparency**:
  - A public-facing privacy policy should outline what data is collected, for what purpose, and how it is secured.

3.3 The City of Niš (Serbia)

3.3.1 Territorial Context



The City of Niš, Serbia's third-largest city, acts as a key regional hub in the southeast with population of 182.797 (2022). The area of the city covers 596.71 km² and includes five municipalities, which contain 68 suburban and rural settlements. The transport system is multimodal but dominated by private cars. Based on 2022 data, car use accounts for 55.6% of all trips, while public transport stands at 12%, and active modes such as walking and cycling make up 25.8% and 5.4%, respectively. Public transport relies entirely on a bus system, structured into urban and suburban subsystems. The urban network comprises 14 lines (130 km) aligned with the existing street grid, while the suburban network includes 37 radial and circular routes covering over 644 km. Despite the presence of 869 public transport stops, the system's modal share remains low—estimated at 13%—which is considered insufficient for a city of this size. Accessibility is limited; a 5-minute isochron analysis shows that only 18% of the city falls within close reach of public transport, with better coverage in the wider central zone.

Traffic congestion is moderate, with peak hours occurring between 6:30–7:30 AM and 3:00–5:00 PM. However, the city lacks a real-time traffic monitoring system, limiting its capacity for dynamic traffic management. Digital infrastructure remains underdeveloped: IoT sensors have been deployed under the "Smart and Safe City" initiative, but technologies like 5G and cloud-based systems are not yet in place. Collaboration with the local Science and Technology Park signals an interest in smart mobility innovation, although practical implementation remains limited and fragmented.

Mobility-related data collection is inconsistent. While public transport usage is tracked annually and micro-mobility (e-scooter) use is monitored monthly, data on pedestrian flows and traffic patterns is generally unavailable. Advanced analytics tools such as GIS and predictive systems are rarely used, and data analysis relies mostly on custom-built applications, some of which are outdated.

Urban mobility challenges include congestion in central areas, poor service coverage in rural zones, lack of cycling infrastructure, and pedestrian safety concerns—especially due to encroachment of sidewalks by parked vehicles. Public transport suffers from the absence of priority lanes and real-time user information, limiting its competitiveness.

Planning frameworks such as the General Urban Plan of Niš (2010–2025) and the City Development Plan (2021–2027) support integrated land use and mobility strategies. Although Niš is formally covered by a Sustainable Urban Mobility Plan (SUMP), implementation remains partial. While initiatives to modernize infrastructure and adopt smart mobility solutions exist, they are hindered by limited funding and institutional constraints. Nevertheless, the city demonstrates clear intent to advance its smart mobility agenda through digitalization and user-centric planning.

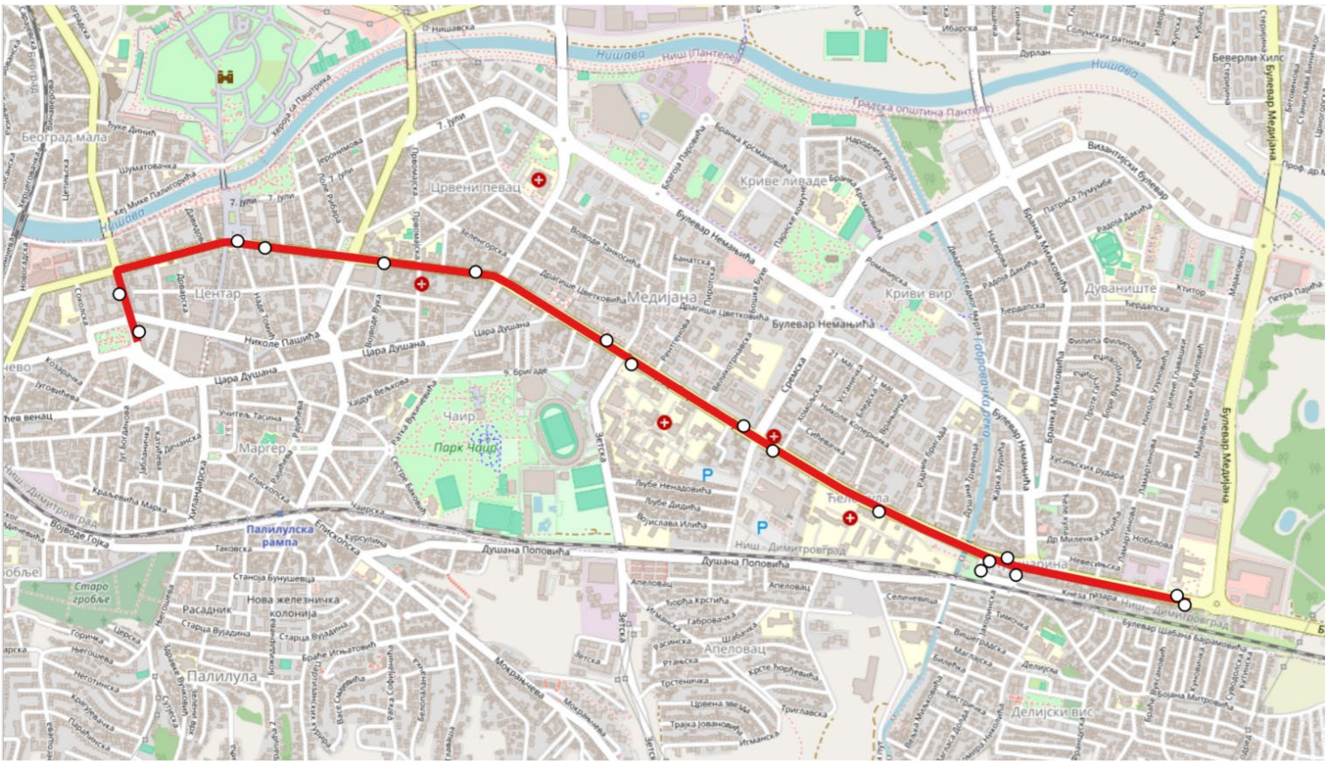
The SMARTMOBAIR pilot in Niš aims to modernize and optimize the city's public transport system through the deployment and integration of advanced ITS solutions. The pilot addresses long-standing challenges related to route efficiency, lack of real-time information, and limited digital integration across the network.

Core technologies for the pilot include **GPS vehicle tracking**, to be **improved** for real-time location monitoring and service management; **GIS cadastre and public transport map integration**, to be **applied** for spatial analysis and route optimization; **GPRS/API-based data exchange**, to be **be improved** for efficient communication between systems; **Passenger information systems (PIS) with enhanced UI/UX**, to be **applied** for better accessibility and responsiveness; and **Mobile data collection via LiDAR and 3D spherical cameras**, to be **applied** for advanced infrastructure and service monitoring. The pilot builds on existing smart GPS infrastructure and fare systems, aiming to transform them into a fully integrated, and responsive public transport ecosystem.

Geospatial coverage focuses on the major urban corridor in Niš, particularly in the municipality of Medijana, where population density and service demand are highest. The corridor starts at Trg Kralja Aleksandra and follows major urban streets: Knjeginje Ljubice – Generala Milojka Lešjanina – Vožda Karađorđa – Boulevard Zorana Đinđića – Ćele kula – Bulevar Svetog cara Konstantina – Roundabout with Boulevard Medijana. The corridor length is around 4 km, and it features 15 bus stops, out of which 5 will be equipped with smart bus info panels. A total of 10 urban public transport lines run through it.

Figure 3.1 Pilot corridor in Niš

Source: SMARTMOBAIR



In Niš pilot, the following 5 bus stops will be equipped with Smart bus panels:

- Trg kralja Milana (direction from Niška Banja)
- Trg kralja Aleksandra (terminal bus stop)
- Ćele-kula (direction to citz center)
- Gradska bolnica (direction from city center)
- Medicinski fakultet.

Expected benefits include reduced operational inefficiencies, increased user confidence in public transport through real-time service visibility, improved multimodal coordination, and scalable digital infrastructure for future mobility services.

3.3.2 TECH-NI1 GIS Public Transport Cadastre

GIS (Geographic Information System) Public Transport Cadastre is a digital, map-based system that collects, manages, and displays geographic data related to public transport infrastructure and services. It includes information such as routes, stops, stations, service areas, etc. By integrating spatial and attribute data, this system helps authorities, planners, and the public to visualise, analyse, and improve public transport networks for better accessibility, planning, and decision-making. The core function of a GIS Public Transport Cadastre is to collect, manage, and visualise spatial data on public transport networks to support planning, analysis, and decision-making.

The GIS Public Transport Cadastre is designed for mixed use, encompassing both public and private sectors. The public sector primarily uses it for transport planning, infrastructure development, service monitoring, policy-making, and public information systems to ensure more efficient, equitable, and data-driven public transportation systems. Primary users are:

- Urban planners
- Public transport planners
- Transport agencies and authorities
- Public transport operators
- Utility companies
- Urban mobility researchers and consultants
- Citizens and commuters (via public interfaces).

The GIS Public Transport Cadastre is typically owned and maintained by public transport authorities or contracted operators. In some cases, shared between public transport and government cadastral authorities, or between multiple government and private stakeholders.

3.3.2.1 Infrastructure required

Infrastructure required for GIS Public Transport Cadastre:

- GIS software platforms (e.g., ArcGIS, QGIS)
- Geospatial databases (e.g., PostgreSQL/PostGIS)
- Surveying tools and satellite imagery data collection tools (see TECH-NI2 Mobile data collection)
- Digital mapping tools
- Servers or cloud-based data storage
- Internet connectivity for real-time updates and access

3.3.2.2 Data Model of the GIS Public Transport Cadastre

The Data Model must be based on traffic and transport legal regulations (national, regional and local)[3], as well as user requirements. This model includes various data groups:

- horizontal traffic signage,
- vertical traffic signage, and
- bus stops.

Horizontal Traffic Signage

Elements of horizontal traffic signage are markings on the road surface that provide road users with important information regarding movement rules, warnings, prohibitions, and guidance. These markings supplement vertical signage and traffic lights and play an important role in improving public transport safety. Key elements of horizontal traffic signage for which spatial data should be collected include:

1. **Road surface markings**
    - **Longitudinal markings** (lines that follow the direction of vehicle travel):
        - Solid line
        - Dashed line
        - Double line (combination of solid and dashed)
    - **Transverse markings** (lines placed across the direction of vehicle travel):
        - Stop lines
        - Pedestrian crossings
        - Bicycle crossing markings
2. **Symbols and inscriptions on the road**
    - Directional arrows
    - Symbols for public transport vehicles, bicycles, taxi stands
    - Inscriptions such as “STOP”, “BUS”, “TAXI”
3. **Special lane markings**
    - Bus lanes
    - Bicycle paths
    - Lanes for slow vehicles

[3] In the Republic of Serbia, these include: **Law on Road Traffic Safety** ("Official Gazette of the Republic of Serbia", no. 41/2009, 53/2010, 101/2011, 32/2013 - decision of the Official Gazette of the Republic of Serbia, 55/2014, 96/2015 - other law, 9/2016 - decision of the Official Gazette, 24/2018, 41/2018, 41/2018 - other law, 87/2018, 23/2019, 128/2020 - other law, 76/2023 and 19/2025); **Regulation on traffic signage** ("Official Gazette of the Republic of Serbia", No 85/2017, 14/2021 and 21/2024); and **Decision on Public Urban and Suburban Passenger Transport in the Territory of the City of Niš** ("Sl. Newspaper of the City of Niš", no. 1/2016 - consolidated text, 18/2017 and 26/2023).

4. **Parking surface markings**
   - Marked parking spaces
   - Spaces for persons with disabilities
   - No-parking or no-stopping zones
5. **Other markings**
   - Warning markings (e.g., school area triangles)
   - Roundabout directional markings
   - Intersection markings

Vertical Traffic Signage

Vertical traffic signage includes all signs placed beside or above the road that visually inform, warn, guide, or instruct road users on how to behave in traffic. It is crucial for the proper functioning of public transport, as it provides clear, universally understandable visual information for safe and efficient mobility.
Key elements of vertical traffic signage for which spatial data should be collected include:

- Traffic signs
- Traffic mirrors
- Traffic lights and light signals
- Information boards and direction signs

Bus Stops

To ensure quality documentation of bus stops in cities, in addition to their location, a set of attributes must be collected to allow comprehensive analysis, planning, and management of public transport. These attributes can be categorized as spatial, physical, and informational.

a) Spatial attributes (geolocation data)

- Stop code and name
- Coordinates (latitude and longitude)
- Affiliated municipality / settlement

b) Physical attributes (infrastructure and equipment)

- Bus stop pole (yes/no)
- Type of stop (on-lane, in a bay, semi-bay, etc.)
- Stop position (before intersection, after intersection, within intersection, before/after pedestrian crossing, distance from intersection)
- Type of stop structure (with shelter, mushroom-type, without structure, number of structures, etc.)
- Platform height
- Presence of bench, trash bin

- Lighting (yes/no)
- Dispatcher booth (yes/no, for termini only)

c) Informational attributes (passenger data)

- Information board (yes/no)
- Digital display of arrival times (yes/no)

3.3.2.3 Open-Source Based Web GIS Platform (Geoportal)

The platform should include a Role-Based Access Control (RBAC) system for access control to features and the subsystems, which usually includes:

- Maps
- Dashboards
- CMS (GeoStories)

The Web GIS platform should support:

- Adding resources (raster and vector data)
- Integration with external OGC standard geoservices
- Editing geometries and attributes on layers

The data for visualising Georeferenced Point Clouds and 3D Spherical Photos is being collected from mobile scanning and 3D spherical photography (see TECH-NI2 Mobile data collection). Field data is being collected, converted into standard GIS formats, and imported into a central database.

The Geoportal should have a module for working with spatial data, as per the GIS Public Transport data model. This module should be publicly accessible and enable the identification and display of parameters on selected elements, as well as the analysis and display of relevant data on spatially filtered cadastre layers.

Geoportal Requirements:

- System architecture should be based on a modern GIS architecture that enables access, search, and retrieval of data from spatial databases on central and remote GIS servers via web services – Service-Oriented Architecture (SOA) – and their display on the GIS portal.
- The geoportal, as a central Web GIS application for accessing all GIS content, publishing, and working with spatial data, should be based on open-source software.
- Open API should be compliant with geoinformatics standards (WMS, WFS, WFS-T, WKB/WKT, SLD, GML, GeoJSON, WMTS, WMS-C, etc.).
- The system should be hybrid and should support working with spatial data in standard vector (point, line, polygon) and raster formats.
- The system should directly connect to databases (PostgreSQL, Microsoft SQL Server, Oracle) that contain geocomponents.

- The system should enable access to external databases via web services, including OGC web GIS services (WMS, WFS, and WFS-T).
- The system should enable independent linking of graphical and textual data, database creation, import from existing databases, and linking external data with GIS databases.
- The security system should include user administration, user grouping, and system management.

Geoportal Functionalities usually include, but are not limited to:

- Creating, storing, and sharing web maps, data, and applications
- Creating and storing web GIS applications with predefined application templates
- Searching GIS content within the portal
- Help system (user manual)
- Integrated interactive map viewer for creating and saving web maps with the ability to:
    - Display and overlay layers
    - Display 2D and 3D spatial data
    - Remove or add layers via the user interface
    - Export data to formats like GeoJSON, DXF-Zip, KML, Zip SHP, GPX
    - Web-based attribute and geometry editing
    - Drag and drop local files (KML/KMZ, Zip SHP, GeoJSON, GPX) to add to the layer list for sharing and saving
    - Perform queries using multiple logical expressions on attribute fields and spatial filters based on defined geometry
    - Advanced printing with predefined format selection
    - Basic tools: length and area measurement, search by street, address, and toponym
- Integrated web application for designing and building web GIS applications using web maps, with support across all web-enabled devices
- Integrated administration tools for managing users, user groups, usage options, and GIS content
- Application with integrated templates for building GIS applications that work on all device formats
- Application for operational monitoring of indicators – analysis via linked interactive maps, charts, tables, and KPIs
- Integrated interactive website builder with GIS themes
- Mobile application for field data collection and editing, displaying the same content as the geoportal, with support for capturing field photos and location data
- 3D sphere visualization
- Multi-language Interfaces (eg, local language and English).

These functionalities should enable efficient data viewing and analysis, support professional users in decision-making, and allow improved coordination and transparency in operations.

3.3.2.4 Security & Privacy module

Public maps typically exclude sensitive personal information. However, GIS cadastre must be protected from typical cyber risks such as unauthorised access to sensitive data records, data tampering or loss due to system failures, and targeted attacks on property databases. This can be achieved through role-based access control, data encryption, audit trails, version tracking, secure cloud environments and backup systems.

The system must comply with local property laws and spatial data regulations, as well as with national and regional privacy laws (e.g., GDPR)[4]. Public and private data layers are typically separated in design, with each represented in independent modules. Users must be given clear terms for how data is collected and shared.

3.3.3 TECH-NI2 Mobile data collection

Mobile data collection using LiDAR and 3D spherical cameras enables the capture of highly detailed, accurate, and comprehensive information about physical environments. LiDAR (Light Detection and Ranging) systems emit laser pulses to generate precise 3D models of surroundings, capturing spatial geometry with high accuracy. Complementing this, 3D spherical cameras record full 360-degree images or videos, offering immersive visual context to the spatial data. Together, these technologies provide a powerful solution for mapping, surveying, and analysing complex environments in real-time.

3.3.3.1 Data collection

Data collected using multisensor survey methods and subsequent processing include:

1) LiDAR Data:

- 3D point cloud data representing surfaces, objects, and terrain
- Depth and distance measurements
- Vegetation and infrastructure details (e.g., trees, buildings, roadways)

2) 3D Spherical Camera Data:

- High-definition 360-degree images and videos
- Contextual information (e.g., road signs, traffic lights, landmarks)
- Color and texture information to complement LiDAR data

3) Geospatial Data:

- GPS coordinates for accurate georeferencing
- Time stamps for temporal analysis

Data is collected continuously during vehicle movement as part of the field survey. High-frequency point cloud capture can have up to millions of points per second, depending on the LiDAR system. 360-degree imagery

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[4] **Law on Personality Data Protection** ("Official Gazette of the Republic of Serbia", No. 87/2018).

captured at a rate of frames per second (FPS), typically 30 FPS or higher for video. The data collection process should be designed to minimise unnecessary data capture.

Data is then processed and stored in the database, as per the GIS Public Transport Model (see 3.3.2 TECH-NI1 GIS Public Transport Cadastre).

Data ownership typically belongs to the entity that operates the mobile data collection system (e.g., construction company, local authority, or research institute). The usage and sharing of data may be subject to licensing agreements or public data policies, depending on the location.

3.3.3.2 Survey Equipment

Imaging is usually conducted from a moving vehicle, although this can be complemented by Aerophotogrammetric recording by plane.

Data collection requires different sensors, such as LiDAR sensors (e.g., rotating laser scanners, solid-state LiDAR) and 3D spherical cameras (e.g., omnidirectional cameras with 360-degree coverage).

For mobile scanning, a LiDAR sensor is typically capable of detecting low-reflectivity targets at long distances, with geodetic-grade accuracy (up to 5 mm), a minimum scanning speed of 250 lines per second, and a 360 ° field of view (FOV). Additionally, since mobile scanning will be performed in urban environments (in the presence of people), the LiDAR sensor must have a Laser Safety Classification 1, meaning the emitted energy must be below the threshold that could cause harm, making it safe for use under normal conditions. The mapping accuracy of point and linear features (horizontal and vertical signage) is usually better than 20 cm.

The spherical camera used for capturing 3D imagery usually has:

- A 360° field of view
- A minimum resolution of 60 MP
- At least 5 frames per second
- An integrated GPS/IMU (Inertial Measurement Unit) system for position and orientation tracking

Additional devices can include environmental sensors (e.g., temperature, humidity). However, these are not mandatory for transport and traffic purposes.

3.3.3.3 System integrations

The mobile data collection system should meet various integration standards (APIs). LiDAR and camera data should integrate with Geographic Information Systems (GIS), Computer-Aided Design (CAD) tools, and 3D modelling software. Integration with traffic management systems or autonomous vehicle systems for real-time use is optional.

API integrations for sharing data with third-party platforms (e.g., environmental monitoring or city infrastructure systems) include, but are not limited to:

- LiDAR data in LAS, LAZ, or E57 formats
- 3D point cloud data standards like OpenLiDAR, PLY, or XYZ

- Industry standards such as CityGML or OGC for geospatial data
- Standardised APIs for data exchange (e.g., REST APIs for easy integration with other systems)

Ensuring consistency between LiDAR and camera data during data fusion processes is a primary challenge in integration. Moreover, the system might face compatibility issues between various 3D modelling and GIS platforms.

3.3.3.4 Security & Privacy module

Data transfer is typically done in real-time, via Wi-Fi, cellular, or satellite for mobile platforms. Depending on the survey sample size, there is also an issue of managing large data sets and ensuring fast processing times. High-capacity data storage solutions (e.g., SSD drives) are required for offline data transfer. Cloud services or local servers can be used for data processing and analysis.

Accessing raw LiDAR and 3D spherical data is subject to user-defined permissions. Secure data access through cloud platforms or local networks is enabled through data encryption and authentication.

Data transfer and usage are under various cyber risks. The transmission process can face unauthorised access to sensitive data (e.g., infrastructure details, vehicle paths). Moreover, the security module must prevent data interception or hacking during transmission (e.g., point cloud or camera data).

Security and privacy issues, such as data manipulation or corruption, can also arise during post-processing.

Technical safeguards typically include:

- End-to-end encryption for data in transit and at rest
- Secure authentication and user access control for cloud or local systems
- Regular audits and intrusion detection systems to protect against breaches

Generally, LiDAR and camera data do not capture personally identifiable information (PII), unless integrated with other systems (e.g., vehicle registration data). However, the system must comply with GDPR and other data privacy regulations[5], especially for geographic and personal data. Anonymisation of data should be used where applicable to reduce privacy concerns.

Transparent data handling practices are crucial, particularly in public or urban planning projects, such as those in SmartMobAir pilots. Users should be provided with clear policies about data use and storage, access permissions, and clear consent mechanisms for data collection.

3.3.4 TECH-NI3 Accessible UI/UX designed real-time information platforms (Smart bus stops)

[5] **Law on Personality Data Protection** ("Official Gazette of the Republic of Serbia", No. 87/2018).

Bus stop information boards come in various forms, ranging from simple static signs to dynamic digital displays. These boards provide essential information to passengers, including route numbers, destinations, and sometimes real-time arrival times.

Static Information Boards display route maps (diagrams showing bus routes and their destinations, helping passengers identify the correct bus to take), planned timetables (printed schedules listing the times buses are expected to arrive at the stop), route nameplates (signs indicating the name of the bus route and its direction), stop nameplates (signs indicating the name of the bus stop).

Accessible UI/UX designed real-time information platforms at smart bus stops provide passengers with immediate, easy-to-understand updates about public transport. These platforms are integrated into digital displays, interactive touchscreens, or mobile-accessible systems at bus stops and are developed according to universal design and accessibility standards.

The platforms deliver real-time information such as live bus arrival/departure times, route changes, service alerts, line maps and multimodal connections. They are designed with a user-friendly interface with high-contrast visuals, readable fonts, tactile or auditory feedback, language options, and user-friendly layouts.

Accessible UI/UX designed real-time information platforms are based on different technologies:

- **LED Displays:**
  Bright digital signs that can display dynamic information like arrival times, delays, and route changes.
- **E-Ink Displays:**
  Low-power screens, ideal for off-grid locations, display static or real-time information.
- **TFT Displays:**
  High-resolution screens that can display detailed information like maps, route diagrams, and real-time data.

The first two technologies are widely used in public transport and therefore subject to the comparison presented in the next table.

Table 3.1 Comparison of the main features of e-Ink (e-Paper) and LED technologies

Category	E-Ink (E-Paper) Panel	LED Panel
Display Technology	Electrophoretic (e-ink particles)	LED matrix (SMD technology)
Color Options	Black/White, 3-color (Red/Yellow), limited full-color	Monochrome (Amber/Red), Tri-color, Full RGB
Brightness / Visibility	Excellent in sunlight, no backlight needed	Very bright, visible in all lighting conditions
Night Visibility	Frontlight (optional), limited without it	Excellent with automatic dimming
Power Supply	Solar + battery (typical); very low power draw	Grid power (main), optional battery backup
Power Consumption	Extremely low (<0.1 W standby, 1–2 W per update)	Moderate to high (30–300+ W depending on size/color)
Connectivity	4G/LTE, LoRa, Wi-Fi, GPS (optional)	Ethernet, 4G/LTE, Wi-Fi, Serial (RS-485)
Refresh Rate	5–15 seconds per full update	Real-time (1–5 sec updates; instant display changes)
Partial Update	Yes (depends on model)	Not applicable
Durability	Vandal-resistant, IP65+, no heat emission	Robust, IP54–IP65, may generate heat
Operating Temp. Range	-20°C to +60°C (some to -30°C)	-30°C to +60°C
Maintenance	Minimal (no fans, no lamps), long lifecycle	Moderate (cooling, LED degradation over years)

Category	E-Ink (E-Paper) Panel	LED Panel
Display Content	Real-time data, Static content, timetables, maps,	Dynamic real-time info, alerts, clocks, animations
Readability	Paper-like, anti-glare	High contrast, good at night or distance
Audio / Accessibility	Optional speaker / button	Optional TTS, buttons, braille support
User Interaction	Optional touchscreen in premium models	Usually display-only; some interactive versions exist
Sustainability	Very energy-efficient, solar-powered	Higher energy use, but can be solar-assisted
Use Cases	Low-traffic stops, off-grid/rural, eco-focused cities	High-traffic stops, urban areas, real-time alert need
Installation Cost	Medium (solar + smart control)	Medium to high (electrical connection required)
Lifecycle Cost	Low (energy + minimal maintenance)	Moderate to high (energy + servicing)

Based on the presented main characteristics, LED technology is recommended for real-time frequent updates (e.g., alerts) and for stops with multiple lines in case of a large display. On the other hand, e-Ink (e-Paper) is recommended for remote/off-grid locations, making this technology ideal for rural deployment, but also for urban locations with limited power sources. Moreover, e-Ink (e-Paper) is energy-efficient (especially with solar panel), easy installed (can be installed on existing poles, bus stop shelters or freestanding) and budget-sensitive (low installation and maintenance costs). Therefore, e-Ink (e-Paper) is considered more suitable for this pilot project.

The Smart Bus Stop system will be owned by the City of Niš and managed by the Public Utility Company Directorate for Public Transport of the City of Niš.

3.3.4.1 E-Ink (E-Paper) Bus Stop Info Panel – Technical Specification (General)

Display Technology

- Type: E-Ink (electrophoretic / e-paper display)
- Size: Typically 13" to 42" (common sizes: 13", 23", 32", 42")
- Resolution: Varies by size (e.g., 1600x1200 for 13", 2880x1440 for 32")
- Color: Black & White or 3-color (B/W/Red or B/W/Yellow); full color emerging but limited
- Viewing Angle: ~180°, excellent outdoor readability
- Sunlight Readability: Excellent; no glare
- Refresh Rate: 5–15 seconds (depending on content and display size)
- Partial Update Capability: Available in advanced models

Power Supply

- Power Source: Solar-powered with battery backup; optional grid connection
- Battery Type: Rechargeable Li-Ion or LiFePO4
- Battery Capacity: Typically 20–100 Wh (depending on size and update frequency)
- Solar Panel: Integrated (typically 20–100 Wp)
- Power Consumption: Ultra-low (standby ~0.01 W, active <2 W per update)

Connectivity

- Wireless:
  - 4G/LTE (primary)
  - 3G fallback
  - Optional: Wi-Fi or LoRaWAN
- GPS Module: Optional (for location and synchronisation)
- Protocol Support: MQTT, HTTPS, REST API, GTFS-RT (real-time), JSON, XML

Controller / Firmware

- Embedded Processor
- Operating System: Linux or RTOS
- Remote Management: Cloud-based content and firmware updates

Housing / Mechanical

- Enclosure: Weatherproof, vandal-resistant (IP65+ rated)
- Material: Aluminium or steel casing, tamper-resistant front glass
- Mounting Options: Pole-mounted, stop shelter-mounted, or freestanding
- Operating Temperature: -20°C to +60°C (some models down to -30°C)
- Certifications: CE, FCC, RoHS, IK09 (anti-vandal protection)
- Optionally, the vendor will deliver all poles for installation if there are no existing ones that could be used

User Interface / Features

- Display Content:
  - Real-time arrival times (via GTFS-RT or similar)
  - Maps, alerts, schedules, service info
- Control push (interactive) buttons: language switching, for visually impaired users to trigger announcements or display other information (tourist info or similar)
- Audio (optional): TTS speaker for visually impaired users
- Lighting (optional): Frontlight or LED for nighttime visibility

Back-end System

- Compatibility:
  - GTFS & GTFS-RT standards
  - Custom integration with the GPS automatic vehicle location (AVL) system
- Content Management System (CMS): a Web-based application allowing remote content scheduling, multi-language support, publishing content instantly or scheduling for certain times, flexibility to customise content, integrated administration tools for managing users, user groups, usage options,

application for operational monitoring of indicators (KPIs) regarding info content displayed and devices (status, malfunctioning, battery health), multi-language Interfaces (eg, local language and English).

Servers

- Vendor should provide cloud-based servers for the pilot duration (a minimum of 5 years)
- Cloud servers should be either in the Republic of Serbia or in EU countries, to comply with national regulations.

3.3.4.2 Integration & Interoperability

Main data sources for smart bus stops are GPS feeds from public transport buses (real-time data on vehicle location, speed, etc.), and other data from public transport control centre APIs (public transport schedule, line routes, public transport e-cadastre data (TECH-NI1), etc.) Data is typically transferred through a mobile cellular network (4G/5G) or Wi-Fi.

The Smart Bus Panels' main integration is with public transport management systems and vehicle tracking platforms. Moreover, the system should be able to integrate with multimodal trip planners and mapping services. To achieve this, the system must fulfil GTFS and GTFS-realtime standards, and optionally SIRI (Service Interface for Real-time Information), OpenAPI or custom APIs for integration.

In the Niš pilot, APIs for data exchange with the GPS automatic vehicle location (AVL) system implemented in Niš[6] must be developed. The AVL system is owned and managed by the Public Utility Company Directorate for Public Transport of the City of Niš. The data exchange APIs should secure fast, safe and reliable transfer of real-time information such as live bus arrival/departure times, route (planned and unplanned) changes, service alerts, line maps and multimodal connections, and other information.

Optionally, the system will have an API with other city institutions, e.g. City Administration for Common Affairs and Information-Communication Technologies – Department for ICT, and the Tourist Organisation of Niš. However, data input from these institutions can be imported manually through CMS, not automatically via a special API.

3.3.5 Security & Privacy

Typical cyber risks can include unauthorised access to the backend system or device firmware, and tampering with public-facing displays. To mitigate this risk, some of the technical safeguards may be:

- Encrypted data transmission (HTTPS, VPN)
- Role-based access control for administrative interfaces
- Firewalls and remote monitoring of smart stop systems

Personal information are not usually collected, but the system must be designed to comply with GDPR, ADA, and Serbian national laws[7].

[6] The system vendor is BusLogic LLC https://bus-ticketing-system.com/en/.

[7] **Law on Personality Data Protection** ("Official Gazette of the Republic of Serbia", No. 87/2018).

3.4 The Municipality of Novo Sarajevo (Bosnia and Herzegovina)

3.4.1 Territorial Context

The Municipality of Novo Sarajevo, located within the Sarajevo metropolitan area, is one of the most densely populated urban units in Bosnia and Herzegovina. With an area of just 9.9 km² and a population of approximately 64,814 residents, the municipality exhibits an average density of 6,370 inhabitants per km², presenting significant spatial constraints for mobility infrastructure development and urban planning.

Administratively, Novo Sarajevo operates as a single jurisdiction and comprises 18 local communities. Its compact size and high density necessitate targeted and integrated mobility planning. While the municipality does not extend across multiple administrative units, its transport system is functionally integrated into the broader Sarajevo Canton, requiring coordination with cantonal authorities for the delivery and regulation of mobility services.

The modal split, as reported in Deliverable D1.1.2, is dominated by private car use (approximately 40%), followed by public transport (30%), and active modes—walking and cycling—each accounting for 15%. Public transport services include buses, trams, and trolleybuses; however, service quality is constrained by ageing fleets, low reliability, and the absence of real-time schedule information or prioritized infrastructure. Despite the presence of formal stops, the lack of passenger information systems and accessible infrastructure contributes to the limited attractiveness of public transport.

Traffic congestion is rated as high, with pronounced peak periods in the early morning (7:00–8:00 AM) and late afternoon (3:00–5:00 PM). The municipality lacks a real-time traffic monitoring system and structured parking availability tracking, which inhibits responsive traffic management and contributes to inefficiencies. Informal parking practices, including on sidewalks and green spaces, further deteriorate the urban mobility environment.

Smart mobility readiness is currently limited. There are no deployed systems for traffic flow monitoring, integrated mobility platforms, or smart parking. Furthermore, no digital infrastructure—such as 5G or cloud-based mobility services—is presently in use. However, initial discussions regarding the deployment of basic monitoring equipment for micro-mobility trends (e.g., e-scooter usage) indicate a growing recognition of the need to adopt data-driven tools for future planning.

Although the Municipality of Novo Sarajevo is formally encompassed by the Sarajevo Canton Sustainable Urban Mobility Plan (SUMP), adopted in 2019, the absence of a dedicated local SUMP limits the strategic integration of mobility objectives at the municipal level. Implementation of SUMP-related measures remains partial and is hindered by institutional capacity and financial constraints.

As part of the SMARTMOBAIR project, the pilot in Novo Sarajevo focuses on advancing the monitoring and management of micromobility flows—particularly e-scooters and e-bikes—through the deployment of stationary measurement devices and a dedicated software application. The aim is to establish a systematic approach for collecting, analyzing, and using data to inform infrastructure planning, improve traffic safety, and encourage sustainable urban mobility behavior.

Core technologies include **stationary traffic and speed measuring devices** (**to be applied and scaled up**), a **monitoring application for e-vehicles** (**to be applied**), and a **central server system for data management** (**to be applied and scaled up**). Additionally, the use of e-scooters and e-bikes will be assessed in terms of frequency, location, and peak times, forming the basis for future infrastructure adaptation (**to be applied and scaled up**). These tools will fill a critical gap in urban planning and help define policy measures to address challenges associated with the growing presence of micromobility devices in public spaces.

Geospatial coverage of the pilot includes selected streets and cycling paths within the Municipality of Novo Sarajevo, where pedestrian and micromobility conflicts are most frequently observed. The intervention area was selected based on current congestion issues and lack of traffic data on non-motorized vehicles.

Exemplar city is not specified in the input but the pilot draws inspiration from cities with established micromobility management frameworks, particularly where real-time tracking and policy integration are already in place.

Expected benefits include improved traffic safety for micromobility users and pedestrians, better regulation of e-scooter and e-bike operations, enhanced data-driven planning capacity for the municipality, and an overall reduction in CO_2 emissions. The pilot also foresees educational components, including training for students and citizens, to foster safer and more informed use of micromobility vehicles. Additionally, the monitoring model may serve as a demonstration tool for academic purposes, promoting innovation and public engagement.

3.4.2 TECH-NS1 Devices for Measuring Traffic and Speed

Traffic and speed measurement devices are smart mobility technologies that enable the automatic collection of data on vehicle count, speed, classification (e.g. bicycle, e-scooter), direction of travel, and time distribution. These devices are essential for infrastructure analysis, improving traffic safety, promoting sustainable mobility, and supporting tourism development.

The core function of the system is the continuous collection of traffic flow data for cyclists and other vehicles along bike paths, enabling data-driven traffic management, infrastructure planning, and the promotion of healthy and environmentally friendly modes of transport.

3.4.2.1 Usage and Target Users

This technology is primarily intended for public use, with the potential for public-private partnerships (e.g. e-scooter service providers). Key users include:

- Municipal traffic departments

- Urban planners

- Public and micromobility transport providers

- Police and traffic enforcement agencies

- Tourism agencies

- Citizens and cycling advocacy groups

3.4.2.2 Infrastructure Requirements

- Surface mounting of sensors

- Power supply via existing installations (e.g. traffic light control cabinets)

- Network connectivity via RS485, USB, GSM, GPRS

- Vandalism-resistant and weatherproof housing (protection from water, dust, extreme temperatures)

- Preferably located under video surveillance or in monitored public area.

3.4.2.3 Data Model

The devices collect and process the following groups of data:

- Traffic characteristics: vehicle counts, classification, speed, direction

- Temporal data: time-of-day and daily distribution

- Technology parameters: JSON format for data exchange

Sensors include inductive loops, with real-time data collection. Data is stored in municipal databases and made accessible to authorized users through dashboards, while public visualizations can be presented via LED totems.

3.4.2.4 Integration and Interoperability

- Integration with GIS platforms, urban control centres, and smart city infrastructure

- Supports JSON traffic data format

- Connectable with police systems and municipal traffic management platforms

3.4.2.5 Security and Privacy

- No personal or biometric data is collected

- Compliant with data protection laws in Bosnia and Herzegovina (Law on Personal Data Protection, aligned with GDPR)

- System is protected via firewalls, antivirus software, and physical security measures

- Public communication on data use is provided via signage, websites, or municipal reports

3.4.2.6 Web GIS Compatibility

Devices can be integrated with geoportals and urban mobility dashboards. Data can be visualized through web GIS applications with functionalities such as:

- Traffic flow analysis

- Spatial-temporal filtering

- Decision support for planners and public authorities

3.4.2.7 Expected Impacts

- Improved traffic safety and data-driven infrastructure design

- Promotion of cycling and micromobility

- Reduction of CO_2 emissions

- Support for eco-tourism and sustainable transport

- Cost-effective traffic data collection

3.4.2.8 Local Adaptability

The technology is compliant with national legislation in Bosnia and Herzegovina, including electrical standards, environmental regulations, and privacy laws. It requires no end-user licensing and does not interfere with pedestrian or disabled access.

3.4.3 TECH-NS2 App for Monitoring Micromobility E-Vehicles Use

The App for Monitoring Micromobility E-Vehicles Use is a mobile and web-based application designed for real-time tracking, analytics, and management of shared micromobility fleets, such as e-scooters and e-bikes. The application supports dynamic rebalancing of fleets, improves vehicle utilization, and enables data-driven decisions by both operators and local governments.

By collecting and analysing spatial and usage data, this technology helps reduce urban congestion, enhance last-mile connectivity, support environmental goals, and offer a better user experience for commuters.

3.4.3.1 Usage and Target Users

This application is intended for mixed use, involving public authorities and private micromobility service providers. Key users include:

- Urban and transport planners

- Micromobility operators

- Public transport authorities

- City administrations

- Commuters and tourists

3.4.3.2 Infrastructure Requirements

- GPS-enabled micromobility vehicles

- Mobile internet (cellular/Wi-Fi) for real-time data transmission

- Cloud-based data servers and analytics platforms

- Integration with city mobility systems and digital infrastructure

3.4.3.3 Data Model

The app collects and processes data from several sources:

- Operational data: real-time vehicle location, speed, battery level, trip start/end points

- User data: trip distance, usage frequency, anonymized demographics (if permitted)

- Sensor data: IoT-based metrics from onboard sensors

Data collection occurs in real time for operational monitoring and in batches for deeper analytics. The data is owned by micromobility operators and may be shared with municipalities under partnership agreements. Users can access their personal data through in-app dashboards and export tools, with built-in privacy controls.

3.4.3.4 Integration and Interoperability

- Compatible with public transit apps and urban mobility platforms

- Supports common data standards: GTFS (General Transit Feed Specification), MDS (Mobility Data Specification), NTCIP

- API-based integration with municipal traffic systems and third-party applications

- Requires API adapters for legacy systems, if applicable

3.4.3.5 Security and Privacy

- Protected against cyber threats such as spoofing or data interception

- Implements end-to-end encryption and follows ISO 27001 security audit practices

- Complies with GDPR, CCPA, and local privacy laws

- Uses anonymization, role-based access controls, and data minimization by design

- Transparent user communication via in-app privacy notices and opt-in consent mechanisms

3.4.3.6 Web GIS Compatibility

Although primarily an app-based system, the platform can feed real-time and historical micromobility data into GIS platforms and urban dashboards. Through spatial visualization and integration, planners and operators can:

- Identify demand hotspots

- Manage micromobility parking zones

- Monitor low-usage or over-congested areas

- Coordinate with public transport hubs

3.4.3.7 Expected Impacts

- Improved fleet efficiency and reduced idle vehicles

- Enhanced last-mile connectivity and commuter convenience

- Lower CO_2 emissions through mode shift from cars to e-vehicles

- Economic benefits through tech job creation and operational cost reduction

- Valuable data support for city-wide mobility planning

3.4.3.8 Local Adaptability

The app is designed to comply with local, regional, and national laws in Bosnia and Herzegovina. It requires operational permits, aligns with environmental goals, and supports digital inclusion through accessibility features (e.g. WCAG compliance). The platform adheres to data sovereignty principles and can be localized in language, regulations, and integrations.

3.4.4 TECH-NS3 Server Computer for Monitoring

A server computer is a central system responsible for collecting, processing, and storing data from various monitoring devices within a smart mobility network. In the context of micromobility and non-motorized traffic, the server continuously receives real-time data from sensors (e.g., inductive loops) related to user counts, speed, direction, and time-based traffic patterns. It enables efficient data management, real-time monitoring, infrastructure planning, and quick response to system issues.

3.4.4.1 Usage and Target Users

This technology is primarily used by public sector institutions but is classified under private or mixed ownership models when hosted or managed by third-party providers. Key users include:

- Municipal traffic departments

- Urban and infrastructure planners

- Local governments and city IT services

- Traffic management centers

3.4.4.2 Infrastructure Requirements

- Traffic counters and sensor systems (e.g., inductive loops)

- Server hardware (local or cloud) with processing and storage capacity

- Internet connection via Wi-Fi, USB, or mobile networks for data transmission

- LED totems or dashboards for visualization (optional, public-facing layer)

3.4.4.3 Data Model

The server processes structured data collected in real time, including:

- Traffic metrics: vehicle counts, speed, movement direction, time-of-day distribution, and classification (e.g., bike, e-scooter)

- Sensor sources: primarily inductive loops and counters

- Transmission methods: Wi-Fi, USB, or SMS for real-time data transfer

The data is owned by the Municipality of Novo Sarajevo and made accessible to authorized users via analytical dashboards. Public visualizations may be made available through external displays (e.g. LED counters).

3.4.4.4 Integration and Interoperability

- Can be integrated with municipal traffic management systems and smart city platforms

- Supports JSON format for traffic data exchange

- Easily scalable to additional areas or other municipalities if connectivity and power are ensured

- Compatible with existing infrastructure through standard API protocols

3.4.4.5 Security and Privacy

- The system does not collect personal or biometric data (no PII)

- Built on principles of privacy-by-design and data minimization

- Cybersecurity threats include data spoofing or unauthorized access

- Uses Advanced Encryption Standard (AES) for secure communication

- Fully compliant with GDPR, CCPA, and local privacy laws in Bosnia and Herzegovina

3.4.4.6 Web GIS Compatibility

Although the server is not a GIS system in itself, it enables seamless data integration into GIS platforms and geoportals for:

- Visualizing traffic volume and patterns

- Supporting accessibility and infrastructure planning

- Enabling data-driven decision-making for public transport and mobility investments

3.4.4.7 Expected Impacts

- Supports real-time and long-term traffic analysis for micromobility planning

- Reduces CO_2 emissions by promoting non-motorized transport modes

- Informs the design and prioritization of infrastructure investments

- Strengthens local digital capacities and supports eco-tourism data analysis

- Cost-effective and scalable for multi-location monitoring

3.4.4.8 Local Adaptability

The server system meets all necessary legal and technical requirements in Bosnia and Herzegovina, including:

- IT infrastructure and traffic monitoring laws

- Public sector implementation permits and ICT certification

- Environmental standards for electronic equipment and energy use

- Data protection laws (aligned with GDPR principles)

- Integration capability with existing platforms used by local authorities and law enforcement

3.5 Municipality of Rethymno (Crete)

3.5.1 Territorial context

The Municipality of Rethymno, located on the northern coast of Crete, is the third-largest city on the island. With an area of 397.48 km² and a population of 57,216 (2021), the city combines a historic urban core with suburban and rural surroundings. Tourism is the main economic driver, with over 700,000 arrivals and 4 million overnight stays recorded in 2022. Rethymno is also home to a student population of approximately 12,000, adding to the city's dynamic mobility needs.

Based on 2022 data, the transport system is heavily car-dependent, with private vehicles accounting for 60% of trips. Public transport represents 15%, while walking (20%) and cycling (5%) complete the modal share. The city operates a bus-based public transport network but lacks rail-based systems. Despite moderate congestion levels, real-time traffic monitoring is enabled through 11 installed thermal cameras, which feed data into a central platform for traffic flow analysis. Rethymno experiences pronounced traffic peaks in the morning (8:00–10:00), early afternoon (13:30–15:30), and evening hours (18:00–21:30), reflecting a combination of commuting patterns, school schedules, and commercial activity.

Smart mobility infrastructure is comparatively advanced. The city has implemented a smart parking system with 600 sensors, a mobile app for users, and integrated tools for the municipal police. Additional platforms collect and analyses data from e-bike sharing, electric vehicle chargers, and PV carports. These tools support planning and monitoring across multiple mobility dimensions.

Challenges persist, particularly in the suburban and rural areas where public transport coverage is limited, contributing to "mobility poverty." Parking violations, gaps in public transport services, and the need for stronger enforcement were highlighted as key issues. While a SUMP is in place, funding limitations and behavioral barriers remain obstacles to full implementation. Nonetheless, Rethymno shows strong commitment to advancing ITS and user-centric mobility planning, supported by ongoing pilots and collaboration with private technology providers.

As part of the SMARTMOBAIR project, the pilot in Rethymno is aimed at **Smart parking stations for personal bikes**. The solution entails Parking, locking and charging system for bikes. It will serve personal bike commuters for short term parking, offering secure parking, modular design, and real-time availability checks through an app. In addition, the system will provide integrated e-bikes charging option, ensuring that users can park and charge their bikes simultaneously.

Core technologies to be applied include mobile app, NFC card reader, smart indicators with alarm system, Smart IoT integration, Cloud infrastructure/dedicated servers/granular access control and centralized hub designed to streamline access management, allowing operators to control and troubleshoot stations from anywhere.

Geospatial coverage of the pilot is concentrated in key traffic corridors and junctions in the city centre of Rethymno, where congestion is typically high during morning, afternoon, and evening peak hours.

Exemplar solution is Ülemiste City in Tallinn, Estonia[8]. It has smart parking stations for personal bikes with Bikeep's secure, tech-enabled bike parking infrastructure. This system combines physical security with digital

[8] https://youtu.be/pcNKJuD6MQ4

access and monitoring, promoting cycling by ensuring safe and convenient parking in a busy urban innovation district.

Expected benefits include access to valuable data, such as peak usage hours, areas with the highest demand, and locations where a network of bases within private businesses (e.g., supermarkets, shopping centers, gyms, cafés) should be developed. Rethymno will also receive real-time alerts. Through the application, the Municipality will be able to identify parts of the city that require additional locking bases and reallocate units from areas with lower demand. The pilot may also encourage local businesses to install locking bases at their own expense to meet customer needs.

3.5.2 TECH-RE1 Mobile App

The mobile app that is going to be implemented by the Municipality of Rethymno is a central digital access point for users of the city's smart bike parking infrastructure. Designed for use with smartphones, the app allows users to locate available docking stations, reserve a slot in advance, and lock or unlock their e-scooter or bicycle. It supports multiple active parking sessions and allows stations to be filtered by proximity or personal preference. The app enhances service accessibility and plays a key role in promoting the use of micromobility solutions within urban areas. Primary users include end users, urban planners, and city authorities. The app is used in mixes public and private contexts.

The Mobile App for the Municipality of Rethymno will serve as the central digital interface for users of the city's bicycle and e-scooter infrastructure. It will be tailored to the city's unique urban character and high seasonal tourism. The app will support multilingual functionality in Greek and English, with an accessible interface that will include features such as large-text modes and simplified navigation to accommodate diverse user needs.

It will provide real-time information on vehicle and docking station availability, allowing users to locate, reserve, and unlock shared vehicles through authentication methods such as QR code scanning (or contactless municipal cards, if wanted in the future to be applied). Integration with an NFC card system will allow for secure, alternative user identification—particularly useful for groups like students or residents participating in city programs.

All personal data will be processed in full compliance with GDPR, using encrypted communication protocols and built-in user consent management.

The app will connect directly to cloud infrastructure hosted on EU-based dedicated servers, ensuring secure and scalable data handling. In addition, it will be integrated with the centralized control hub, which will enable remote monitoring, maintenance coordination, and system diagnostics.

Smart infrastructure elements—such as tamper detection sensors—will provide real-time input to the app's backend, ensuring operational reliability. Anonymized usage data will be forwarded to the city's analytics platform, supporting planning decisions related to micromobility usage patterns and infrastructure development.

Overall, the app will enhance daily mobility while contributing to sustainable urban transport and data-driven municipal strategy.

3.5.2.1 Infrastructure Required

The operation of the mobile app depends on a combination of digital infrastructure and integrated hardware. The system requires:

- Internet connectivity (Wi-Fi or cellular)
- Smartphones with the installed application
- IoT-enabled docking stations with built-in sensors
- Backend cloud platform for data storage and processing

This infrastructure ensures continuous communication between user devices and the station network, allowing real-time updates and management.

3.5.2.2 Data Collection

The app enables real-time collection and monitoring of operational data from docking stations.

- **Types of data collected include:**
  - Dock usage frequency
  - Parking duration
  - Energy consumption
- **Sensors and data sources:**
  - Built-in sensors at the docking stations
  - Mobile app interface inputs
- **Collection method and frequency:**
  - Data will be collected in real time and transmitted via internet connection
- **Data management:**
  - The data will be owned by the Municipality of Rethymno
  - Users can access relevant data through the app
  - Data usage and sharing may be subject to licensing agreements.

This data supports both operational oversight and strategic planning.

3.5.2.3 Integration & Interoperability

The mobile app is designed to integrate with Rethymno's broader smart mobility infrastructure. It supports:

- REST API-based integration with city dashboards and third-party systems
- Compatibility with payment platforms and mobile services
- Interoperability with other components of the micromobility system (e.g., lock management, user access control)

The system does not support outdates platforms or legacy systems, ensuring security and future scalability.

Scalability is high, though integration challenges may arise, such as ensuring compatibility with existing municipal platforms and compliance with local data policies.

3.5.2.4 Security & Privacy Module

The app implements a comprehensive security and privacy framework aligned with EU data protection laws.

- **Key cyber risks addressed include:**
  - Unauthorized access to user accounts
  - Interception of payment data
  - Exploitation of user identity or geolocation data
- **Technical safeguards include:**
  - End-to-end encryption for data transmission
  - Secure cloud-based data storage
  - Strong authentication protocols
- **Personal data handling:**
  - Personally identifiable information (PII) is encrypted during transmission
  - Access to PII is strictly limited to authorized personnel
  - Users are informed of privacy policies via the app and website

The system is fully GDPR compliant and follows privacy-by-design principles.

3.5.2.5 Expected Impacts

The deployment of the mobile app is expected to lead to a measurable increase in micromobility usage in Rethymno by reducing access barriers and improving the reliability of smart parking services. The expected benefits include:

- Increased user satisfaction and convenience
- Reduction in CO_2 emissions through a modal shift
- Improved data-driven urban planning
- Higher efficiency in managing parking stations

Key evaluation indicators include:

- Usage rates of docking stations
- Bicycle turnover time
- Number of thefts or vandalism incidents prevented

3.5.3 TECH-RE2 NFC Card Reader

The NFC card reader system that is going to be implemented in Rethymno provides an alternative, contactless method of authentication for users accessing smart bike and e-scooter docks. Integrated directly into the station infrastructure, it enables users to unlock or lock a vehicle using NFC technology. Primary users of the system include end users, city authorities, and local managers. The solution is deployed in mixed-use environments (public and private access).

The NFC Card Reader will be installed directly on Rethymno's smart docking stations, offering users a secure and convenient contactless method to lock/unlock bikes and e-scooters. It will support local NFC card standards, operate reliably outdoors, and integrate with the municipality's micromobility management system. The system will comply with GDPR and data privacy policies and it will give the option to the Municipality of Rethymno, at any time, to provide cards as an alternative for users without smartphones.

3.5.3.1 Infrastructure Required

The NFC card reader system requires minimal but essential infrastructure for operation:

- NFC-compliant contactless devices
- Built-in NFC reader modules at docking stations
- A centralized management platform or back-end system
- Internet connectivity for real-time data communication

This infrastructure allows seamless integration with the existing micromobility management system and supports real-time user interaction.

3.5.3.2 Data Collection

Card-based access supports real-time tracking of user interactions.

- **Types of data collected:**
  - User ID (anonymized and linked to internal user accounts)
- **Sensors and sources:**
  - NFC reader at docking station
  - Back-end system
- **Transmission method:**
  - Local NFC communication, then forwarded to the central server
- **Data access and ownership:**
  - Data will be owned by the Municipality of Rethymno
  - Only authorized administrators will be able to access the collected information

All data handling complies with GDPR and local data policies.

3.5.3.3 Integration & Interoperability

The NFC system is integrated into the central management platform used for micromobility services.

- Supports integration with smart city platforms
- Operates in conjuction with existing software through standart protocols (where applicable)
- Requires NFC-compliant devices;no legacy system support

Scalability is straightforward, although integration may require:

- NFC card issuing infrastructure
- Compatibility with various card formats
- Coordination with municipal access control systems

3.5.3.4 Security & Privacy Module

The NFC card reader system is designed with strong privacy and cybersecurity safeguards.

- **Cyber risks addressed include:**
  - Unauthorized access attempts
  - Cloning of NFC cards
- **Technical safeguards:**
  - Encrypted card communication
  - User ID is anonymized and securely linked to user profiles
  - Minimal data collection (privacy by design)
- **Compliance:**
  - Fully compliant with GDPR
  - Privacy policies are available through the operator's platform

3.5.3.5 Expected Impacts

The system enhances overall accessibility and equity by providing a simple, alternative method of access for users without smartphones or who are less familiar with digital tools.

Expected benefits:

- Increased number of users due to inclusive design
- Greater convenience and flexibility
- Potential reduction of CO_2 emissions through increased micromobility use

Evaluation metrics:

- NFC usage frequency

- Number of failed access attempts

3.5.4 TECH-RE3 Smart Indicators with Alarm System

The Smart Indicators with Alarm System to be deployed in Rethymno are integrated visual and acoustic signaling devices embedded into micromobility docking stations. These indicators provide real-time feedback to users and emit warning signals in case of unauthorized actions such as tampering or improper use. By combining visual (lights) and acoustic (alarms) outputs, the system serves as both a guidance mechanism for users and a deterrent against theft and vandalism. Primary users include end users and city authorities. The solution is designed for mixed public and private use environments.

The Smart Indicators with Alarm System will be embedded in Rethymno's docking stations to provide immediate visual and acoustic alerts in case of tampering or unauthorized use. The system will be weather-resistant and suitable for outdoor installation, ensuring reliable operation in the local climate. It will be fully integrated with the city's central monitoring platform to enable real-time alerts and quick responses, enhancing security and user confidence.

3.5.4.1 Infrastructure Required

To operate effectively, the system requires:

- Docking stations equipped with integrated lights and sound systems
- Tamper sensors and trigger mechanisms
- Internet-connected control units for real-time communication
- A central management platform for event monitoring and system configuration

This infrastructure allows continuous monitoring and immediate alerting of unauthorized activity.

3.5.4.2 Data Collection

The system collects anonymized operational data to support safety monitoring and maintenance analysis.

Types of data collected:

- Tamper detection events
- Alarm activations
- Changes in docking status

Sensors and sources:

- Integrated tamper sensors
- Light/sound trigger systems
- Central backend logging tools

Collection method and frequency:

- Real-time data transmission through the station's internet connection

Data management:

- Data will be owned by the Municipality of Rethymno
- Alerts will be available to system operators; no personal data is collected or accessible by end users

3.5.4.3 Integration & Interoperability

The smart indicator system is integrated with Rethymno's micromobility management platform.

- Compatible with municipal dashboards and alert systems
- May require integration with city emergency or safety platforms
- No external API is provided specifically for this subsystem
- Requires modern docking infrastructure for compatibility

The system is scalable and adaptable across different sites as long as basic infrastructure requirements are met.

3.5.4.4 Security & Privacy Module

The system addresses key cyber risks and follows best practices in hardware and firmware protection.

Potential cyber threats include:

- Remote disabling of indicators
- Spoofing of alarm signals

Technical safeguards:

- Secure firmware and encrypted communication
- Tamper-proof housing design

Privacy compliance:

- The system does not collect personally identifiable information (PII)
- Fully compliant with privacy regulations
- Operates under privacy-by-design principles

User communication is exclusively non-verbal, delivered through lights and alarm sounds at the docking station.

3.5.4.5 Expected Impacts

The smart indicators are expected to significantly increase the security and attractiveness of micromobility services in Rethymno.

Expected benefits include:

- Theft and vandalism deterrence
- Higher confidence and usage of shared e-bikes and e-scooters

- Reduced CO_2 emissions and noise pollution due to increased active mode share

Evaluation metrics:

- Alarm activation frequency
- Number of reported incidents

3.5.5 TECH-RE4 Cloud Infrastructure with Dedicated Servers and Granular Access Control/Smart IoT Integration and Centralized Hub for Remote Access and Troubleshooting

For the Municipality of Rethymno, the backend technologies—Cloud Infrastructure with Dedicated Servers, Centralized Hub for Remote Access and Troubleshooting, and Smart IoT Integration—will be implemented as a single integrated system. The stations will be equipped with integrated IoT infrastructure that connects each hardware unit to a centralized cloud management platform, enabling real-time data collection, remote monitoring, device control, and diagnostics. This architecture supports centralized management through a secure cloud infrastructure—or optionally dedicated servers—allowing configuration and maintenance of the network while enforcing granular access controls for authorized personnel. Through a cloud-based centralized dashboard, operators can efficiently monitor, manage, and troubleshoot docking stations, enhancing operational transparency, system responsiveness, and the overall reliability of micromobility services.

More analytically, this solution enables centralized, secure management of micromobility docking infrastructure and user data via a cloud infrastructure or dedicated servers. It provides administrators with real-time monitoring, remote configuration, and maintenance capabilities, while implementing granular role-based access control to ensure that only authorized personnel can access sensitive data and functions.

The Smart IoT Integration solution to be deployed in Rethymno enables continuous remote monitoring, diagnostics, and control of micromobility docking infrastructure. Each station is equipped with IoT modules that connect to a centralized cloud management platform. This setup supports real-time data collection, infrastructure status checks, and immediate decision-making capabilities for operators.

The Centralized Hub enables operators to monitor, manage, and troubleshoot micromobility docking stations remotely through a secure, cloud-based dashboard. It provides centralized access control and real-time diagnostics, helping to minimize downtime, enhance system responsiveness, and improve overall operational transparency. Primary users include municipal IT departments, system administrators, and micromobility operators. The system is currently deployed in private-use contexts.

3.5.5.1 Infrastructure Required

To operate efficiently, the system requires:

- Reliable internet connectivity
- A secure cloud platform or dedicated server infrastructure
- Administrator interfaces for system configuration and access control

This setup allows centralized management of all docking stations and continuous access to operational and user data.

3.5.5.2 Data Collection

Enables real-time and scheduled data collection.

Types of data collected:

- User activity logs
- System performance metrics
- Error reports
- Maintenance records
- Access logs

Sources:

- Docking station hardware
- Server-side monitoring tools

Data transmission and management:

- Data will be transmitted securely via the station's internet connection
- Will be owned and managed by the Municipality of Rethymno
- Access to data is strictly governed by role-based policies

User data access is restricted and requires explicit authorization.

3.5.5.3 Integration & Interoperability

The system integrates with Rethymno's city dashboards and digital mobility platforms.

- Supports REST APIs (OAuth 2.0)
- Connects to central management platforms
- Not compatible with legacy systems that lack modern authentication mechanisms

Scalability:

Easily scalable across infrastructure and organizations. May require coordination with:

- Cloud service providers
- Internet providers

Integration challenges:

Complexity in access role configuration across multiple departments or stakeholders.

3.5.5.4 Security & Privacy Module

The infrastructure includes robust security features designed to protect sensitive data and ensure compliance with privacy standards.

Cyber risks addressed:

- Unauthorized access to user or system data
- Unauthorized configuration changes

Technical safeguards:

- Two-factor authentication for administrative access
- Encrypted data transmission
- Role-based access control policies

Privacy compliance:

- Fully compliant with GDPR
- Follows privacy-by-design principles
- Personally identifiable information (PII) access is restricted and requires authorization
- Privacy policies will be available through the official municipal platform.

3.5.5.5 Expected Impacts

Expected benefits:

- Improved control and oversight of infrastructure
- Increased system uptime and reliability
- Cost savings through efficient diagnostics and remote configuration

Sustainability:

- Contributes to CO_2 reduction through better system management and less manual intervention

Evaluation metrics:

- Uptime percentage
- System error rates
- Data latency
- Frequency and outcomes of access policy audits

3.6 The Municipality of Shkodra (Albania)

3.6.1 Territorial context

The Municipality of Shkodra, located in northern Albania, spans 872 km² and includes both urban and rural zones. It serves as a regional center with relatively developed infrastructure, including schools, hospitals, and local markets. The city of Shkodra itself hosts over 116,000 inhabitants, with the broader municipality reaching 213,000.

The modal split reflects a high reliance on active modes, with walking (35%) and cycling (23%) comprising the majority of trips. Private vehicles account for around 40%, while public transport use remains limited at only 2%. Traffic congestion is generally moderate, with peak hours occurring between 07:00–09:00 and 12:00–16:30, particularly during school and tourist seasons.

Urban mobility challenges include poor public transport coverage in peripheral areas, a lack of infrastructure for cyclists and pedestrians, and behavioral issues such as disregard for road signage. These factors collectively limit the efficiency and safety of the local transport system.

Public transport is available via bus and taxi, but the service lacks integration and real-time monitoring. Data collection is fragmented: public transport use is monitored daily, e-scooter trends monthly, but no pedestrian counts or traffic flow data are available. Most data are collected manually and are not publicly accessible. The city does not currently have a Sustainable Urban Mobility Plan (SUMP), though planning efforts are underway.

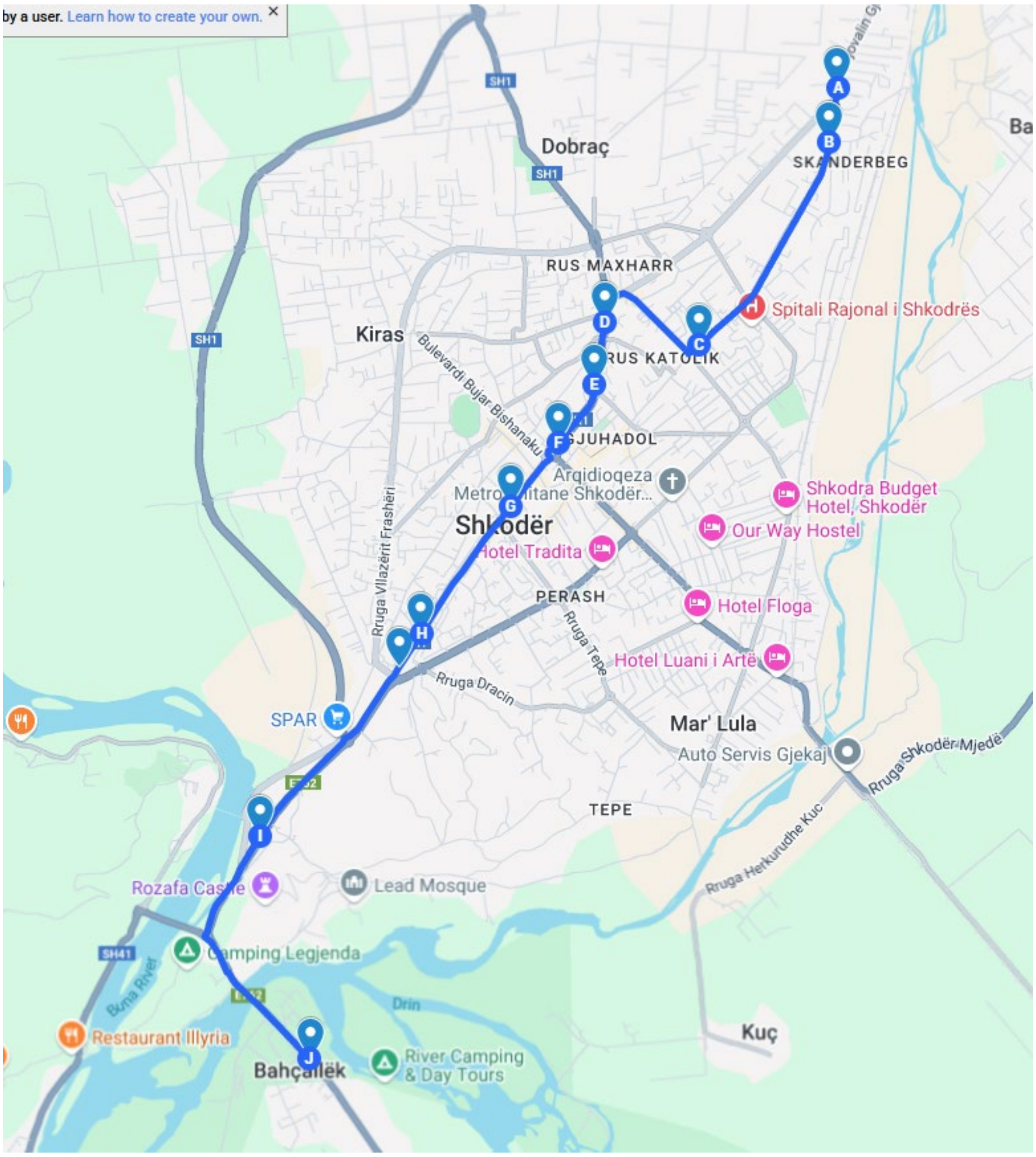
As part of the SMARTMOBAIR project, the pilot in Shkodra focuses on enhancing the management of urban mobility flows by implementing a modular traffic data monitoring system, namely Bus transport GPS tracking and Passenger Counting. The goal is to collect and analyze key mobility data—particularly related to traffic volume, direction, and vehicle classification—to support evidence-based planning and reduce urban congestion. Currently, the public bus system in Shkodra lacks digital tools for tracking, monitoring, and passenger engagement. There are no real-time information systems or digital ticketing platforms. This pilot will introduce and apply GPS and passenger data technologies for the first time in this context.

Core technologies to be applied are **GPS Tracking and Passenger Counting Systems.**

Geospatial coverage of the pilot will include selected access routes and arterial roads leading into and out of the city of Shkodra. The selected route for implementation is **Line Bahçallëk–Fermentim**, a public urban transport line operated by a private company within the framework of the municipal bus transport system. The route includes 11 bus stops. A visual representation of the route and its stations is provided below.

Figure 3.2 Line-Bahcallek - Fermentim, urban bus Shkoder City

Source: SMARTMOBAIR



Athens (Greece) is selected as exemplar city. Athens has implemented an advanced real-time public transport information system, offering live bus tracking.[9] While Athens serves as a strong reference for ITS development, pilot in Shkodra focuses on a more foundational application: introducing GPS tracking and passenger counting technologies.

Expected benefits include Improved efficiency and reliability of public bus services; Better planning through real-time operational data; Enhanced passenger satisfaction; Data-driven long-term transport planning and Foundation for broader ITS adoption in Albania.

[9] https://citysightseeing.gr/en/athens-line-live-tracking

3.6.2 TECH-SHK1: GPS Vehicle Tracking System

The GPS Vehicle Tracking System is a foundational Intelligent Transport System (ITS) solution designed to improve the reliability, transparency, and efficiency of urban transport services in Shkodra. In the current setup, buses on the Bahçallëk–Fermentim line—operated by a private company—do not have digital tools for real-time monitoring or performance tracking.

As part of the SMARTMOBAIR pilot, GPS devices will be installed on these buses. The collected data will be shared with the Municipality of Shkodra through a centralized digital platform. This setup enables two levels of benefit: (1) **operational improvements** such as real-time location tracking, timetable compliance monitoring, and incident detection, and (2) **strategic benefits** such as performance analytics, reporting, and data-driven decision-making for urban mobility planning.

In the long term, this system will serve as a critical building block for a more integrated, citizen-oriented public transport system, supporting both the operator and the municipality in delivering higher-quality services.

3.6.2.1 Core Functionalities:

- Real-time tracking of bus locations and service compliance
- Incident detection and deviation alerts from planned routes
- Data collection to support service analytics, reporting, and informational services for end users

3.6.2.2 Infrastructure requirements:

- GPS devices with 4G/5G connectivity installed on each bus
- Centralized digital platform for fleet monitoring and control
- Server or cloud-based database for storage and analysis
- Integration with information panels or applications for citizens.

3.6.2.3 Data Collection

The GPS Vehicle Tracking System will collect real-time geolocation data from the buses operating on the Bahçallëk–Fermentim line. This includes key operational indicators such as vehicle position, speed, route adherence, and timing. The data is transmitted via mobile networks (4G/5G) to a centralized digital platform managed in coordination with the Municipality of Shkodra.

Key data fields collected include:

- Timestamp – time of data capture
- Bus ID – unique identifier for each vehicle
- Latitude & Longitude – real-time GPS coordinates
- Speed – current speed of the bus
- Direction – movement heading (e.g. northbound)
- Route ID / Line number – identifier for the assigned bus line
- Stop Arrival/Departure Time – time of arrival at or departure from stops
- Deviation Flags – indicators for delays, skipped stops, or route changes

The system generates a historical record of vehicle movement, enabling performance analysis and identification of service gaps. This data supports both day-to-day monitoring (e.g., delays, incidents, fleet positioning) and long-term planning (e.g., route optimization, scheduling improvements, and policy evaluation).

To comply with Albania's data protection framework, the pilot will require clear definition of roles and responsibilities related to data ownership, usage rights, access controls, and retention periods as part of future agreements with involved stakeholders. While the data collected is not personally identifiable, it must still be handled securely and in line with national legislation.

3.6.2.4 System Integration & Interoperability

The GPS Vehicle Tracking System will operate through a centralized digital platform that collects and displays real-time data from buses on the selected line. In its initial phase, the system is expected to function as a standalone solution used by the transport operator and shared with the municipality for monitoring and analysis.

While full integration with other systems is not planned during the pilot stage, the platform should maintain basic compatibility with commonly used data formats (e.g., JSON, CSV, XML) and allow for API-based access to essential datasets (e.g., location, performance metrics). This ensures a baseline level of interoperability, enabling potential future connections with:

- Public transport dashboards
- Mobility planning tools
- Digital information services for passengers

If real-time passenger displays or public transport apps are introduced at a later stage, the system should be able to support real-time data feeds (e.g., GTFS-RT or equivalent). The platform's architecture should remain modular enough to support gradual enhancements based on future needs and available resources.

3.6.2.5 Security & Privacy Module

Although the GPS Vehicle Tracking System does not collect personally identifiable information (PII), it generates sensitive operational data, including vehicle locations, service patterns, and historical movement records. This data must be protected against unauthorized access, tampering, or unintended disclosure.

The system will implement essential security measures to ensure safe data handling. These include:

- User authentication and role-based access controls to limit data access to authorized personnel
- Secure data transmission protocols (e.g., HTTPS or VPN) to protect information during transfer
- Basic encryption or protection mechanisms for stored data

Data may be hosted on a cloud platform or a local server, depending on the chosen system architecture. In both cases, compliance with Albania's legal framework on data protection is required. While the system does not process personal data, it will follow key principles such as data minimization, access restriction, and accountability.

Responsibilities for data storage, access, and use will be formally established in future agreements between the Municipality and the transport operator.

3.6.3 TECH-SHK2: Automatic Passenger Counting (APC) System

The Automatic Passenger Counting (APC) system is intended to provide accurate, real-time data on passenger flow for the selected urban transport line. By automatically registering the number of passengers boarding and alighting at each stop, the system supports more efficient service monitoring and planning.

Passenger load information is essential for understanding ridership trends, identifying peak hours, and informing decisions on scheduling and resource allocation. This data will also complement the GPS tracking system, enabling combined analysis of movement and usage patterns along the route. The specific sensor technology (e.g., infrared, 3D, or AI-based) will be selected in the future based on availability, compatibility, and compliance with relevant data protection requirements.

3.6.3.1 Core Functionalities:

- Counting passenger entries and exits at bus doors
- Measuring ridership by line, time, and direction
- Analyzing peak hours, load factors, and frequency needs
- Supporting operational optimization and planning

3.6.3.2 Infrastructure requirements:

The APC system will consist of essential components installed on buses operating along the selected line. These include:

- Sensors on bus doors (infrared, 3D or AI cameras)
- Data processing unit and modem for transmission
- Platform for visualization, analysis, and reporting
- Integration with GPS for advanced analysis

3.6.3.3 Data Collection

The Automatic Passenger Counting system will collect real-time data on the number of passengers boarding and alighting at each stop along the selected line. The data will be anonymized and aggregated, providing valuable insights into ridership patterns without identifying individuals.

Key data fields may include:

- Timestamp – time of passenger entry or exit
- Vehicle ID – identifier for the bus
- Stop ID – location of boarding or alighting
- Direction of travel – outbound or inbound
- Boarding and alighting count – number of passengers per door, per stop

This data will support operational analysis, capacity planning, and optimization of service frequency. Data will be transmitted to a central platform through onboard processing units and must be stored and managed in compliance with Albania’s data protection regulations.

3.6.3.4 System Integration & Interoperability

The APC system should function independently but must remain compatible with the GPS tracking platform used in the pilot. Integration will enable combined analysis of passenger movement and vehicle performance on the selected line.

The system should support common data formats such as CSV, JSON, XML, or Excel-compatible formats (.xlsx), and allow for API-based access if required. This ensures potential future integration with digital dashboards, planning tools, or other ITS components.

While full integration is not a requirement for the pilot phase, technical compatibility should be ensured for possible future scaling or connection with other urban mobility systems.

3.6.3.5 Security & Privacy Module

Although the APC system does not collect personal data, it generates sensitive operational insights related to passenger volumes, service demand, and movement trends. This information must be protected against unauthorized access or misuse.

The system must implement:

- User authentication and access control to limit who can view and manage the data
- Secure data transmission protocols to protect data while in transit
- Basic protections for stored data, whether cloud-based or local

All data collection and processing must comply with Albania's legal framework on data protection. Ownership, access rights, and data retention responsibilities will be clarified through future agreements between the municipality and the service provider.

4 Concluding remarks

The report presents technical specifications of selected technologies to be applied, improved or scaled up in partner territories. The selection of adoptable smart mobility technologies to be included was based on the inputs gathered from the six SMARTMOBAIR pilot territories and aligned with the specific technologies envisaged for implementation in their respective pilot actions.

All of the selected technologies are in a mature stage of their development and are widely used in other urban and suburban areas. However, implementing such technologies in real mobility systems requires certain adjustments due to local specifics and different levels of maturity of the existing mobility system in the implementation area. Therefore, the deliverable highlights the main technical characteristics of potentially adoptable technologies in terms of main functionalities, equipment needed, data collection activities and standards, integration and interoperability, security and privacy, with the aim of supporting pilot territories in the pilot implementation process.

After a detailed analysis of the summarised information in all aspects provided in the Factsheets (D1.4.2), the members of the working group for each pilot site have identified the need for adjustment, and these are presented in this report. Anticipated areas of customisation are: National and Local laws; Licensing and Permits; Accessibility and inclusiveness Standards; Environmental Standards; Data Collection; Integration and interoperability; and Security and privacy.

The technical specifications will help pilot sites to implement the selected smart mobility technologies with the capacity to remove the mobility problem identified in pilot territories and customise them to tackle identified challenges. All technologies are connected to existing mobility and transportation goals at the same time, responding to environmental, social and economic goals, and thus might impact long-term plans for smart mobility deployment.

The outputs of this report will be an input for a realistic, smooth and efficient solution procurement phase, carried out in the activity A. 2.2. Procurement, implementation and monitoring of SMARTMOBAIR pilot actions.