SMARTMOBAIR project

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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
D.1.4.2	***Factsheets on adoptable smart mobility technologies***	YES	YES	YES	YES	YES	B. Monaco (AREA)

Table of Contents

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

List of Tables

List of Figures

Executive Summary

This report presents the Factsheets on adoptable smart mobility technologies planned within pilot implementation on six pilot territories included in the SMARTMOBAIR project. The report is build parallel with D.1.4.1. Technology gap assessment upon earlier project deliverables and preparatory activities, the report consolidates prior insights and introduces a dedicated assessment framework. The selection of the adoptable technology Factsheets are 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

The report highlights the main characteristics of potentially adoptable technologies in terms of product application, data collection, integration and interoperability, security and privacy, expected impacts.

The development of each smart mobility technology factsheet follows a structured and consistent methodology designed to ensure clarity, comparability, and practical relevance. The approach is grounded in a five-category analytical framework, with six guiding questions defined for each category. These questions support a systematic exploration of each technology's characteristics, functionality, and implications, allowing for in-depth yet accessible insights.

Each category is addressed through direct answers to its six guiding questions, providing a consistent and repeatable structure across factsheets. This method not only ensures a comprehensive understanding of each technology but also enables comparisons between different solutions.

Once drafted, each factsheet undergoes internal review and quality assurance to achieve the highest possible level of uniformity.

A clear understanding of the target audience—such as urban planners, transport authorities, or policymakers—informs the level of detail and type of language used in the final factsheet.

The findings of this report will together with *D.1.4.1. Technology gap assessment* will provide a strategic foundation for the preparation of *Technology Roadmaps* in the next stages of the SMARTMOBAIR project. Outcomes of this deliverable will serv on the one had in the process at selecting and tailoring the identified solution to peculiarities of pilot territories and, on the other one, it will ensures the standardization of pilot implementation and their comparability.

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.

The report is structured into four main chapters. Following the introduction, the second chapter presents the methodological framework for the development of smart mobility technology factsheet. At the center are the Factsheets on adoptable smart mobility technologies. This chapter provides in-depth insights into each technology's characteristics. The chapter is divided into four sections for defined categories. 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 factsheet follows a structured and consistent methodology designed to ensure clarity, comparability, and practical relevance.

The methodology was developed through two interconnected phases. The first phase involved defining a suitable approach to identify all necessary areas and information that the future Factsheet needs to contain. The second phase translated this conceptual framework into a practical template to be filed by the project's pilot territories.

The proposed approach was introduced to project partners at a Steering Group meeting, where the methodology and key steps were discussed and endorsed. A draft version of the Word-based template was subsequently shared with all Technical Partners (TPs).

To support the implementation of the methodology, a dedicated presentation was prepared and shared with partners as a practical guide for data collection. The process itself was carried out by the Technical Partners (TPs) in collaboration with their respective Institutional Partners (IIPs, representing pilot territories) and supported by the Stakeholder Working Groups (SWGs) in each pilot territory.

The table below summarizes the key steps in the methodology development and implementation:

Table 2.1 Timeline of Methodology Development for the Technology Gap Assessment
Source: The Authors

STEP	DATE
Preparation of the methodology	March-April 2025
Conceptual approach presented	8th May 2025
Template and supporting material shared	12th May 2025
Data collection end	26th May 2005
Draft Report shared with PPs for review	16th June 2025

The approach is grounded in a five-category analytical framework, with six guiding questions defined for each category. These questions support a systematic exploration of each technology's characteristics, functionality, and implications, allowing for in-depth yet accessible insights.

The process begins with the selection and scoping of the technology to be profiled. Technologies have already been chosen within Activity 1.4. Assessment of technology gaps in pilot territories based on their relevance to the planned pilot.

Once a technology is selected, desk research is conducted to gather information, besides the technology name and description, 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 research process is guided by a predefined set of six questions under each of the five analytical categories: Product Application, Data Collection, Integration and Interoperability, Security and Privacy, and Expected Impacts.

The factsheet template is presented in Figure 2.1.

Factsheets for core pilot relevant technologies mapped within data collection for the technology gap assessment (D.1.4.1.). Factsheets for each of the foreseen smart technologies were then structured around these categories.

Figure 2.1 Factsheet template

Source: Authors

Technology Name:		
Description:		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
[What is the core function of the technology?]	[What mobility challenges does it aim to solve (e.g., congestion, accessibility, emissions)?]	[In what settings is it typically deployed (e.g., intersections, transit systems, on-demand services)?]
Infrastructure required?	Primary users?	Public/private/mixed use?
[What infrastructure is required for deployment?]	[Who are the primary users (e.g., city planners, commuters, logistics operators)?]	[Is it intended for public, private, or mixed use?]
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
[What types of data does the technology collect (e.g., location, usage, environmental)?]	[What sensors or data sources are used?]	[How frequently is the data collected (e.g., real-time, batch)]
Data ownership?	Transmission method?	User data access?
[Who owns the collected data (e.g., city, private vendor, users)?]	[What methods are used for data transmission (e.g., Wi-Fi, cellular, V2X)?]	[Are there mechanisms for users to control or access their data?]
Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
[Which systems or services must it integrate with (e.g., public transport, traffic control, payment platforms)?]	[What APIs or data standards does it support (e.g., GTFS, DATEX II, NTCIP)?]	[Can it work with legacy infrastructure or systems?]
Scalability?	Third-party needs?	Integration challenges?
[How scalable is the solution across different cities or regions?]	[Are third-party partnerships required for full functionality?]	[What challenges or limitations exist in integrating this technology?]
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
[What are the key cybersecurity risks (e.g., unauthorized access, data breaches)?]	[What technical safeguards are in place (e.g., encryption, firewalls, intrusion detection)?]	[Does the technology comply with legal/privacy frameworks (e.g., GDPR, CCPA)?]
Handling PII?	Privacy by design?	User communication?
[How is personally identifiable information (PII) managed?]	[Is privacy by design implemented in the system architecture?]	[How are users informed about privacy policies and data use?]
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
[What are the expected short-term and long-term benefits (quantitative or qualitative)?]	[How does it contribute to sustainability goals (e.g., reducing CO_2 emissions, fuel use)?]	[What are the economic impacts (e.g., cost savings, job creation)?]
Accessibility/equity?	Unintended effects?	Evaluation metrics?
[Does it improve accessibility or equity in mobility?]	[What potential risks or unintended consequences could emerge?]	[What metrics or KPIs should be used to evaluate its success?]

In the **Product Application** section, the factsheet explores the core function of the technology, the contexts in which it is used, the stakeholders involved, its components, maturity, and deployment models.

The **Data Collection** section examines the types of data gathered, the mechanisms and entities involved in data acquisition, and the frequency, format, and transparency of the process.

In the **Integration and Interoperability** category, the analysis focuses on how well the technology interacts with other systems, the use of standards and APIs, the support for legacy infrastructure, and the barriers that hinder seamless integration. The Security and Privacy section evaluates the protective measures in place, the handling of personal data, compliance with legal frameworks such as GDPR, and the broader ethical or risk considerations.

Finally, the **Expected Impacts** section assesses the potential outcomes of the technology, including improvements in mobility efficiency, safety, environmental performance, accessibility, economic effects, and any unintended consequences.

Each category is addressed through direct answers to its six guiding questions, providing a consistent and repeatable structure across factsheets. This method not only ensures a comprehensive understanding of each technology but also enables comparisons between different solutions.

Once drafted, each factsheet undergoes internal review and quality assurance. This includes verifying claims against sources, ensuring all six questions are meaningfully addressed, and reviewing the content for clarity and neutrality. Where possible, external and internal experts were consulted to validate the findings and to ensure the highest possible level of uniformity.

The final factsheets are formatted to be visually clean and easy to navigate, typically limited to 1–2 pages to encourage readability. They are intended to serve as **living documents and are therefore subject to periodic updates as technologies evolve, new standards are introduced, or deployment experiences grow**.

This methodology ensures that each factsheet provides a reliable, structured, and insightful overview of the smart mobility technologies shaping the future of transport systems.

3 Factsheets on adoptable smart mobility technologies

This section presents the Factsheets developed in line with the methodology outlined in Section 2. A total of 18 Factsheets were created. For ease of reference, they are grouped into four categories:

1. Public transport
2. Micromobility
3. Urban mobility management
4. Smart Mobility Infrastructure & Integration (horizontal domain)

Table 3.1 includes the domain, corresponding Factsheets, and the number of entries per category (in brackets), along with the overall total.

Table 3.1 Overview of Factsheets by Category

Category/Domain	**Associated Factsheets** (18)
Public Transport (6)	GPS vehicle tracking
	Accessible UI/UX designed real-time information platforms (Smart bus stops)
	Trip booking and payment customer's APP
	Bookings managing software and trip planning software
	Driver Communication On-Board Equipment
	Infrared Passenger Counting System (IR-PCS)
Micromobility (4)	Micromobility System Mobile App
	Traffic volume and speed measurement devices
	Shared mobility vehicles (e-bikes and e-scooters)
Urban mobility management (2)	GIS Public Transport Cadastre
	Geofancing and restricted access control
Smart mobility infrastructure and integration (6)	GPRS data exchange/API management platforms
	Mobile data collection
	Cloud infrastructure and dedicated servers
	NFC card
	Smart Indicators with Alarm System
	Smart IoT integration

NOTE: The selection of the adoptable technology Factsheets is 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

In the following subsections (Sections 3.1–3.4), each category and its associated Factsheets are presented in detail.

3.1 Public transport related Factsheets

This section outlines adoptable smart technologies in the field of public transport. A total of six technologies have been identified and are described in the accompanying factsheets.

Table 3.2 GPS vehicle tracking

Technology Name:		
GPS vehicle tracking		
Description:		
GPS (Global Positioning System) vehicle tracking is a technology that uses satellite-based navigation to determine and monitor the real-time location of vehicles. By installing GPS tracking devices in vehicles, fleet operators, businesses, and individuals can collect data on vehicle position, speed, route history, and idle time. These devices communicate location data to a central system via cellular or satellite networks, allowing users to view and analyze vehicle activity through a web or mobile application. GPS tracking enhances fleet management by improving route efficiency, monitoring driver behavior, reducing fuel consumption, and increasing vehicle security. It also supports geofencing capabilities, alerting users when a vehicle enters or exits predefined areas. In many cases, this technology integrates with other systems such as dispatch software, telematics platforms, and maintenance tracking tools.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
GPS vehicle tracking systems monitor the real-time location, movement, and operational status of vehicles using satellite-based positioning	Improves fleet efficiency and punctuality Reduces congestion through route optimization	Commercial and public transport fleets On-demand mobility services (e.g., taxis, delivery vehicles) Service vehicles (e.g., waste collection, emergency response
Infrastructure required?	Primary users?	Public/private/mixed use?
GPS-enabled hardware (in-vehicle trackers) Cellular or satellite communication network Centralized platform/dashboard for fleet management and analytics Optional: integration with vehicle diagnostics systems (OBD-II ports)	Fleet operators and managers Public transport agencies City public transport departments	Mixed use — both public and private
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Geolocation (latitude, longitude) Speed, time Vehicle status (start/stop, driving)	GPS receivers Cellular network connections Vehicle telematics systems (via OBD-II or CAN bus)	Real-time (as often as every 1–10 seconds) Adjustable intervals depending on system configuration
Data ownership?	Transmission method?	User data access?
Typically owned by the fleet operator or service provider In public deployments, data may be co-owned or shared with city authorities	Primarily cellular (3G/4G/5G) Satellite (for remote/off-grid areas) Wi-Fi (occasionally, for data offloading)	User dashboards for data visibility Opt-in policies for employee tracking in some jurisdictions

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Public transport management systems Traffic management platforms Smart mobility dashboards Third-party apps (e.g., route optimization)	RESTful APIs (most common) Some providers support integration with GTFS-RT for real-time transit info	Can be retrofitted into older vehicles using OBD-II or hardwired devices Compatibility may vary based on vehicle make/model
Scalability?	**Third-party needs?**	**Integration challenges?**
Highly scalable — suitable for deployment from small fleets to national-scale	Often necessary for mapping services (e.g., Google Maps, HERE) Optional partnerships with analytics, insurance, or mobility-as-a-service providers	Lack of standardization across vendors Connectivity issues in low-signal areas
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Unauthorized tracking or location spoofing Data interception or breaches during transmission Insider threats or misuse of sensitive data	End-to-end encryption (e.g., SSL/TLS) Role-based access control Regular firmware updates and patching	Most commercial platforms align with GDPR, CCPA, and local privacy laws Employment tracking subject to labor regulations in many countries
Handling PII?	**Privacy by design?**	**User communication?**
Pseudonymization and anonymization for stored data Access logging and audit trails Strict data retention policies	Includes consent management and minimal data collection principles	Privacy policies available through mobile apps and web portals Some platforms include clear terms of use and tracking notifications
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Better fleet visibility and dispatch accuracy Data-driven planning Improved punctuality, efficiency and customer satisfaction	Reduces emissions by minimizing unnecessary travel and idling Enables eco-routing and fleet right-sizing	Cost savings in fleet operations
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Enables real-time tracking for public transport users Improves service reliability in underserved areas when integrated with demand-responsive transit	Over-surveillance and employee privacy concerns Dependence on vendor platforms (lock-in risk) Environmental cost of hardware manufacturing and e-waste	On-time performance Fleet utilization rate

Table 3.3 Accessible UI/UX designed real-time information platforms (Smart bus stops)

Technology Name:		
Accessible UI/UX designed real-time information platforms (Smart bus stops)		
Description:		
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, and multimodal connections. They are designed with high-contrast visuals, readable fonts, tactile or auditory feedback, language options, and user-friendly layouts.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Provide users with dynamic, up-to-date information with a user-friendly interface. These platforms focus on delivering critical information related to mobility, transportation, services, or urban events in an accessible, intuitive manner.	Accessibility for all user groups Public transport uncertainty and information gaps Passenger confidence and system usability	Smart bus stops Transport hubs and transfer points Public kiosks and digital signage in urban environments
Infrastructure required?	Primary users?	Public/private/mixed use?
Power and connectivity (e.g., electricity, 4G/5G/Wi-Fi) Digital display units (e.g., e-ink screens, LCD panels) Optional: speakers, haptic interfaces, and voice control modules	Commuters and public transport riders (including persons with disabilities) Transit agencies and city planners (for deployment and oversight)	Primarily public use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Public transport schedule and vehicle location data Interaction data (e.g., button presses, language choices) Optional usage analytics (e.g., dwell time at the interface)	GPS feeds from buses Transit control center APIs Built-in sensors in smart displays	Real-time or near real-time
Data ownership?	Transmission method?	User data access?
Typically owned by the transit authority Interaction data may be managed by the platform vendor	Cellular (4G/5G) Wi-Fi Wired Ethernet	Generally not applicable, as PII is not required Where data is collected, platforms may include opt-out or privacy info notices

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Public transport management systems Vehicle tracking platforms Multimodal trip planners and mapping services	GTFS and GTFS-realtime SIRI (Service Interface for Real-time Information) Optional: OpenAPI or custom APIs for integration	Can be adapted to legacy systems if data is standardized or made accessible through middleware
Scalability?	Third-party needs?	Integration challenges?
Highly scalable Suitable for city-wide deployment across different lines and geographies	Often required for hardware supply, installation, software development, or data services	Variability in data quality from legacy systems Lack of real-time data availability in smaller transport systems Accessibility feature implementation may vary by vendor
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to the backend system or device firmware Tampering with public-facing displays	Encrypted data transmission (HTTPS, VPN) Role-based access control for administrative interfaces Firewalls and remote monitoring of smart stop systems	Systems designed to comply with GDPR, ADA, and national accessibility laws Minimal personal data collection reduces regulatory risk
Handling PII?	Privacy by design?	User communication?
PII is typically not collected	Yes — interfaces are designed to function without user registration or tracking	Privacy and accessibility notices may be displayed on-screen or accessible via QR codes or linked mobile apps
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Improved passenger experience and public transport real-time visibility Greater ridership, reduced inequality in access, increased system trust	Encourages use of public transport, indirectly reducing car dependence and emissions	Operational savings through reduced customer service demand Supports smart infrastructure development and accessibility-focused tech sectors
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Directly improves access to transport service for people with disabilities, older adults, and digitally excluded groups	Potential overreliance on digital platforms by transit agencies Maintenance costs or vandalism in public areas Digital exclusion where infrastructure is lacking (e.g., rural areas)	User engagement and feedback Increase in on-time boarding or reduced wait-time uncertainty Accessibility feature usage rates Reduction in customer complaints or inquiries

Table 3.4 Trip booking and payment customer's APP

<table>
<tr><th colspan="3">Technology Name:</th></tr>
<tr><td colspan="3">Trip booking and payment customer's APP</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">The app allows the user who intends to use the on-demand transport service to book one or more trips and pay for them via the app or via electronic payment systems (credit card, PayPal, etc.). The booking can be made days in advance. Given the nature of the service under study, which is developed in an extra-urban context, the possibility of allowing the booking of the trip even a few minutes before boarding is being evaluated. The application allows the user to enter the origin and destination addresses of the desired trip as well as the departure times. The software can propose the actual times of the trip and keep the user updated on the arrival times and significant changes to the service. The possibility of having the user make the payment when booking the ride or when using the service is being evaluated.</td></tr>
<tr><th colspan="3">Technology Application</th></tr>
<tr><td>Core function?</td><td>Mobility challenges?</td><td>Deployment setting?</td></tr>
<tr><td>The app allows users to plan trips, book tickets, and make payments for public transport (buses, trains, metro, etc.) through a unified digital interface.</td><td>Reduces friction in multimodal travel
Enhances accessibility and convenience
Decreases reliance on private vehicles
Can reduce congestion and emissions by encouraging public transport use</td><td>Urban and suburban public transport networks
Integrated with mobility hubs, park-and-ride facilities, and multimodal transit corridors</td></tr>
<tr><td>Infrastructure required?</td><td>Primary users?</td><td>Public/private/mixed use?</td></tr>
<tr><td>Backend integration with transport operators' ticketing and scheduling systems
Mobile app development (iOS/Android)
Secure payment gateway infrastructure
Real-time data feeds (e.g., vehicle locations, schedules)</td><td>All local public transport users.
Tourists and occasional riders
City planners and transit agencies (as administrators)</td><td>Primarily public use, but with potential mixed applications (e.g., partnerships with ride-hailing services or mobility-as-a-service (MaaS) platforms)</td></tr>
<tr><th colspan="3">Data Collection</th></tr>
<tr><td>Types of data?</td><td>Sensors/sources?</td><td>Collection frequency?</td></tr>
<tr><td>Location (for trip planning and nearby service info)
Trip history and preferences
Payment details
Device identifiers
Transit usage data (e.g., boarding times, routes taken)</td><td>GPS (via mobile device)
APIs from transport providers (schedules, real-time vehicle locations)
Payment system logs
App usage analytics</td><td>Real-time (location, trip planning, ticket validation)
Periodic or batch (usage analytics, reporting)</td></tr>
<tr><td>Data ownership?</td><td>Transmission method?</td><td>User data access?</td></tr>
<tr><td>Typically shared or jointly managed by transit agencies and app developers/platform providers.
Varies based on public-private agreements</td><td>Cellular networks (4G/5G)
Wi-Fi (optional)
Encrypted APIs (for backend integration)</td><td>In-app privacy settings
Consent-based data collection
GDPR-compliant data access and deletion options (in Europe and similar jurisdictions)</td></tr>
</table>

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Public transport systems (ticketing, vehicle tracking) Payment processors and banks Journey planning systems Other mobility services (e.g., bike-share, ride-hail) for multimodal options	GTFS/GTFS-RT (General Transit Feed Specification) SIRI or DATEX II (in Europe) for real-time data EMV for contactless payment integration Mobile payment APIs (Apple Pay, Google Pay)	It often includes middleware or APIs to connect with older ticketing and scheduling systems.
Scalability?	**Third-party needs?**	**Integration challenges?**
High — adaptable across cities and regions with similar transit APIs and data standards	Often essential (e.g., with fintech providers, call centres, transport agencies, MaaS platforms)	Data standard inconsistencies Varying levels of digital maturity among transport providers Negotiation over data sharing and revenue models
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Data breaches of payment or personal information Unauthorized access to transit accounts Service disruption via DDoS or software vulnerabilities	End-to-end encryption for data transmission Secure authentication (2FA, biometric logins) Firewalls, access control systems, intrusion detection tools	GDPR (EU), CCPA (California), or other local frameworks Privacy policies aligned with transport agency and app provider responsibilities
Handling PII?	**Privacy by design?**	**User communication?**
Minimal retention policies Data anonymization for analytics Encrypted storage of sensitive data (e.g., card details)	Increasingly adopted, especially in public-sector-led deployments Transparent user consent and privacy dashboards	In-app privacy notices User agreements and permissions are presented at installation and update points
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Improved rider satisfaction and convenience Increased public transport ridership, better multimodal integration, operational cost savings	Modal shift from private cars to public transport Reduced CO_2 emissions and fuel usage Better demand forecasting supports efficient fleet management	Boosts to the local economy from improved mobility access Reduced fare collection costs Potential job creation in tech and operations support
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Can improve access for underserved populations (if inclusive design and payment options are supported) Potential barriers if smartphones or bank accounts are required	Digital divide (e.g., seniors or unbanked populations left out) Data misuse or surveillance concerns System outages affecting access to transit	App adoption and retention rates Increase in multimodal/public transport use Ticket sales and revenue growth Reduction in cash-based transactions Customer satisfaction scores

Table 3.5 Bookings managing software and trip planning software

<table>
<tr><th colspan="3">Technology Name:</th></tr>
<tr><td colspan="3">Bookings managing software and trip planning software</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">The application allows the user or customer to plan the desired trip using the addresses and times of origin and destination of the trip as input data. The user who has booked a ride can check the position of the bus in real time and consult any updates regarding the status of the trip of interest. The user/driver (transport company) interface proposes an optimized itinerary, provides drivers with turn-by-turn driving instructions and automatically updates their programs, minimizing distractions on the road.</td></tr>
<tr><th colspan="3">Technology Application</th></tr>
<tr><td>Core function?</td><td>Mobility challenges?</td><td>Deployment setting?</td></tr>
<tr><td>Bookings Management Software: Manages seat reservations, cancellations, capacity allocation, and user bookings across transport services.
Trip Planning Software: Enables users to find optimal routes, schedules, and multimodal travel options based on real-time or scheduled data.</td><td>Improves public transport efficiency and reliability
Enhances user experience through personalized travel planning
Reduces no-shows, overcrowding, and underutilization of transit resources</td><td>Regional bus and rail networks, intercity transport services
Demand-responsive transport (DRT), paratransit, and mobility-as-a-service (MaaS) platforms
Urban and suburban public transport systems</td></tr>
<tr><td>Infrastructure required?</td><td>Primary users?</td><td>Public/private/mixed use?</td></tr>
<tr><td>Server-side software (cloud or on-premise)
Integration with transport management systems, scheduling engines, and APIs
Mobile and/or web interfaces for both users and operators</td><td>Transport operators and dispatchers
City planners and transit authorities
Commuters, tourists, and mobility service users</td><td>Mixed use — public sector (e.g., transit agencies) and private operators (e.g., shuttle providers, MaaS platforms)</td></tr>
<tr><th colspan="3">Data Collection</th></tr>
<tr><td>Types of data?</td><td>Sensors/sources?</td><td>Collection frequency?</td></tr>
<tr><td>User data: profiles, preferences, trip history
Booking details: origin, destination, times, seat allocation
Operational data: vehicle locations, schedules, capacities
Demand analytics and service usage trends</td><td>GPS and AVL (Automatic Vehicle Location) systems
Real-time APIs from transport operators
Passenger check-in/check-out systems
Manual inputs from booking interfaces</td><td>Real-time vehicle location, availability, and route planning
Per transaction for bookings and modifications
Periodic for analytics and reporting</td></tr>
<tr><td>Data ownership?</td><td>Transmission method?</td><td>User data access?</td></tr>
<tr><td>Usually owned by the transport operator or service provider
User data may be co-owned or governed by third-party vendors/platforms depending on terms of service</td><td>Cellular (4G/5G), Wi-Fi, or secure API connections
Cloud-based dashboards and mobile platforms</td><td>Account management and data access settings
Options to opt out of data sharing for analytics or marketing
GDPR/CCPA-compliant privacy controls and data export tools</td></tr>
</table>

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Ticketing and fare collection systems Vehicle tracking and scheduling platforms Customer apps and MaaS platforms Dispatch and fleet management tools	GTFS & GTFS-RT (for schedules and real-time info) API for MaaS integration Transmodel, SIRI, or NeTEx in Europe Booking APIs (custom or RESTful)	Often supports middleware to connect with older booking and dispatch systems Can operate in hybrid environments
Scalability?	Third-party needs?	Integration challenges?
High scalability across transport modes, regions, and operators Suited for both small fleets and metropolitan transit networks	Often necessary for payment systems, maps/navigation services, and mobility platform integration	Inconsistent data formats between providers Legacy system limitations Privacy/legal concerns when sharing user data across platforms
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Booking system fraud (e.g., duplicate or fake reservations) Data breaches involving personal and payment info Unauthorized access to backend systems or APIs	User authentication (passwords, biometrics, 2FA) Data encryption (at rest and in transit) Role-based access controls and audit logs Secure API gateways and firewalls	Must comply with GDPR, CCPA, and other jurisdiction-specific regulations Includes data retention policies and access transparency
Handling PII?	Privacy by design?	User communication?
Limited to operational need (e.g., names, contact info, payment data) Encrypted storage with secure access and deletion capabilities Anonymous or aggregated data used for analytics where possible	Standard in modern SaaS platforms, with consent-first data architecture Minimal data collection unless explicitly required for service	Privacy policy accessible via app/web Clear opt-in and opt-out prompts Notifications for changes to data practices
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Improved scheduling accuracy, reduced wait times, streamlined reservations Smarter transport planning, increased ridership, data-driven decision-making	Supports efficient vehicle deployment (reduced empty miles) Enables optimized routes, lowering emissions Encourages shared mobility over personal vehicle use	Reduce operational costs (e.g., fewer manual bookings, better capacity planning) New market opportunities for software vendors and mobility startups Improved resource utilization leads to better ROI for transport providers
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Enhance service accessibility for riders with disabilities or limited digital literacy (when paired with inclusive design) Can be adapted for demand-based pricing or service models in underserved areas	Digital access limitations for non-tech-savvy users Over-reliance on automation or algorithms leading to planning gaps Risk of service exclusion if bookings become mandatory without alternatives	Booking system uptime and error rate Average trip planning time and success rate Ridership growth and booking volume On-time performance improvements Customer satisfaction scores

Table 3.6 Driver Communication On-Board Equipment

Technology Name:		
Driver Communication On-Board Equipment		
Description:		
The driver can interact with the operations centre even if he cannot make reports. Through the application, it is possible to see where the bus is and carry out monitoring. Pop-up messages may appear.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
The equipment enables real-time communication between public transport drivers and central control centres or dispatch teams. It may also facilitate internal communication between drivers and passengers or other drivers in a fleet.	Enhances operational coordination and safety Supports rapid incident response and traffic management Reduces delays and service disruptions Facilitates better fleet supervision and dynamic routing	Buses, trams, light rail, and demand-responsive transport vehicles Urban and intercity public transport networks Special use in emergency or event-based transport operations
Infrastructure required?	Primary users?	Public/private/mixed use?
On-board communication devices (e.g., radio, tablets, voice terminals, or multi-function driver consoles). Mobile data network connectivity. Integration with back-office fleet management and dispatch systems. Mounting hardware and power interfaces in vehicles.	Bus/tram drivers	Primarily public sector use by municipal or regional transit agencies; private operators may also deploy similar systems in mixed fleets
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Voice communications (live and recorded) Driver status (e.g., login/logout, breaks, incident reports) Location, speed, and route adherence Incident or emergency alerts Message logs and system diagnostics	GPS and AVL (Automatic Vehicle Location) systems Driver input via touchscreens, microphones, or emergency buttons Integration with vehicle CAN bus for status data (optional)	Real-time for location and communication Event-based (e.g., manual alerts, voice calls, system warnings) Periodic diagnostics or performance logs
Data ownership?	Transmission method?	User data access?
Typically owned by the public transit agency or contracted operator Voice recordings and logs may be subject to labor agreements or legal oversight	Cellular networks (4G/5G) Dedicated radio Wi-Fi (in depots or terminals)	Drivers usually have limited control over communication data Access is governed by organizational policies and labour agreements Some systems allow access to communication history for dispute resolution or audits

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Fleet management software and dispatch platforms AVL and route management systems Emergency communication protocols (police, first responders) Passenger information systems (for driver-triggered alerts)	ETSI ITS standards (for V2X in Europe) TETRA/DMR radio protocols (where applicable) NTCIP standards for message exchange (in North America) Custom APIs for dispatch or scheduling platforms	Can often be retrofitted into older vehicles with minimal upgrades Middleware solutions available to connect with legacy radio or scheduling systems
Scalability?	**Third-party needs?**	**Integration challenges?**
Scalable across multiple vehicle types, routes, and cities Particularly useful in large, distributed fleets requiring centralized coordination	Often involves vendors for communication hardware, integration software, and mobile connectivity Some systems are provided turn-key by OEMs or smart mobility platform providers	Signal coverage issues in tunnels or remote areas Compatibility with legacy infrastructure and fleet variation Labour concerns around data monitoring and recording
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Unauthorized interception of communications Hacking of on-board equipment Remote access to sensitive operational systems	End-to-end encryption of communications Role-based access control for dispatch tools Secure firmware and software updates Regular network and hardware audits	Must comply with labour laws and privacy regulations (e.g., GDPR, local worker protections) Retention and use of voice recordings subject to legal and union agreements
Handling PII?	**Privacy by design?**	**User communication?**
Typically limited, focused on driver ID, shift data, and communications logs Stored securely with restricted access policies	Systems are often designed with opt-in policies for certain data collection (e.g., voice recording) Real-time voice-only systems may reduce data retention risks	Drivers informed via internal policies, training, and union-negotiated agreements Consent and dispute resolution processes for recorded communications
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Quicker issue resolution, smoother dispatch coordination Improved service reliability, better workforce support, and safer operations	Indirect: reduces unnecessary detours or idle time Enables proactive maintenance and more efficient routing	Fewer service disruptions and delays Potential reduction in operational costs from faster response times and better oversight Improved passenger satisfaction leading to ridership retention
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Enhances service equity through more responsive driver-dispatch support (e.g., for assisting riders with disabilities or disruptions) Can support real-time adjustments in underserved areas or during emergencies	Privacy or labour concerns around driver monitoring Overdependence on communication systems in the event of signal failure Complexity and cost of integration with older vehicles	Communication reliability and call success rate Incident response times Driver satisfaction and feedback System uptime and maintenance intervals Reduction in service disruptions attributed to poor coordination

Table 3.7 Infrared Passenger Counting System (IR-PCS)

Technology Name:		
Infrared Passenger Counting System (IR-PCS)		
Description:		
Infrared Passenger Counting Systems (IR-PCS) are technologies used to automatically count passengers entering and exiting vehicles. They use infrared sensors, usually installed above vehicle doors, to detect movement and direction when a person passes through. These sensors track the number of boardings and alightings without collecting personal information. By providing accurate passenger data, IR-PCS supports better planning and management of public transport services. The data can help operators adjust routes and frequencies based on demand, measure vehicle occupancy, and generate reports for performance and funding. Infrared systems are cost-effective, simple to install, and reliable in typical boarding conditions. They can also be combined with other systems, such as GPS tracking or ticketing, to provide more detailed insights into passenger behavior and mobility patterns.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Counts passengers getting on and off public transport vehicles.	Improves accuracy of passenger data collection Supports route planning and service adjustment Reduces need for manual passenger counting	At the doors of buses, trams, or other public vehicles.
Infrastructure required?	Primary users?	Public/private/mixed use?
Infrared sensors above doors, onboard device for storing/transmitting data.	Fleet operators and managers Public transport agencies City public transport departments	Mixed use — mainly public, but possible in private shuttle or fleet systems.
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Boarding and alighting counts Passenger flow per stop or time frame Direction of movement (boarding vs. exiting)	Infrared beam sensors installed above vehicle doors Optional onboard processing unit	Real-time data capture during door openings Aggregated per stop, trip, or defined time intervals
Data ownership?	Transmission method?	User data access?
Typically owned by the public transport operator or service provider May be shared with local or regional authorities	Cellular or Wi-Fi connection to central server Local storage with batch upload via USB or wireless sync	Access through operator dashboard or reporting platform No personal data collected; aggregated anonymous data only

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Public transport management systems Ticketing or validation systems GPS vehicle tracking platforms	REST APIs for data exchange Standard formats for reporting and analytics Compatible with common fleet management software	Can be installed on older buses Works independently of vehicle model or age
Scalability?	Third-party needs?	Integration challenges?
Highly scalable — suitable for deployment from small fleets to national-scale. Easily expandable by adding more units to vehicles	May require integration support from the technology provider Data analysis or dashboard software often provided by vendor	Differences in data format between systems Need for synchronization with other tools (e.g., GPS, fare collection)
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to counting data Tampering with devices or stored information	End-to-end encryption (e.g., SSL/TLS) Role-based access control Password-protected access to the system	Usually does not collect personal data
Handling PII?	Privacy by design?	User communication?
No personally identifiable information (PII) is collected All data is numerical and anonymous	Designed to count without identifying individuals No cameras or audio recording involved	No direct interaction with users Privacy notices may be included in operator policies if needed
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Improves service planning with real passenger data Enables performance monitoring and reporting Reduces manual workload for staff	Supports efficient fleet use by matching service to demand Reduces unnecessary trips and energy use	Saves time and labor costs from manual counting Helps justify funding based on accurate usage data
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Data can reveal underserved routes or peak crowding times Helps improve service coverage and frequency	May be less accurate in very crowded or fast boarding situations Sensors may require maintenance or recalibration Environmental cost of hardware manufacturing and e-waste	Accuracy of boarding/alighting data Number of reports generated or used in planning Changes made based on passenger flow trends

3.2 Micromobility related Factsheets

Here, we highlight four adoptable smart solutions for micromobility, with full descriptions provided in the folowing factsheets.

Table 3.8 Micromobility System Mobile App

<table>
<tr><th colspan="3">Technology Name:</th></tr>
<tr><td colspan="3">Micromobility System Mobile App</td></tr>
<tr><th colspan="3">Description:</th></tr>
<tr><td colspan="3">A mobile/web application that provides real-time tracking and analytics for shared micromobility fleets (e-scooters, e-bikes). It optimizes vehicle distribution, reduces congestion, and supports data-driven decision-making for cities and operators.

The mobile app allows users to locate, unlock, and lock e-scooters securely.

It also supports multiple parking sessions, booking any available spot right on your way to it, arrange stations by predefined criteria. The app enhances service accessibility and operational efficiency for dock-based micro-mobility systems.</td></tr>
<tr><th colspan="3">Technology Application</th></tr>
<tr><td>Core function?</td><td>Mobility challenges?</td><td>Deployment setting?</td></tr>
<tr><td>Tracks vehicle location, usage, and battery levels; enables dynamic rebalancing.
For stations App allows real-time access control, station monitoring, locating, unlocking, and reserving.</td><td>Reduces congestion consequently lowering emissions, improves last-mile connectivity.</td><td>On demand services in urban areas, and campuses, integrated with public transport systems</td></tr>
<tr><td>Infrastructure required?</td><td>Primary users?</td><td>Public/private/mixed use?</td></tr>
<tr><td>GPS-enabled vehicles, cellular/Wi-Fi, cloud servers</td><td>End users, micromobility operators, urban planners, city authorities</td><td>Mixed use</td></tr>
<tr><th colspan="3">Data Collection</th></tr>
<tr><td>Types of data?</td><td>Sensors/sources?</td><td>Collection frequency?</td></tr>
<tr><td>Location, trip distance, battery levels, user demographics, dock usage, parking duration, energy consumption – charge status</td><td>Vehicle GPS, IoT sensors, built-in dock sensors, and user app inputs,</td><td>Real-time (location), batch (analytics).</td></tr>
<tr><td>Data ownership?</td><td>Transmission method?</td><td>User data access?</td></tr>
<tr><td>Owned by the system operator
Usage and sharing of data may be subject to licensing/agreements.</td><td>Cellular, V2X, encrypted APIs</td><td>Accessible to users via the mobile app</td></tr>
</table>

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Public transport apps and traffic management systems. Payment platforms and municipal dashboards	Supports proprietary REST APIs for integration with third-party systems. GTFS, MDS (Micromobility Data Specification), NTCIP.	Limited or does not support legacy systems
Scalability?	**Third-party needs?**	**Integration challenges?**
Highly scalable with localization	Payment providers, Telecommunication providers Partnerships with cities OEMs	Ensuring compatibility with existing municipal platforms and compliance with local data policies
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Exposure to unauthorized account access, Interception of payment data Potential exploitation of user location or identity information	End-to-end encryption Secure cloud infrastructure Secure authentication	GDPR, CCPA, local privacy laws
Handling PII?	**Privacy by design?**	**User communication?**
Collected PII through the app is encrypted during transmission Access to PII is restricted	Embedded data minimization principles.	Privacy policies and data are available through the app and website. Opt-in consent
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Increase micromobility use due to convenience (short-run and long-run) Reduction in idle vehicles Improved fleet efficiency	Promoting the use of micromobility vehicles thus reduces CO_2 emissions	Increases investment in smart technologies Creates tech jobs; lowers operational costs for cities
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Subsidized pricing for low-income users.	Sidewalk clutter, safety incidents	Dock usage rates Turnover time Energy efficiency Number of prevented thefts/vandalism incidents Utilization rates user satisfaction

Table 3.9 Traffic volume and speed measurement devices

Technology Name:		
Traffic volume and speed measurement devices		
Description:		
Traffic volume and speed measurement technology encompasses a range of different systems and sensors that enable the collection of data on the number of vehicles, their speeds, vehicle types, direction of movement and other traffic parameters. These devices are essential for traffic planning, increasing safety and enforcing laws. The goal of such a system is to continuously collect data on traffic flows of cyclists and other vehicles moving along the cycle path and use them for analysis and forecasts in order to make the best possible decisions in the field of traffic regulation and management, as well as promotion for the purpose of tourism.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Monitoring and analyzing non-motorized traffic: bicycle and e-scooter flows, speeds, and movement patterns.	Addresses infrastructure planning, user safety, space allocation, and environmental goals by encouraging sustainable transport.	Deployed on bicycle lanes, mixed-use pathways
Infrastructure required?	Primary users?	Public/private/mixed use?
Basic surface mounting for sensors; The electrical installation will be on the existing traffic light installation - a new switchboard nearby through which the traffic lights are powered.	Cyclists, e-scooters, and everyone who promotes sustainable mobility.	Primarily public use, with potential for private partnerships (e.g. e-scooter providers) in mixed use.
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Counts, direction, speed, time-of-day distribution, vehicle classification (bike, e-scooter).	Inductive loops	Real-time
Data ownership?	Transmission method?	User data access?
Municipality	Data transmission system: RS485, USB, GSM, GPRS, consider the possibility of connecting to the traffic light system communication channel if available.	Authorized users access via dashboards or reports. Citizens can receive public visualizations (e.g. LED totems for counters).

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Urban mobility dashboards, GIS systems, traffic control centers.	Supports JSON for traffic data exchange.	Can integrate with existing smart city infrastructure if connectivity and power are available.
Scalability?	Third-party needs?	Integration challenges?
Highly scalable to additional locations or other cities.	Access will also be provided to third parties	Limited access to power/network at the target location
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Data breach risks from connected devices, especially video analytics systems.	Firewall and antivirus: Protect the system from malicious attacks through firewall and antivirus software. - Physical security of equipment: Locations for installing bicycle counters should be under video surveillance or in places that are under constant surveillance (e.g. cameras, lights).	The project must comply with electrical installation standards, as well as regulations relating to environmental protection and data security.
Handling PII?	Privacy by design?	User communication?
No PII collected; AI video analytics does not store identifiable faces or license plates.	Yes — system avoids collecting personal or biometric data.	Public signage, websites, or municipal reports explain data use and privacy protections.
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Better infrastructure design, increased safety, promotion of cycling and micro-mobility.	Reduces CO_2 emissions by encouraging non-motorized transport modes.	Cost-effective data collection; supports eco-tourism and micromobility industries.
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Supports inclusive mobility planning.	Vandalism protection: The meter must be protected from physical damage or theft. This includes installation in protective boxes or frames made of resistant material (e.g. metal boxes, concrete mountings). - Weather resistance: The device must be waterproof, resistant to high and low temperatures, dust and humidity, in order to operate in all weather conditions.	Daily/weekly traffic counts, peak hour usage, average speed, safety incident correlations.

Table 3.10 E-bikes

Technology Name:		
E-bikes		
Description:		
An e-bike system in a city consists of a connected network of electric bicycles integrated with a digital platform for shared use. It enhances urban mobility by offering a sustainable, efficient, and flexible transportation option		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Facilitate short-distance urban mobility through a sustainable and efficient mode of transport.	Addresses congestion, emissions, last-mile connectivity, and affordability.	Urban areas, near transit hubs, campuses, and commercial zones.
Infrastructure required?	Primary users?	Public/private/mixed use?
Parking zones, GPS/IoT connectivity, charging stations.	Commuters, tourists, students, urban residents.	Mixed use — private ownership and shared services.
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Location, usage, trip data, battery level, environmental data.	GPS, torque sensor, battery sensor, IoT devices.	Real-time and batch.
Data ownership?	Transmission method?	User data access?
Usually held by private operators municipalities may access.	Cellular, Bluetooth, Wi-Fi.	Accessible via apps; varies by provider.

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Public transport, MaaS, city traffic systems.	GBFS 2.0, MDS, Siri2, OpenCharge for e-bikes.	Can integrate with existing cycling and public transport infrastructure.
Scalability?	Third-party needs?	Integration challenges?
Highly scalable in urban settings.	Map providers (HERE/Google), payment gateways, SMS providers.	Local regulatory variations in e-bikes classification, Safety concerns, theft prevention, maintenance logistics.
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Fleet hijacking, rider spoofing, data interception.	Encryption, secure APIs, firewalls.	GDPR, CCPA, local laws.
Handling PII?	Privacy by design?	User communication?
Anonymization and secure processing.	On-device processing for sensitive data. Implemented by major providers.	Via app policies and websites.
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Reduced congestion, sustainability, convenience.	Lower CO_2, reduced noise, eco-friendly transport.	Job creation, reduced transport costs.
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Expands access to cycling for older or less fit users.	Overcrowded bike lanes, safety issues with speed differentials.	Trips/day, CO_2 saved, user feedback, health impact data, incident data.

Table 3.11 E-scooters

Technology Name:		
E-scooters		
Description:		
An e-scooter system in a city refers to a network of shared electric scooters managed through a digital platform. These systems are designed to provide flexible, eco-friendly transportation options for short urban trips, while reducing traffic congestion and pollution.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Facilitate short-distance urban mobility through a sustainable and efficient mode of transport.	Addresses congestion, emissions, last-mile connectivity, and affordability.	Urban areas, near transit hubs, campuses, and commercial zones.
Infrastructure required?	Primary users?	Public/private/mixed use?
Parking zones, GPS/IoT connectivity, charging stations.	Commuters, tourists, students, urban residents.	Mixed use — private ownership and shared services.
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Location, usage, trip data, battery level, environmental data.	GPS, accelerometer, gyroscope, IoT modules.	Real-time and batch.
Data ownership?	Transmission method?	User data access?
Usually held by private operators; municipalities may access.	Cellular (4G/5G), Wi-Fi.	Accessible via apps; varies by provider.

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Public transport, MaaS, city traffic systems.	GBFS 2.0, MDS, Siri2, OpenCharge for e-bikes.	Can function without legacy systems.
Scalability?	Third-party needs?	Integration challenges?
Highly scalable in urban settings.	Map providers (HERE/Google), payment gateways, SMS providers.	Local regulatory variations in e-sccoters classification.
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Fleet hijacking, rider spoofing, data interception.	Encryption, secure APIs, firewalls.	GDPR, CCPA, local laws.
Handling PII?	Privacy by design?	User communication?
Anonymization and secure processing.	On-device processing for sensitive data. Implemented by major providers.	Via app policies and websites.
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Reduced congestion, sustainability, convenience.	Lower CO_2, reduced noise, eco-friendly transport.	Job creation, reduced transport costs.
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Affordable and inclusive if equitably deployed.	Sidewalk congestion in high-demand zones.	Trips/day, CO_2 saved, user feedback, incident data.

3.3 Urban mobility management related Factsheets

The following pages introduce two urban mobility management related technologies. Comprehensive profiles has been presented in the following factsheets.

Table 3.12 GIS Public Transport Cadastre

Technology Name:		
GIS Public Transport Cadastre		
Description:		
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.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
The core function of a GIS Public Transport Cadastre is to collect, manage, and visualize spatial data on public transport networks to support planning, analysis, and decision-making.	Improving urban mobility planning by integrating land use and transport data Improves transport infrastructure planning and land acquisition Inadequate coverage and accessibility of public transport Lack of reliable data for users and operators	Urban and metropolitan regions Transport planning agencies and authorities Smart city initiatives City transport planning departments Transport infrastructure projects (e.g., road expansion, public transport corridors, etc.)
Infrastructure required?	Primary users?	Public/private/mixed use?
GIS software platforms (e.g., ArcGIS, QGIS) Geospatial databases (e.g., PostgreSQL/PostGIS) Surveying tools and satellite imagery Field data collection tools (e.g., GPSenabled devices) Digital mapping and data collection tools Servers or cloudbased data storage Internet connectivity for realtime updates and access	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)	Mixed use, primarily public sector use, is used in transport planning, infrastructure development, service monitoring, policymaking, and public information systems to ensure more efficient, equitable, and datadriven public transportation systems.
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Route geometry and network topology Stop/station locations/ equipment Traffic lights Traffic horizontal and vertical signalization Other traffic devices/equipment Other elements of road infrastructure (kerbs, sidewalks, street parking, public lighting, green areas, etc.)	GNSS/GPS surveying equipment Satellite and aerial imagery Field surveys and LIDAR GPS devices on public transport vehicles Public transport agencies and operators' databases Crowdsourced user feedback	Periodic updates (upon land registration, ownership change, or rezoning) Realtime collection is possible via mobile GIS apps for field updates

Data ownership?	Transmission method?	User data access?
Typically owned and maintained by public transport authorities or contracted operators In some cases, shared between public transport and government cadastral authorities In some cases, shared between multiple government and private stakeholders	Cloudbased GIS portals Mobile networks or WiFi for field syncing Manual uploads from field devices	Rolebased access to sensitive property data Public cadastral maps are often available with limited information Detailed records accessible to authorized stakeholders
Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Urban and transport planning systems Traffic and infrastructure databases Automatic vehicle location (AVL) systems Transport operator databases Smart city data platforms	APIs (Common Types): RESTful APIs for accessing and integrating transport cadastre data; Open Data APIs provided by transport authorities; Realtime APIs (WebSocket or streaming) for dynamic data feeds; GeoJSON/KML/WFS for spatial data access GTFS (General Transit Feed Specification) for sharing static transit data (routes, stops, schedules). Essential for integration with trip planners. DATEX II: for exchanging traffic and travel information between traffic management centers. NTCIP (National Transportation Communications for Intelligent Transportation System Protocol): Primarily used in the U.S. useful when integrating GIS cadastre with traffic control systems. Transmodel: An underlying conceptual model for public transport data that supports consistency across standards like NeTEx and SIRI.	Often digitizes and integrates older paperbased records May require transformation tools for legacy GIS formats
Scalability?	Thirdparty needs?	Integration challenges?
Highly scalable across regions, from local to national land management Cloudbased systems improve accessibility and performance	Often involves private surveyors, GIS consultants, and other data providers Integration with real estate platforms and planning consultancies	Data inconsistencies between systems High cost and time investment for full digitization of the complete network Legal discrepancies in parcel ownership records
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to sensitive data records Data tampering or loss due to system failures Targeted attacks on property databases	Rolebased access control and data encryption Audit trails and version tracking Secure cloud environments and backup systems	Compliant with local property laws and spatial data regulations Subject to national and regional privacy laws (e.g., GDPR)

Handling PII?	Privacy by design?	User communication?
Public maps typically exclude sensitive owner identity info Property owner details stored securely and accessed by permission	Data minimization and access limitation principles applied Public/private data layers separated in design	Legal notices provided on public platforms Clear terms for how data is collected and shared
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Shortterm benefits: Better planning for public transport infrastructure and routes Enhanced DecisionMaking: Provides planners and authorities with accurate spatial data for quick assessments and interventions Better Public Communication: Offers clear, accessible public transport infrastructure info to commuters through apps and web platforms Longterm benefits: Supports smart city and sustainable urban development Enables datadriven mobility and land use coordination	Improves coordination for transitoriented development Optimizes routes and promotes public transport usage, contributing to environmental goals	Supports efficient public infrastructure investment Supports efficient public transport infrastructure maintenance
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Optimizes routes and promotes public transport usage, contributing to environmental goals Aids in planning inclusive mobility infrastructure in underserved areas	Risk of exclusion if data is outdated or biased Privacy concerns if ownership data is not properly protected	Public transport accessibility matrices Public transport infrastructure maintenance matrices

Table 3.13 Geofancing and restricted access control

Technology Name:		
Geofancing and restricted access control		
Description:		
Geofencing is a location-based technology that uses GPS, RFID, Wi-Fi, or cellular data to create a virtual geographic boundary. When a device or vehicle enters or exits this boundary, a pre-programmed action is triggered—like sending a notification, opening a gate, or logging a data point. **Restricted access control** is a security method that limits entry or usage of a physical space, or resource to only authorized individuals, vehicles**. Access control** is a method of regulating who or what can view or use resources in a given environment.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Limit and regulate, who can access specific part of the city	Congestion management (e.g., limiting access to city centers). Emissions reduction (e.g., enforcing low-emission or zero-emission zones). Road safety (e.g., prohibiting vehicle access to pedestrian-heavy areas). Regulatory enforcement (e.g., automated zone-based speed or access restrictions)	City centers and low-emission zones. Parking facilities or logistics hubs. School zones, event venues, and pedestrian areas
Infrastructure required?	Primary users?	Public/private/mixed use?
Retractable bollards with automatic license plate recognition system Connectivity infrastructure (Wi-Fi, 4G/5G, Bluetooth, or LoRa). Optional: RFID tags, IoT beacons, automated gates, or cameras for validation.	Municipality, residents, business entities	Typically mixed use: public authorities define and manage zones; private vendors operate within them
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Real-time location and movement (GPS/GNSS). Device or vehicle IDs. Zone entry/exit time stamps. Zone-specific behavior (e.g., speed, idling, parking). User data (optional for certain use cases).	Vehicle telematics units. Smartphones or apps with location services. IoT infrastructure (e.g., RFID readers, BLE beacons, cameras, automatic license plate recognition system)	Real-time
Data ownership?	Transmission method?	User data access?
Mostly owned by the municipality	Wi-Fi, cellular, optic network	Mainly no, but some platforms allow users to view or download their location history

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Traffic management and control systems. Smart parking platforms. Public transport and MaaS platforms. Payment systems for tolling, congestion pricing, or permits	None	Can integrate with some limitations
Scalability?	Third-party needs?	Integration challenges?
Highly scalable if built on cloud infrastructure and open standards. Geofence zones can be deployed or modified remotely. Scalability depends on mobile network availability and device compatibility	Often required for hardware supply, installation, software development, or data services	Intergration with other systems is not well defined and it require standardization across vendors
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Data breaches involving personal data and vehicle-related information.	TLS/SSL encryption for data in transit. Secure APIs and firewalls. Role-based access control	Systems must comply with GDPR (Europe)
Handling PII?	Privacy by design?	User communication?
Anonymization or pseudonymization is recommended. PII minimization strategies (collect only what's necessary). Clear data retention and deletion policies.	Geofencing zones defined without requiring constant identity tracking. Edge processing to reduce cloud exposure	Notices provided in-app or at point of entry into zones. Public dashboards or FAQs on data use. Mandatory acceptance of data policies before participation
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Less traffic congestion, less pollution, less noise, more efficient land use	Reduce CO_2 emissions and fuel consumption Encourages modal shift to public or shared transport	Reduced Operational Costs - the need for manual labor such as guards or attendants, lowering long-term staffing expenses
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Can restrict or enhance access—requires careful design Opportunity to provide exceptions for essential services or disadvantaged users	Political risk - public resistance Over-restriction may displace congestion to other areas	Measures how many vehicles or users pass through controlled access points per hour/day to evaluate capacity and flow User satisfaction and incident reports Changes in traffic flow and emissions

3.4 Supporting technologies Factsheets

This section outlines adoptable smart mobility infrastructure and integration (horizontal domain/supporting technologies). A total of six technologies have been identified and are described in the accompanying factsheets

Table 3.14 GPRS data exchange/API management platforms

Technology Name:		
GPRS data exchange/API management platforms		
Description:		
GPRS (General Packet Radio Service) data exchange platforms enable the transmission of mobile data over cellular networks, particularly in scenarios where low-bandwidth, wide-area connectivity is sufficient. These platforms are commonly used in smart mobility applications to transmit small packets of data from mobile units—like vehicles, traffic sensors, or parking meters—to centralized servers or cloud systems. API (Application Programming Interface) management platforms sit on top of these data exchange layers, enabling standardized, secure, and scalable communication between different software systems. They provide developers and system integrators with tools to access, publish, secure, and monitor APIs that are used to share mobility-related data across various stakeholders, including transportation authorities, service providers, and application developers. Together, GPRS data exchange and API management platforms support the real-time collection and dissemination of data such as GPS location, vehicle diagnostics, fare transactions, and traffic conditions. They are especially valuable in environments where devices need to remain connected over long distances without requiring high-speed internet.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
GPRS data exchange and API management platforms facilitate the exchange of data over mobile networks and enable the management of APIs used for communication between various systems or devices.	Enables real-time data transfer for mobile and IoT devices (e.g., vehicles, smart meters) Supports seamless data exchange in areas with limited or no broadband infrastructure Enhances application scalability in transport systems and urban mobility	Vehicle telematics and fleet management systems Public transport systems (e.g., real-time vehicle tracking) Smart city infrastructure (e.g., traffic sensors, environmental monitoring) Industrial IoT applications
Infrastructure required?	Primary users?	Public/private/mixed use?
GPRS-enabled mobile devices or sensors API management platform Cellular network infrastructure Web services for API exposure Secure data storage and processing capabilities	Mobile network operators IoT solution providers Enterprises and developers integrating data into apps Fleet operators and logistics companies City planners and transport agencies	Mixed-use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Location data Sensor data (e.g. fuel levels, speed) Performance and diagnostics data Transaction data (e.g., payment) Usage data (e.g., frequency of API calls, data volumes exchanged)	Mobile sensors and IoT devices (e.g., GPS units) API endpoints that aggregate data from multiple sources Network infrastructure (e.g., cellular towers, data centers)	Real-time data transmission (e.g., continuous updates for fleet tracking, sensor monitoring) Batch uploads for non-time-sensitive data (e.g., daily reports)

Data ownership?	Transmission method?	User data access?
Typically owned by the service provider or enterprise using the platform User and usage data may be co-owned between the platform provider and the customer Data retention policies depend on contractual agreements between users and API providers	GPRS (for low-data, high-coverage environments) 3G/4G/5G cellular networks for higher bandwidth API calls over the internet via REST or SOAP protocols	Role-based access control to monitor and manage API calls Authentication methods like OAuth, API keys, and SSL/TLS encryption API rate limiting and monitoring dashboards for usage visibility
Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Integrates with backend systems such as databases, analytics tools, and enterprise resource planning (ERP) software Interoperates with vehicle telematics systems, environmental sensors, and smart city platforms Payment platforms for integration with mobility-as-a-service (MaaS)	RESTful APIs for easy integration with web applications JSON or XML data formats for data exchange OAuth and other authentication protocols for secure access Open data standards like OpenAPI and Swagger for defining APIs	Can be integrated with legacy systems that expose data through older protocols (e.g., SOAP or FTP) Middleware might be required to connect legacy APIs with modern RESTful platforms
Scalability?	Third-party needs?	Integration challenges?
Scalable from small-scale implementations (e.g., a few devices) to large deployments (e.g., city-wide sensor networks) Cloud-based platforms facilitate scalability and global access	Integration with third-party API providers (e.g., mapping services, traffic data sources) Collaboration with mobile network operators for optimized data transmission Partnering with cloud service providers for hosting and data processing	Ensuring data consistency and reliability across multiple systems Managing API versioning and backward compatibility Handling network connectivity issues in remote or rural areas Standardizing data formats across different service providers
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to sensitive API endpoints Data breaches during transmission or storage Denial of service attacks or API misuse Insider threats compromising data integrity	Secure API authentication (e.g., OAuth, API keys) End-to-end encryption of data in transit (e.g., TLS) Intrusion detection and API traffic monitoring Regular security audits and vulnerability testing	GDPR and other privacy regulations for handling user data Compliance with regional data protection laws for cross-border data transfer Adherence to industry standards like PCI-DSS for financial transactions
Handling PII?	Privacy by design?	User communication?
Minimal collection of personally identifiable information (PII), if any Data anonymization and pseudonymization where possible Explicit user consent for data collection and usage	Data retention policies that limit storage of sensitive data Built-in data encryption and access controls to ensure privacy Transparency in how data is used and shared via API documentation	Privacy policies clearly outlined to users regarding data collection and sharing Opt-in consent mechanisms for user data collection in mobile apps and IoT devices

Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Improved operational efficiency for mobile applications and IoT systems Enhanced customer experience with responsive services (e.g., real-time updates for passengers) Better decision-making through real-time, high-quality data	Supports sustainability goals by optimizing resources (e.g., reducing fuel consumption through efficient route planning) Reduces CO_2 emissions by enabling smarter mobility systems and improving traffic flow	Potential cost savings in operational efficiencies (e.g., better fleet management, reduced fuel costs) New business models for data sharing and API monetization Job creation in IoT, data management, and app development sectors
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Provides real-time data for accessible public transportation systems Equitable access to services that rely on mobile networks and APIs	Data overload or privacy breaches if not managed properly Dependency on mobile network availability in remote or underdeveloped areas Potential misuse of API data by unauthorized parties	Number of API calls and data exchanges per unit of time Data transfer latency and throughput API uptime and availability Customer satisfaction based on real-time data responsiveness

Table 3.15 Mobile data collection

Technology Name:		
Mobile data collection		
Description:		
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 analyzing complex environments in real-time.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Mobile data collection using LiDAR and 3D spherical cameras involves capturing highly detailed, accurate, and comprehensive data about the physical environment. LiDAR (Light Detection and Ranging) systems use laser pulses to create precise 3D models of the surroundings, while 3D spherical cameras capture full 360-degree images or videos, providing a rich visual context to the data.	Provides accurate 3D maps of transportation infrastructure (e.g., roads, intersections, bridges) Enhances safety by helping design safer roadways and public spaces Assists in urban planning, traffic flow optimization, and asset management Aids in autonomous vehicle development by providing detailed, accurate environmental data Supports the development of smart cities with better spatial planning and infrastructure management	Road surveying and infrastructure mapping for transportation agencies Autonomous vehicle navigation systems Construction sites for digital twins and 3D modeling Urban planning for smart cities and detailed environmental monitoring Environmental monitoring and landscape mapping
Infrastructure required?	Primary users?	Public/private/mixed use?
Mobile platform or vehicle (e.g., cars, drones) equipped with LiDAR sensors and 3D spherical cameras Data processing systems (e.g., cloud computing, on-premise servers) for real-time data analysis High-performance storage and data transfer solutions to handle large volumes of data Software tools for visualising and analysing LiDAR data (e.g., GIS software, CAD applications)	Urban planners, City authorities Public transport agencies Autonomous vehicle manufacturers and developers Surveying companies and construction firms Environmental monitoring agencies Researchers and academia	This technology is primarily used in both public (e.g., city governments, transport authorities) and private (e.g., construction, autonomous vehicle manufacturers) sectors to gather and analyze detailed spatial data for planning, infrastructure management, and autonomous systems.

Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
LiDAR Data: 3D point cloud data representing surfaces, objects, and terrain Depth and distance measurements Vegetation and infrastructure details (e.g., trees, buildings, roadways) **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 **Geospatial Data:** GPS coordinates for accurate georeferencing Time stamps for temporal analysis	LiDAR sensors (e.g., rotating laser scanners, solid-state LiDAR) 3D spherical cameras (e.g., omnidirectional cameras with 360-degree coverage) GPS and IMU (Inertial Measurement Unit) systems for position and orientation tracking Environmental sensors (e.g., temperature, humidity) in some applications	Continuous, real-time data capture during vehicle movement during the survey High-frequency point cloud capture (up to millions of points per second, depending on the LiDAR system) 360-degree imagery captured at a rate of frames per second (FPS), typically 30 FPS or higher for video Periodic updates (upon infrastructure or equipment changes)
Data ownership?	Transmission method?	User data access?
Data ownership typically belongs to the entity that operates the mobile data collection system (e.g., construction company, local authority, or research institute) Usage and sharing of data may be subject to licensing agreements or public data policies depending on the location	Real-time data transmission via Wi-Fi, cellular, or satellite for mobile platforms High-capacity data storage solutions (e.g., SSD drives) used for offline data transfer Cloud services or local servers for data processing and analysis	User-defined permissions for accessing raw LiDAR and 3D spherical data Secure data access through cloud platforms or local networks APIs for integrating data into other systems or applications Data encryption and authentication for secure access
Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
LiDAR and camera data must integrate with Geographic Information Systems (GIS), CAD tools, and 3D modeling software Integration with traffic management systems or autonomous vehicle systems for real-time use API integrations for sharing data with third-party platforms (e.g., environmental monitoring or city infrastructure systems)	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 Standardized APIs for data exchange (e.g., REST APIs for easy integration with other systems)	Older GIS systems may need upgrades to process large point clouds or high-definition images Some legacy infrastructure may require conversion of data formats or middleware for full compatibility
Scalability?	Third-party needs?	Integration challenges?
Scalable from small survey projects (e.g., a few city blocks) to large-scale urban mapping or country-wide infrastructure monitoring Cloud platforms support the scalable processing of large data sets, allowing users to handle more complex analyses as needed	Partnerships with software providers for data analysis and visualization (e.g., Esri for GIS, Autodesk for CAD) Integration with autonomous vehicle platforms for map creation and real-time navigation Collaborations with construction and engineering firms for design and modeling solutions	Managing large data sets and ensuring fast processing times Compatibility issues between various 3D modeling and GIS platforms Ensuring consistency between LiDAR and camera data during data fusion processes

Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to sensitive data (e.g., infrastructure details, vehicle paths) Data interception or hacking during transmission (e.g., point cloud or camera data) Data manipulation or corruption during post-processing	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	GDPR and other data privacy regulations, especially for geographic and personal data Industry standards and safety regulations for data use in autonomous vehicles or public infrastructure
Handling PII?	Privacy by design?	User communication?
Generally, LiDAR and camera data do not capture personally identifiable information (PII), unless integrated with other systems (e.g., vehicle registration data) Anonymization of data where applicable to reduce privacy concerns	Ensuring that the data collection process is designed to minimize unnecessary data capture Providing users with clear policies about data use and access permissions Transparent data handling practices, especially in public or urban planning projects	Users informed of how their data is used and stored, especially if linked to individual movements or infrastructure projects Clear consent mechanisms for data collection, especially in regulated environments
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Quick, accurate mapping and data collection for construction or transportation projects Enhanced visualization of infrastructure, roads, and buildings for planning and design purposes Real-time data can inform immediate decisions (e.g., traffic management, road safety improvements) Creation of detailed 3D models and digital twins for urban environments, leading to better city planning Aided development of autonomous vehicles by providing high-accuracy maps for navigation Better understanding of environmental and infrastructure changes over time	Helps optimize infrastructure development, reducing the need for resource-intensive physical surveys Supports green building and urban sustainability efforts by providing accurate data for smart city initiatives	Reduces time and costs associated with traditional surveying and mapping methods Stimulates growth in industries like construction, autonomous vehicles, and urban planning Increases investment in smart infrastructure and technology
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Facilitates better urban planning that can include underserved or neglected communities Enhances safety and accessibility for public spaces through more accurate data	Privacy concerns related to capturing detailed imagery or mapping infrastructure Data misinterpretation or reliance on inaccurate models if not properly processed	Accuracy and resolution of LiDAR data and 3D imagery Data processing time (e.g., time to convert raw data to usable 3D models) Cost savings compared to traditional surveying methods Adoption rate of data-driven solutions in urban planning, construction, and autonomous vehicles

Table 3.16 Cloud infrastructure and dedicated servers

Technology Name:		
Cloud infrastructure and dedicated servers		
Description:		
This architecture enables the centralized management using a secure cloud infrastructure or optionally dedicated servers. It allows real-time monitoring, configuration, and maintenance of the network while applying granular access policies that ensure only authorized users can access specific data or controls. It collects, processes, and stores data from other devices within a network and it is used to constantly monitor the system, enabling analysis and rapid response to potential problems		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
The server collects and processes data from other infrastructure and user data with tiered access levels	Lack of data	All modes of transport (public transport, micromobility, etc)
Infrastructure required?	Primary users?	Public/private/mixed use?
Sensor counters Secure local or cloud platform for data processing and storage Internet connection for data transfer (Wi-Fi, mobile network)	System administrators Municipalities Micro-mobility operators	Private use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
User activity System performance Error logs Maintenance records	Data collected from hardware access logs	Real-time and scheduled intervals
Data ownership?	Transmission method?	User data access?
Owned by the system operator or Municipality	Data transmitted via the station's internet connection	Restricted through role-based access control. Authorized users access via dashboards or reports. Citizens can receive public visualizations

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Management platform Connects with city dashboards Traffic control centar	Supports REST APIs (OAuth 2.0) Supports JSON for traffic data exchange	Not compatible with legacy systems lacking modern authentication
Scalability?	**Third-party needs?**	**Integration challenges?**
Highly scalable to additional locations or other cities	Cloud service providers Internet Providers	Role-based access complexity
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Unauthorized access System configuration breaches	Two-factor authentication Encrypted communication Access control policies	Fully GDPR compliant and local privacy laws
Handling PII?	**Privacy by design?**	**User communication?**
Access to PII is restricted, access requires explicit authorization	Yes — system avoids collecting personal or biometric data	Privacy policies and data available through website
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Improves planning and prioritization	Promotion of sustainable modes of transport	Cost-effective data collection; supports eco-tourism
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Not applicable	Cyber attacks	Activity level Uptime System error rates Data latency Access policy audits

Table 3.17 NFC card

Technology Name:		
NFC card reader		
Description:		
NFC card readers use short-range wireless communication (typically within 4 cm) to exchange data with NFC-enabled cards, smartphones, or wearables.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Contactless authentication and access control. They authenticate users or devices for quick, contactless interactions.	Improves accessibility for users without smartphones Minimizing contact surfaces (important post-COVID). Improving system accessibility and user experience	On demand services Payment of services Micromobility stations
Infrastructure required?	Primary users?	Public/private/mixed use?
NFC-enabled terminals or validators Supported NFC cards Backend servers for authentication, fare calculation, and transaction logging Backend servers for authentication, fare calculation, and transaction logging	End users City authorities Micromobility operator Payment system vendors	Mixed use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Card ID Time and location of tap-in/tap-out events. Fare or access permissions. Transaction history	NFC chipsets in readers and user devices/cards. Contactless smartcards or smartphones. Backend systems	Real-time
Data ownership?	Transmission method?	User data access?
Typically owned by the transport agency or mobility operator Payment data may be co-owned with financial institutions	Local NFC communication Backend transmission via Wi-Fi, cellular, or Ethernet	Limited, accessible only by authorized administrators User portals or apps may offer access to trip history and receipts. Opt-in terms for storing personal data or linking to payment methods. Data subject access requests supported under GDPR

Integration & Interoperability		
System integrations?	**APIs/standards?**	**Legacy support?**
Central management platform Payment platforms (credit/debit cards, mobile wallets). Micromobility systems. MaaS platforms	Depends on software	Requires NFC-compliant cards
Scalability?	**Third-party needs?**	**Integration challenges?**
Easy scalable	Banks/payment processors for EMV card acceptance. Mobile platforms (Apple Pay, Google Pay). Smartcard providers and terminal manufacturers	Ensuring compatibility with different card formats
Security & Privacy		
Cyber risks?	**Technical safeguards?**	**Compliance?**
Cloning of NFC cards Unauthorized access attempts	Card encryption Mutual authentication between reader and card	Fully GDPR compliant
Handling PII?	**Privacy by design?**	**User communication?**
Card ID data is anonymized and linked to internal user accounts with restricted access	Yes, minimizing data collection	Privacy policies and data available through operator's platform
Expected Impacts		
Expected benefits?	**Sustainability?**	**Economic impacts?**
Increase the number of end users	Reducing CO_2 emissions Promotes public and shared mobility by improving user experience	Cost savings on fare collection and cash handling. Stimulates innovation in mobility fintech and platform integration. Opens opportunities for third-party app ecosystems
Accessibility/equity?	**Unintended effects?**	**Evaluation metrics?**
Simple use for not familiar to technology (smartphone apps) users	Dependence on proprietary technology may raise vendor lock-in. Digital divide issues if mobile-based access is prioritized over cards. Fraud or technical failure could disrupt operations at scale	NFC usage frequency Number of unique card users Failed access attempts

Table 3.18 Smart Indicators with Alarm System

Technology Name:		
Smart Indicators with Alarm System		
Description:		
This system includes integrated visual and acoustic indicators at the docking stations that provide real-time feedback to users and signal alarm conditions in the event of tampering or misuse. The indicators serve both as a user guidance mechanism and as a deterrent for theft and vandalism.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Visually and acoustically inform users and deter unauthorized actions	Reduces theft and vandalism Increases user confidence Increase use of e-bike and scooters	On-demand services/ mobility hubs
Infrastructure required?	Primary users?	Public/private/mixed use?
Docking station with integrated lights and sound system Connection to the central management platform	End users City authorities	Mixed use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Tamper detection events Alarm activations Docking status changes	Integrated tamper sensors Light/sound trigger Central system logs	Real-time
Data ownership?	Transmission method?	User data access?
Owned by the system operator (Municipality of Rethymno)	Data transmitted via the station's internet connection to backend platform	No, system-level alerts only

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Management platform Alert systems	No direct external APIs for indicators	Requires modern smart docking infrastructure
Scalability?	Third-party needs?	Integration challenges?
Scalable	May require for integrating with municipal emergency or safety systems	Ensuring reliable alert triggering
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Disabling indicators remotely Spoofing alarms	Secure firmware Tamper-proof housing	Fully compliant
Handling PII?	Privacy by design?	User communication?
Does not collect personal data	Yes (exclusion of PII)	Signals delivered visually (lights) and acoustically (alarms)
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Increase security Increase e-bikes use	Reduce CO_2 emissions and noise level	None
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Not applicable	Not applicable	Alarm activation rates Incident reports

Table 3.19 Smart IoT integration

Technology Name:		
Smart IoT integration		
Description:		
Integrated IoT infrastructure connects each hardware unit to a centralized cloud management platform. This integration allows remote monitoring, data collection, device control, and system diagnostics in real time.		
Technology Application		
Core function?	Mobility challenges?	Deployment setting?
Centralized, remote monitoring and control of all dock units and user interactions	Operational optimization of parking infrastructure Real-time decision making	On-demand services Real-time monitoring of infrastructure
Infrastructure required?	Primary users?	Public/private/mixed use?
Internet connectivity IoT-enabled docking stations Data analytics tools	Infrastructure managers City authorities	Private use
Data Collection		
Types of data?	Sensors/sources?	Collection frequency?
Usage data Availability Logs Charging status Sensor diagnostics, etc	Dock sensors Smart modules	Real-time
Data ownership?	Transmission method?	User data access?
Owned by the system operator or municipality	Data transmitted via the station’s internet connection	Limited to administrators

Integration & Interoperability		
System integrations?	APIs/standards?	Legacy support?
Management platform Connects with city dashboards Payment services	Supports REST APIs (MQTT and HTTPS protocols)	Not compatible with non-IoT or analog infrastructure
Scalability?	Third-party needs?	Integration challenges?
Highly scalability	Cloud service providers Internet Providers	Potential for interoperability issues across different platforms
Security & Privacy		
Cyber risks?	Technical safeguards?	Compliance?
Unauthorized access to control systems Data breaches Denial of service	Secure firmware Eencrypted communication Access control policies	Fully GDPR compliant
Handling PII?	Privacy by design?	User communication?
Does not collect personal data, data is anonymized and used for operational purposes	Yes (minimum necessary data)	Applies to administrative backend only
Expected Impacts		
Expected benefits?	Sustainability?	Economic impacts?
Continuous monitoring Smooth system running Future system improvement	Improves urban mobility planning	Cost savings due to remote monitoring
Accessibility/equity?	Unintended effects?	Evaluation metrics?
Not applicable	Not applicable	Uptime System error rates Data latency

4 Concluding remarks

The report investigates the current context and state of the art of 18 selected technologies to be applied, improved or scaled up in partner territories. The selection of adoptable smart mobility technologies to be included in the actsheets 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.

Factsheets on adoptable technologies are grouped in four categories. The first two categories include smart technologies focused on two sustainable transport modes: public transport and micromobility. The remaining two categories are more general. The first group relates to the organization and management of urban mobility, while the latter covers the overall support technologies for the smart mobility infrastructure and integration.

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, with the aim of supporting pilot territories in selecting the best solution to meet identified territorial mobility-related needs.

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.

Deliverable 1.4.1 – Technology gap assessment has revealed that while technologies related to mobility data collection, data security, and real-time user information — have reached levels of operational deployment in multiple territories, the broader technological aspects remain at an early stage of development. The cross-territorial analysis further confirms that while early digitalization initiatives are underway, systemic smart mobility readiness remains fragmented.[1]

Therefore, another goal of creating a detailed Factsheet for planned technologies was to identify areas where the technology should be adapted to local conditions. After a detailed analysis of the summarized information in all aspects provided in this deliverable, the members of the working group for each pilot site will easily identify the need for adjustment. This represents the logical next step and serves as preparation for Activity 2.1 and Deliverable D.2.1.1 – Technical specification of SMARTMOBAIR intelligent transport system technologies.

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.

The Factsheets will help pilot sites to select smart mobility technologies and customize them to tackle identified common challenges: heavy urban traffic congestion caused by the wide use of private motorized vehicles resulting in high levels of air pollution and low road safety; the lack of mobility data, especially on the use of micromobility e-vehicles that are spreading rapidly; a scarce use of public transport due to its low efficiency and attractiveness the low efficiency of traditional public transport services in suburban rural and low-density areas.

[1] For more information on the cross-territorial assessment of technical readiness in SmartMobAir pilots please refer to D.1.4.1 – Technology gap assessment.