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
D1.4.1	Technology gap assessment	YES	YES - Fully aligned with Activity 1.4 in the Application Form	YES - identifies and assesses technology gaps in partner territories	YES	YES – involvement of local SWGs	B. Monaco (AREA)

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List of abbreviations and terms

ALPR	Automatic License Plate Recognition
AVM	Automatic Vehicle Monitoring System
DATEX	DATa EXchange between traffic and travel information centers
GAT	Gap Analysis Tool
GIS	Geographic Information System
GTFS	General Transit Feed Specification
IIPs	Institutional Partners
ITS	Intelligent Transport Systems
KETs	Key Enabling Technologies
MaaS	Mobility-as-a-Service
NeTEx	Network Timetable Exchange
PIS	Passenger Information Systems
PP	Project Partner
PT	Public Transport
SA	Self-Assessment
SSL	Secure Socket Layer
SUMP	Sustainable Urban Mobility Plan
SWG	Stakeholder Working Group
TPs	Technical Partners
TRL	Technical Readiness Level
VANET	Vehicular Ad hoc NETwork
WP	Work Package

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Executive Summary

This report presents the findings of the technology gap assessment conducted across six pilot territories within the SMARTMOBAIR project, offering a structured analysis of smart mobility readiness and identifying pathways for future scaling and integration. Building upon earlier project deliverables and preparatory activities, the report consolidates prior insights and introduces a dedicated assessment framework.

A Gap Analysis Tool (GAT) was specifically developed to support this assessment, through a structured process encompassing conceptualization and operationalization phases. Its conceptual foundations draw from key international sources, including the World Bank Smart Mobility Toolkit and the European Commission's Sustainable and Smart Mobility Strategy. The tool structures the assessment across five thematic dimensions—Technical Readiness, Interoperability, Scalability, Sustainability Impact, and User Acceptance—further broken down into sub-dimensions and associated with a set of Key Enabling Technologies (KETs) reflecting advanced smart mobility functions.

The assessment is qualitative in nature. It is based on a maturity levels, ladder of development ranging from non-existent to fully optimized deployment. It was implemented through a participatory approach, involving local Stakeholder Working Groups (SWGs) across the pilot territories to ensure context-sensitive appraisals. Importantly, the methodology does not involve benchmarking or ranking between territories; it is conceived as a self-assessment tool, designed to provide a snapshot ("time cut") of current smart mobility maturity. Moreover, the GAT is structured to support continuous use over time, enabling territories to monitor their progress toward higher levels of technological maturity and systemic integration. The appraisal of values reflects each territory's own informed judgment. As such, the results represent locally grounded perspectives rather than objective or externally validated measurements. Differences in city size and context also influence the presence or absence of specific technologies.

The recommendations presented in the report are not prescriptive, but rather serve as strategic guidance, reflecting each territory's specific developmental context. Recommendations are drawn based on the assessed maturity levels of key technologies and enablers, following a structured analysis of identified strengths, gaps, and territorial context. At the territorial level, recommendations are tailored individually for each city or municipality, while at the macroregional level (ADRION region), a broader synthesis highlights shared priorities and potential pathways for coordinated advancement.

Each territorial gap analysis follows a consistent structure: a performance gap summary, detailed analysis across thematic dimensions and Key Enabling Technologies (KETs), and a concluding set of recommendations. At the macroregional level, the report mirrors this structure, presenting a consolidated overview of technical readiness and cross-cutting enablers, followed by strategic reflections and high-level recommendations to support smart mobility development across the ADRION region. The cross-territorial comparison places particular emphasis on real-world deployment as a threshold criterion for identifying shared strengths and gaps. Only technologies demonstrating operational presence (real-world deployment) were considered when assessing cross-regional patterns, ensuring a pragmatic and implementation-focused perspective.

The assessment reveals a landscape characterized by emerging strengths alongside persistent structural gaps. Operational deployment is observed in areas such as mobility data collection, basic user information services, and data security infrastructures. However, systemic integration, dynamic traffic control, integrated fare management, and sustainability impact monitoring remain underdeveloped across most territories. These findings highlight both a promising foundation for smart mobility advancement and the need for coordinated efforts to bridge critical technological and systemic gaps.

The findings of this report will directly inform the development of the *forthcoming Factsheets on Adoptable Smart Mobility Technologies* and will provide a strategic foundation for the preparation of *Technology Roadmaps* in the next stages of the SMARTMOBAIR project.

1 Introduction

Smart and sustainable mobility is a key enabler of Europe's development, as outlined in strategic frameworks such as the European Green Deal, the Green Agenda for the Western Balkans, the Economic and Investment Plan, and the EU Sustainable and Smart Mobility Strategy. Transforming urban mobility is essential to achieving the objectives of the Green Deal and addressing growing urban challenges through inclusive, digital, and low-emission solutions. With over 70% of EU citizens living in urban areas that account for 23% of transport-related greenhouse gas emissions, cities are at the heart of the transition toward climate-neutral and resilient mobility systems. The Urban Mobility Framework supports this transition by promoting smart, safe, accessible, and sustainable transport across the EU.

While EU-level strategies set the overall direction, the implementation of smart and sustainable mobility depends strongly on regional and local capacities, which vary significantly across Europe. In this context, regional policies and transnational cooperation are essential to translating strategic objectives into concrete actions. The Adriatic-Ionian (ADRION) region, characterized by its territorial, infrastructural, and socioeconomic diversity, faces both common and context-specific mobility challenges. 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. Within this framework, the SMARTMOBAIR project promotes sustainable and smart urban mobility by facilitating the deployment of Intelligent Transport Systems (ITS) and data-driven planning approaches across six pilot territories. Through collaboration among 16 partners, the project aims to enhance regional readiness for adopting innovative ICT-based mobility services, in line with the objectives of the Green Deal and the EUSAIR Strategy.

This report (Deliverable 1.4.1) presents the results of a technology gap assessment carried out to better understand the capacity of partner cities and municipalities to implement smart mobility solutions. It focuses on identifying the functional gaps that hinder the adoption of ITS and Key Enabling Technologies (KETs), and provides insight into the scalability, upgrade potential, and deployment conditions of existing systems. The results are intended to guide the design of pilot actions, inform strategic planning, and support the broader goal of accelerating the transition toward data-driven and inclusive urban mobility across the Adriatic-Ionian region.

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). 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 five main chapters. Following the introduction, the second chapter presents the methodological framework for the technology gap assessment. At the center is the Gap Analysis Tool (GAT), specifically developed to support this assessment. This chapter explains the tool's conceptual foundations, its core elements and functionalities, and the data collection procedures carried out within a participatory approach setting. The third chapter presents the results of the gap assessment across six pilot territories. Each territory is assessed following a consistent structure: beginning with a performance gap summary, continuing with a detailed analysis across dimensions and Key Enabling Technologies (KETs), and concluding with a summary of findings and corresponding recommendations. The fourth chapter offers a cross-territorial analysis, applying a similar structure to identify shared patterns, strengths, and gaps across all pilot territories. The report concludes with a final chapter outlining key observations and recommendations, and pointing toward the next steps of the project, which will build on the findings and insights provided in this analysis.

2 Methodology

The methodology adopted for the technology gap assessment was developed through two interconnected phases: conceptualization and operationalization. The conceptual phase involved defining a suitable approach to evaluate the technological readiness and gaps in smart mobility systems, based on a maturity model grounded in quality management principles and self-assessment logic. The operationalization phase translated this conceptual framework into a practical tool to be applied 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 Excel-based gap analysis tool was subsequently shared for review. Following valuable input—particularly from the lead partner of Activity 1.5—the tool was refined to ensure alignment with the work on future technology trends and to incorporate Key Enabling Technologies (KETs) within each thematic area. Bilateral consultations helped coordinate Activities 1.4 and 1.5, ensuring consistency in scope and indicators.

To support the implementation of the methodology, a dedicated presentation was prepared and shared with partners as a practical guide for data collection. The assessment 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.

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	Jan-Feb 2025
Conceptual approach presented	24th February 2025
Draft tool shared for review	7th March 2025
Bilateral consultations with A.1.5 lead partner/ Alignment between Activities 1.4 & 1.5	Early March 2025
Supporting material prepared	Early March 2025
Data collection launched	15th March 2025
Draft Report shared with PPs for review	16th May 2025

2.1 Conceptualization

Choosing the appropriate methodological approach for a technology gap assessment in the field of smart mobility is not a purely technical decision. It requires sensitivity to the diversity of local contexts, the need for stakeholder engagement, and the varying levels of institutional and digital maturity across regions. In the SMARTMOBAIR project, these considerations led to the adoption of a self-assessment (SA) approach—adapted from the field of quality management and increasingly recognized as a suitable method for structured, participatory evaluation in complex policy environments.
Rooted in Total Quality Management (TQM), self-assessment provides a framework for internal reflection and continuous improvement. Rather than measuring compliance against fixed standards, it encourages actors to evaluate their current state against an ideal or optimal condition, often structured as a "ladder of development" or maturity model. This model does not merely assess compliance, but supports a dynamic understanding of progress, guiding from current state toward a more advanced, optimal one. This approach is particularly well-suited to supporting learning, capacity-building, and context-sensitive planning—outcomes that are essential for enabling the successful deployment of Intelligent Transport Systems (ITS) in diverse territorial settings. Compared to alternative methods such as SERVQUAL or external benchmarking, self-assessment offers greater

flexibility and fosters internal ownership of results. It is especially valuable in settings where governance is fragmented, and where a one-size-fits-all evaluation model would be both inappropriate and ineffective. It also enables progress to be tracked over time, supporting iterative development rather than one-off evaluations.
This approach has already been introduced into the field of urban mobility planning, most notably through the ADVANCE project, which proposed a self-assessment framework for evaluating the quality of Sustainable Urban Mobility Plans (SUMPs) and institutional benchmarking in road safety[1][2] further support its relevance here. In the context of SMARTMOBAIR, the SA approach allows pilot territories to assess their smart mobility capacities in a structured yet adaptable way, identifying gaps and development priorities in line with their unique local conditions. Supported by the project's Stakeholder Working Groups (SWGs), the method ensures that technical analysis is complemented by local expertise and practical insight, reinforcing both the legitimacy and usefulness of the results.
In the context of SMARTMOBAIR, the use of self-assessment is particularly appropriate given the diversity of institutional capacities, technological maturity, and planning practices across the Adriatic-Ionian region. Rather than applying a one-size-fits-all benchmark, the self-assessment approach enables each pilot territory to evaluate its own situation in a context-sensitive way, while still aligning with a common reference framework. Moreover, the tool is designed to be repeatable, supporting ongoing evaluation, tracking progress over time, and guiding the strategic development of smart mobility systems and Intelligent Transport Systems (ITS).

2.2 Operationalization-Gap Analysis Tool

Building on the conceptual foundation of self-assessment and maturity models, the operationalization phase focused on translating this methodological framework into a **structured and user-friendly tool** that could be applied consistently across the pilot territories. The result was the development of the **Gap Analysis Tool (GAT)**—an Excel-based instrument designed to assess the technological maturity and development needs of **Intelligent Transport Systems (ITS)** and smart mobility solutions across diverse local contexts. While the tool was structured to center on the **pilot solutions** as concrete reference points, its design allows for **broader analysis and filtering**, enabling comparisons across thematic areas, technologies, or territories. It is composed of a series of **interlinked sheets**, each corresponding to a key step in the self-assessment process—from the initial description of the pilot, to detailed appraisal of enabling technologies, and final synthesis of results.
The structure of the GAT includes dedicated sheets for:

- Describing the pilot ITS solution (Pilot ITS Solution);
- Providing respondent information (Respondent Info);
- Entering self-assessment scores across five thematic areas (Input Data);
- Viewing automated summaries and visualizations of maturity across areas and a consolidated view of performance gaps (Performance Gap).
  The layout of the blank tool is presented in Figure 2.1

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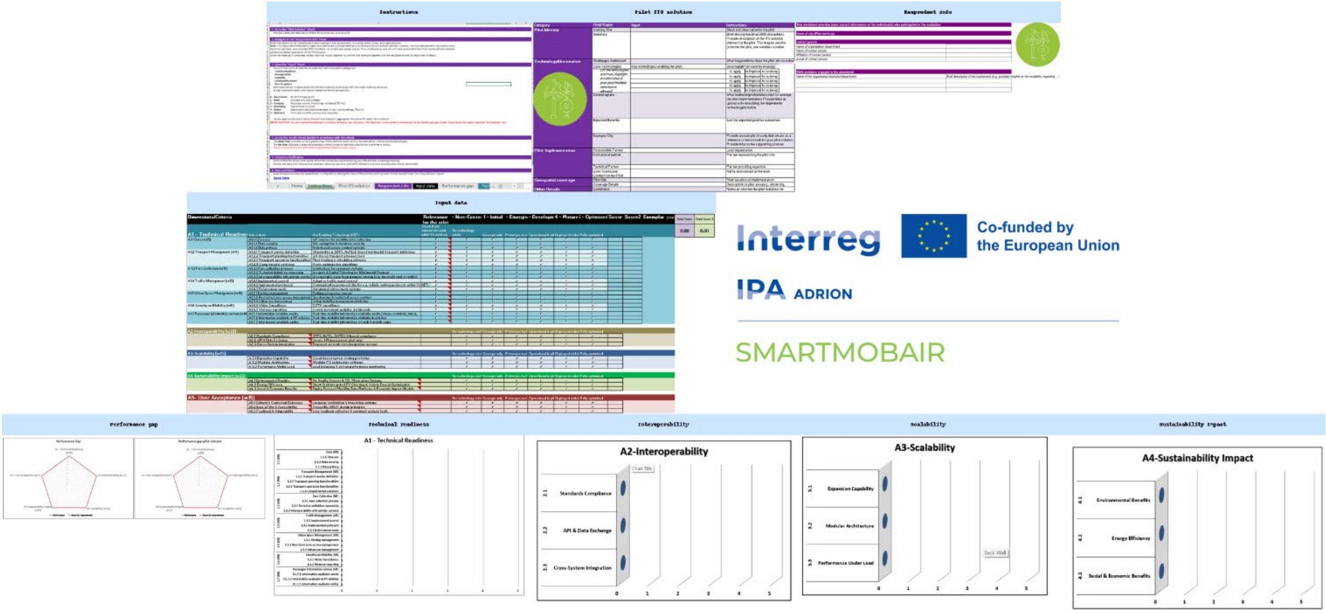
[1] **Petrović, M., Vidović, N. (2019).** "TQM tools in support to urban mobility shift: Exploring possibilities to transfer EU practice in Serbia". In Proceedings of the 7th International Conference Transport and Logistics, Niš, Serbia, pp. 103-111, Available in https://til.masfak.ni.ac.rs/images/til-pedja/Proceedings_til2019-1.pdf

[2] **Petrović, M. T., Bojković, N. Z., Tarle, S. A. P., & Parezanović, T. M. (2017).** Quality management audit schemes in sustainable urban mobility-learning from EU experience. In International Working Conference ''Total Quality Management – Advanced and Intelligent Approaches'', 5 – 9th June, 2017, Faculty of Mechanical Engineering, University of Belgrade, Serbia. Available at: https://www.researchgate.net/profile/Marijana-Petrovic-4/publication/333682766_Quality_management_audit_schemes_in_sustainable_urban_mobility_-learning_from_EU_experience/links/5cff9101299bf13a384ca065/Quality-management-audit-schemes-in-sustainable-urban-mobility-learning-from-EU-experience.pdf

Figure 2.1 GAT layout

Source: Authors



These functional sections of the GAT are underpinned by three core methodological components:

- The definition of thematic areas, indicators, and Key Enabling Technologies (KETs);
- The application of a structured maturity scale (ladder of development), and
- A participatory data collection procedure, involving multiple project partners and local stakeholders.

The following subsections explain each of these components in detail, highlighting how the tool supports a consistent, participatory, and context-sensitive assessment process across the SMARTMOBAIR pilot territories.

2.2.1 Thematic areas, indicators, and Key Enabling Technologies (KETs)

The Gap Analysis Tool (GAT) is structured around **five thematic areas that reflect both the strategic priorities of the European Union and the empirical insights gathered from the SMARTMOBAIR pilot territories**. The selection of these areas was based on a combination of policy alignment, regional diagnostics, and technical literature, ensuring the tool's conceptual relevance and operational applicability.

From a policy perspective, the thematic areas are consistent with the objectives set forth in the revised **ITS Directive (EU) 2023/2661**[3]**, the European Strategy for Data (2020)**[4]**, and the Sustainable and Smart Mobility Strategy (2020)** [5]. These documents underscore the importance of digital infrastructure, interoperability, real-time information, sustainability, and user-centric design in transforming urban mobility systems.

[3] **European Parliament and Council.** (2023). *Directive (EU) 2023/2661 of 22 November 2023 amending Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes.* Official Journal of the European Union, L, 2023/2661. Directive - EU - 2023/2661 - EN - EUR-Lex

[4] **European Commission.** (2020). *A European Strategy for Data.* COM(2020) 66 final. Brussels. EUR-Lex - 52020DC0066 - EN - EUR-Lex

[5] **European Commission.** (2020). *Sustainable and Smart Mobility Strategy – Putting European transport on track for the future.* COM(2020) 789 final. Brussels. EUR-Lex - 52020DC0789 - EN - EUR-Lex

In the internal analysis phase, the thematic structure of the Gap Analysis Tool (GAT) was informed by findings from both **Deliverable D1.1.2 (Report on Availability of Mobility-Related Data and Problems) and Deliverable D1.1.3 (Assessment of Mobility Planning Documents and Regulatory Framework).** These two deliverables provided complementary insights into the state of smart mobility readiness across the six pilot territories in the Adriatic-Ionian region. D1.1.2 offered a detailed examination of the availability, quality, and use of mobility-related data, including the presence of digital infrastructure (e.g., IoT sensors, GPS tracking, mobile applications), data collection methods, and the use of tools such as GIS and custom applications for traffic and public transport planning. These findings directly supported the development of all five thematic areas in the GAT—Technical Readiness, Interoperability, Scalability, Sustainability Impact, and User Acceptance—each operationalized through functional indicators and assessed via corresponding Key Enabling Technologies (KETs).

D1.1.3, in contrast, focused on the assessment of regulatory frameworks and mobility planning documents, identifying legal gaps, outdated policy instruments, and institutional barriers that may hinder the uptake of ITS and smart mobility solutions. While these governance-related aspects are critical, they were not included in the GAT, as the tool was specifically designed to assess technological maturity and deployment potential, rather than institutional or policy readiness. Similarly, while D1.1.2 addressed the presence of smart mobility initiatives and stakeholder collaboration, these elements were not formalized as appraisal dimensions in the GAT. Nevertheless, they were indirectly reflected through the participatory process. The involvement of Stakeholder Working Groups (SWGs) in the appraisal process enabled local stakeholders to share contextual knowledge, including ongoing projects and planned technology deployments. This focused methodological choice allowed the GAT to remain a practical, technology-oriented assessment instrument. Broader institutional and regulatory conditions influencing smart mobility deployment are instead examined through the complementary analytical activity A.1.3, which is dedicated to the assessment of the legal and planning framework across pilot territories. Final list of thematic areas includes:

- Technical Readiness
- Interoperability
- Scalability
- Sustainability Impact
- User Acceptance

Each thematic area is broken down into specific subdomains, with corresponding Key Enabling Technologies (KETs) and organizational or infrastructural elements identified as assessment items. These items form the core of the self-assessment.

The selection of these areas was further informed through **discussions with project partners** during the conceptualization phase of the methodology. Their relevance and applicability were reviewed and **jointly agreed upon** to ensure alignment with both the project's goals and the practical needs of pilot territories.

While the overarching thematic areas are grounded in policy, the **subdomains and indicators** within each area were drawn from a combination of **scientific literature** and **practitioner-based sources**. It is important to note that **no single comprehensive framework currently exists** for systematically assessing the deployment of smart mobility technologies across multiple dimensions. Therefore, the SMARTMOBAIR methodology draws selectively from multiple sources to construct a **structured yet flexible assessment framework**. In particular:

- The **World Bank Smart Mobility Toolkit** (2023)[6] was used to inform the technological scope of the assessment, especially regarding smart solutions and readiness levels.

[6] **World Bank.** (2023). *Smart Mobility Toolkit: Implementing Smart Urban Mobility Solutions.* Washington, DC: World Bank Group. Available at: http://documents.worldbank.org/curated/en/099041624092522974

- The **JRC report on Public Transport Research and Innovation** (2021)[7] offered additional perspective on socio-technical enablers such as interoperability, accessibility, and user acceptance.

The association between **Key Enabling Technologies (KETs)** and the indicators used in the Gap Analysis Tool (GAT) was developed through a structured and evidence-informed logic. This approach draws on two primary sources:

- The **World Bank Smart Mobility Toolkit** (2023), which provides practical guidance on the deployment of smart mobility technologies and categorizes them according to functional areas relevant to urban transport systems.
- The review article by **Paiva et al.** (2021)[8], which outlines how digital technologies such as IoT, AI, and data platforms are applied in urban smart mobility, linking these technologies to specific operational capabilities.

Each KET was assigned to one or more subdomains in the GAT based on its functional contribution to a specific aspect of an ITS solution. The mapping process was guided by three main principles:

1. **Function-based alignment.**
   Each subdomain represents a specific capability within a smart mobility ecosystem, such as data collection, system integration, emissions tracking, or user feedback. KETs were selected based on how directly they enable or enhance that function.

   For example, in the subdomain *"Data Use"*, IoT sensors were identified as the relevant KET because they enable real-time data flows necessary for monitoring and predictive analysis (Paiva et al., 2021).

2. **Relevance to practical implementation.**
   KETs were selected based on real-world implementation cases and technology recommendations outlined in the World Bank Toolkit. These include widely used building blocks such as cloud infrastructure, integrated data platforms, and automation systems.

   For example, for the subdomain *"Modular Architecture"*, cloud-based systems were included as a KET due to their role in enabling scalable and flexible deployment of ITS platforms.

3. **Compatibility with international frameworks.**
   Where applicable, KETs were selected to reflect established international standards or common formats for transport systems. This ensures alignment with interoperability requirements and replicability across different contexts.

   For example, for *"Standards Compliance"*, GTFS, NeTEx, and DATEX II were identified as key technologies, as they are globally recognized formats for mobility data exchange and are referenced in both policy and operational guidance.

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[7] **European Commission Joint Research Centre (JRC).** (2021). *Public Transport Research and Innovation in Europe: Key achievements and directions for the future.* Luxembourg: Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC130482

[8] **Paiva, S., Ahad, M. A. R., Tripathi, G., Feroz, N., & Casalino, G.** (2021). Enabling Technologies for Urban Smart Mobility: Recent Trends, Opportunities and Challenges. *Sensors*, 21(7), 2143. **https://doi.org/10.3390/s21062143**

The table below provides a set of examples illustrating how KETs were mapped to specific subdomains in the tool, while Table 2.3 provides a full overview of the domains, subdomains and associated KETs.

Table 2.2 Association of domains and KETS, an example
Source: The Authors

Sub-criteria	Key Enabling Technology (KET)	Justification
A1.1.1 Data Use	IoT Sensors for Mobility Data Collection	Enables **real-time data** acquisition, improving monitoring and decision-making
A2.1 Standards Compliance	GTFS, NeTEx, DATEX II	Ensures **structured data exchange** between different mobility providers
A3.2 Modular Architecture	Cloud-Based System Scaling	Supports **on-demand scalability** of transport management platforms
A4.1 Environmental Benefits	Emission Tracking & Monitoring Tools	Enables **real-time emissions tracking**, aligning with **CO2 reduction goals**

The Gap Analysis Tool (GAT) comprises a total of **33 indicators** distributed across **five thematic areas**, each assessed using a six-level maturity ladder and linked to one or more Key Enabling Technologies (KETs). These indicators are **unevenly distributed**, reflecting the functional scope and technological depth of each thematic area. The majority—**21 out of 33 indicators**—fall under the **Technical Readiness** thematic area. This expanded coverage reflects both the **complexity of Intelligent Transport Systems (ITS)** and the **centrality of technical infrastructure** in enabling smart mobility deployment. Unlike other areas, which address integrative or outcome-focused dimensions, Technical Readiness covers multiple operational subsystems that require dedicated assessment. These include data infrastructure, transport planning and operations, fare collection systems, traffic control, urban space management, and passenger information services—all of which constitute the technological backbone of smart mobility ecosystems.

This imbalance was a **deliberate design choice** rather than a methodological limitation. It ensures that foundational technologies are appraised with sufficient granularity to support system-wide readiness diagnostics. The remaining thematic areas—**Interoperability (3 indicators)**, **Scalability (3)**, **Sustainability Impact (3)**, and **User Acceptance (3)**—are addressed through more integrated indicators. Namely, while **Technical Readiness offers the most comprehensive view**—the accompanying domains of **Interoperability, Scalability and Sustainability Impact, and User Acceptance function as cross-cutting enablers** and assess the **systemic readiness conditions that influence long-term integration, adaptability, and societal responsiveness of smart mobility solutions**.

Each indicator is linked to one or more **predefined KETs**, selected based on their alignment with the functional scope of the subdomain and their relevance for current smart mobility practices, as documented in relevant policy and technical literature.

To account for local context and solution-specific applicability, the tool also allowed partners to mark indicators in the Technical Readiness area as **"not relevant for the pilot solution."** Nevertheless, partners were encouraged to complete the full appraisal regardless of current deployment status, in order to support broader strategic insights and identify future upgrade potential.

This mapping allows the tool to evaluate not only the presence of specific technologies, but also their relevance, applicability, and potential impact within each thematic area.

D.1.4.1 – Technology gap assessment

Table 2.3 Thematic areas, associated sub-criteria (indicators) and KETs,

Source: The Authors

Thematic area	Sub-criteria (Indicators)	Key Enabling Technology (KET)
A1 - Technical Readiness (w40)		
A1.1 Data (w25)	A1.1.1 Data use	IoT sensors for mobility data collection
	A1.1.2 Data security	SSL encryption & database security
	A1.1.3 Data privacy	Role-based access control systems
A1.2 Transport Management (w15)	A1.2.1 Transport service definition	Standard (e.g. GTFS, NeTEx) -based multimodal transport definitions
	A1.2.2 Transport planning functionalities	GIS-based transport planning tools
	A1.2.3 Transport operation functionalities	Fleet tracking & scheduling software
	A1.2.4 Complemental solutions	Route optimization algorithms
A 1.3 Fare Collection (w15)	A1.3.1 Fare collection process	Contactless fare payment systems
	A1.3.2 Technical definition ownership	Integrated Digital Ticketing for Multimodal Payment
	A1.3.3 Interoperability with private services	Interoperable open-loop payment system (e.g. via credit card or wallet)
A1.4 Traffic Management (w15)	A1.4.1 Implemented control	Adaptive traffic signal control
	A1.4.2 Implemented protocols	Communication protocols like for e.g. vehicle routing protocols within VANETs
	A1.4.3 Enforcement tools	Automated enforcement systems
A1.5 Urban Space Management (w10)	A1.5.1 Parking management	Parking occupancy sensors
	A1.5.2 Restricted area access management	Geo-fencing & restricted access control
	A1.5.3 Urban use management	Urban mobility management platforms
A1.6 Security on Mobility (w10)	A1.6.1 Video Surveillance	CCTV surveillance
	A1.6.2 Violence reporting	Crowd movement analytics dashboards
A1.7 Passenger information system (w10)	A1.7.1 Information available onsite	Real-time mobility information available onsite (stops, terminals, hubs),
	A1.7.2 Information available in PT vehicles	Real-time mobility information available in vehicles
	A1.7.3 Information available online	Real-time mobility information via web & mobile apps
A2-Interoperability (w15)		
	A2.1 Standards Compliance	GTFS, NeTEx, DATEX II-based compliance
	A2.2 API & Data Exchange	Secure API management platforms
	A2.3 Cross-System Integration	Transport network data integration systems
A3- Scalability (w15)		
	A.3.1 Expansion Capability	Cloud-based system scaling platforms
	A 3.2 Modular Architecture	Modular ITS architecture software
	A 3.3 Performance Under Load	Load balancing & system performance monitoring
A4-Sustainability Impact (w15)		
	A4.1 Environmental Benefits	Air Quality Sensors & CO_2 Monitoring Systems
	A4.2 Energy Efficiency	Smart Grid-Integrated EV Charging & Vehicle Energy Optimization
	A4.3 Social & Economic Benefits	Equity-Focused Mobility Data Platforms & Economic Impact Models
A5- User Acceptance (w15)		
	A5.1 Cultural & Contextual Relevance	Language localization & translation systems
	A5.2 Ease of Use & Accessibility	Accessible UI/UX design principles
	A5.3 Feedback & Adaptability	User feedback collection & sentiment analysis tools

2.2.2 Maturity scale- Ladder of development

Each item in the tool is evaluated using a **six-level maturity scale, ranging from 0 ("Non-Existent") to 5 ("Optimised"), which reflects progressive stages of technological development**. This structure draws **inspiration from the Technology Readiness Level (TRL) framework** developed by the European Commission for assessing innovation maturity, particularly in complex and infrastructure-intensive sectors such as energy and mobility (European Commission, Directorate-General for Research and Innovation, 2017) [9]. The adapted ladder reflects key TRL milestones—such as concept development, lab validation (TRL 4–5), and real-world demonstration (TRL 6–7)—but translates them into an operational format more suited for policy assessment and urban transport applications.
By anchoring the self-assessment in these established readiness principles, the **SMARTMOBAIR** tool ensures conceptual alignment with broader European innovation evaluation standards while tailoring the interpretation to the specific dynamics of urban ITS deployment. The scale also integrates a qualitative dimension by considering institutional readiness, contextual integration, and continuous improvement, which are often overlooked in purely technical TRL assessments. This hybrid approach allows pilot territories to assess not only the existence of technologies, but also their real-world applicability, scalability, and systemic maturity. The full scale is presented in the table below:

Table 2.4 Ladder of development

Source: The Authors

Maturity Level	Description	Interpretation
0 – Non-Existent	No technology exists	The technology **does not exist** yet.
1 – Initial	Concept only (early stage)	The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started.
2 – Emerging	Prototype tested (Technology validated, TRL 4-5)	The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
3 – Developing	Operational in pilots	The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
4 – Mature	Deployed widely (Demonstrated in real-world settings, TRL 6-7)	The technology is **adopted across the entire city** and integrated into the overall transport system.
5 – Optimized	Fully optimized & continuously improved	The technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.

This laddered structure encourages pilot territories to reflect not only on whether specific technologies or practices are in place, but also on their degree of integration, institutional support, and operational maturity. This supports a more nuanced and context-sensitive understanding of progress, allowing for identification of both current gaps and future development trajectories.

2.2.3 Scoring Logic and Visualization

[9] European Commission: Directorate-General for Research and Innovation, Strazza, C., Olivieri, N., De Rose, A., Stevens, T. et al., *Technology readiness level – Guidance principles for renewable energy technologies – Final report*, Publications Office, 2017, https://data.europa.eu/doi/10.2777/577767

To facilitate comparative analysis across pilot territories and support data-driven prioritization, the Gap Analysis Tool (GAT) incorporates a structured scoring methodology. Each thematic area is operationalized through a set of sub-criteria (indicators), which are individually assessed on a six-level maturity scale (0–5). These scores are then aggregated into weighted thematic scores and a final composite readiness index.

The overall readiness score, ranging from **0 to 5**, serves as a high-level indicator of a pilot territory's technological maturity in the domain of smart mobility. It synthesizes scores across all thematic areas into a single composite value, facilitating a comparative perspective while remaining grounded in qualitative self-assessment.

The following interpretation applies:

- **0.0 – 0.99: Non-Existent to Initial:** Technologies are absent or exist only in conceptual form, with no tangible implementation or preparatory actions.
- **1.0 – 1.99: Emerging:** Technologies have been validated in test or simulated environments but have not entered real-world deployment.
- **2.00 – 2.99: Developing:** Technologies are in early operational stages—typically through pilot projects or limited deployment—with growing integration.
- **3.00 – 3.99: Mature:** Technologies are broadly implemented and used in regular operations, though some optimization may still be needed.
- **4.00 – 5.00: Optimized:** Technologies are fully deployed, integrated into system-wide workflows, and subject to continuous performance monitoring and improvement.

This scale offers a structured but approximate indication of maturity. It should be interpreted with caution, given its aggregation of diverse indicators and potential compensatory effects. Its primary purpose is to support internal reflection and strategic planning rather than benchmarking or ranking.

Weights were applied at two levels:

- **Thematic area level** (e.g. Technical Readiness: w40; Interoperability: w15)
- **Sub-criteria level within Technical Readiness** (e.g. Data: w25; Transport Management: w15; Passenger Information: w10)

The application of **differential weights** reflects both the policy relevance and functional complexity of each domain. For instance, Technical Readiness was assigned a higher overall weight due to its encompassing nature and critical role in enabling ITS deployment. Within this domain, sub-criteria were further weighted based on their operational significance. Where no explicit weight is indicated (i.e. in thematic areas A2–A5), **equal weighting was applied across sub-criteria**, ensuring methodological consistency while simplifying aggregation.

Recognizing the breadth of the Technical Readiness domain and the diversity of local contexts, a **dual appraisal approach** was introduced, allowing marking aspects and KETs not relevant for the pilot, allowing contextual analysis in the frame of the SMARTMOBAIR project.

The Gap Analysis Tool (GAT) automatically generates (in separate sheets) **radar charts** (sheet performance gap) that visualize performance gaps across the five thematic areas. Complementing the radar charts, the tool also produces **bar charts** for each thematic area. These illustrate the scores of individual sub-criteria (indicators), offering a more detailed view of where specific strengths or weaknesses lie. This layered structure enables **technical experts** to identify underperforming areas and supports **non-specialist stakeholders** in understanding the broader performance landscape in a clear and accessible way.

2.2.4 Reflections on Limitations

While the scoring logic provides a structured framework for synthesizing maturity levels across thematic areas, it is important to underscore that the Gap Analysis Tool is **not a diagnostic instrument designed for benchmarking or ranking**. The overall score should be interpreted as a **preliminary screening tool**—a way to visualize internal consistencies, highlight potential development gaps, and facilitate strategic dialogue among stakeholders. The weighting scheme, while grounded in expert judgement, remains **normative and project-specific**, and no formal sensitivity analysis has been applied to test the robustness of the results.

Moreover, the aggregation of sub-scores into a single value may introduce **compensatory effects**, whereby high scores in certain dimensions mask critical gaps in others. As such, the quantitative output should not be viewed as an objective indicator of readiness but rather as a **structured reflection of qualitative judgments** derived from local self-assessment and stakeholder dialogue. The tool is most valuable as a **facilitator of structured discussion**, not as a definitive measure of technological maturity. Its primary contribution lies in **mapping knowledge gaps**, identifying priority areas for intervention, and building a shared understanding of readiness dimensions within and across pilot territories.

2.2.5 Data Collection Process with a Participatory Approach

The data collection process for the Gap Analysis Tool (GAT) was designed with a participatory approach, ensuring consistency, contextual relevance, and stakeholder engagement across the six pilot territories. The self-assessment was conducted by the **Technical Partners (TPs)** in each territory, in close collaboration with their respective **Institutional Implementation Partners (IIPs)** and supported by local **Stakeholder Working Groups (SWGs)**. This collaborative setup ensured that the appraisal process reflected not only technical and infrastructural realities but also institutional practices and the experiences of key local actors.

To support the implementation of the tool, the project coordination team prepared and disseminated a **guidance presentation** that introduced the rationale, structure, and usage of the GAT. In parallel, a detailed **instructions sheet embedded within the Excel file** offered item-by-item explanations for all sections, including how to interpret maturity levels and associate Key Enabling Technologies (KETs) with specific indicators. An initial **two-week period** was allocated for the data collection. During this phase, the lead partner also **shared reflections and examples** from their own experience, promoting horizontal learning and a more consistent understanding of the tool's purpose and use.

Upon receiving the completed tools, the coordination team undertook a **quality review** to ensure completeness and internal consistency. In several cases, partners were contacted to **update missing entries**, particularly where maturity levels had been left unapprised.

This multi-actor, participatory process enhanced both the credibility and utility of the tool. By capturing diverse perspectives—technical, institutional, and societal—it supported shared understanding among local actors and provided a foundation for more targeted, evidence-based planning of smart mobility strategies across the Adriatic-Ionian region.

The participatory nature of the process—rooted in the involvement of SWGs and inter-institutional cooperation—ensured that the resulting dataset captured both the technological conditions and the operational realities of each pilot. This aligns with best practices in sustainable urban mobility planning, where inclusive engagement is increasingly recognized as a prerequisite for effective and locally adapted smart mobility strategies.

3 Technology Gap Assessment Results by Pilot Territory

This chapter presents the results of the technology gap assessment conducted across the six pilot territories involved in the SMARTMOBAIR project: Gorizia, Koper, Niš, Novo Sarajevo, Rethymno and Shkodra. Each subsection is structured around three key components:

- **Territorial Context:** A short territorial profile outlining demographic, geographic, and infrastructural characteristics relevant to smart mobility, based on presentations of the institutional partners at kick-off meeting and Deliverable D1.1.2 on availability of mobility-related data and problems. This section also includes Pilot Solution Overview: A brief summary of the smart mobility solution selected for piloting in each city, based on local priorities and technological capacities based on the data collected within this assessment.
- **Technology Gap Assessment:** A detailed analysis of the results obtained using the Gap Analysis Tool (GAT), including scores and visual outputs. . It includes three parts, i.e. subsections: Performance Gap Summary, Technical readiness including a part on pilot-related assessment results **and Cross-cutting enablers for smart mobility:** subsection related to the results on the Interoperability, Scalability, Sustainability Impact and User Acceptance.
- **Recommendations:** A concise list of priorities to address the identified gaps and accelerate smart mobility deployment. They follow the structure based on the methodology and clustered maturity levels as presented in the table below.

Table 3.1 Structure of the recommendations based on the GAT methodology and clustered maturity levels

Category	Definition	Recommended Action
Non-Existent / Conceptual (Levels 0–1)	Technologies either not present or only at the concept stage	**Initiate and Strategize** — Start feasibility studies, include in policy frameworks, and secure funding to kick-start development.
Emerging / Developing (Levels 2–3)	Technologies tested in pilots or early real-world deployment	**Scale Up and Integrate** — Build on existing pilots, expand deployment, and embed into broader urban mobility systems.
Deployed / Optimized (Levels 4–5)	Technologies fully operational, often city-wide	**Leverage and Sustain** — Maintain, improve, and use these as lead for further ITS expansion. Ensure interoperability and gather user feedback.

3.1 Province of Gorizia (Turriaco e Sagrado, Italy)

3.1.1 Territorial context

Comune di Sagrado

Turriaco and Sagrado are both located in the Friuli Venezia Giulia region in Italy and near the Slovenian border. These municipalities are part of the Province of Gorizia and jointly form a modestly sized territorial unit, covering a combined area of approximately 20 km². The total population is around 5,000 inhabitants, with 2,460 residing in Turriaco and 2,048 in Sagrado.

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

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

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

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

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

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

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

As part of the SMARTMOBAIR project, the pilot in Gorizia labeled as "Public service on call in the Municipalities of Turriaco and Sagrado" focuses on enhancing the efficiency, reliability, and digitalization of public transport services. It will offer a better and more flexible service, reducing the time and effort for operational management.

The application for drivers includes: quick responses to booking requests, integrated navigation, functions with the possibility of automation, adaptation to services with traditional or autonomous driving.

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

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

Trieste Trasporti's on-demand service has been identified as an exemplar for its innovative approach to flexible public transport, offering responsive, user-oriented mobility solutions that complement traditional scheduled services.[10]

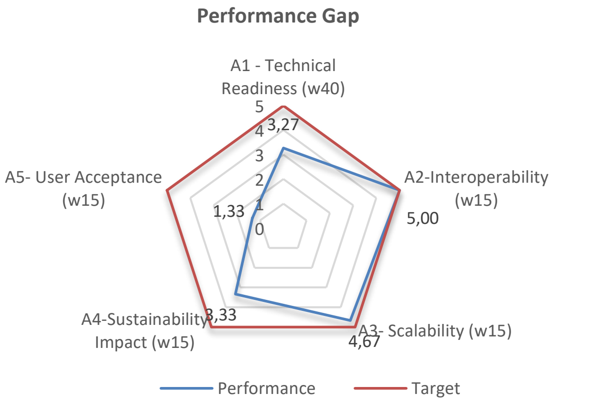
Expected benefits of the pilot include enhanced real-time visibility of services, increased operational efficiency, improved public trust in public transport, and a foundational step toward regional MaaS integration.

3.1.2 Performance Gap Summary

The performance gap analysis for Gorizia reveals a relatively strong starting position in terms of smart mobility deployment, with considerable variation across the assessed dimensions. The appraisal compares the current state of Key Enabling Technologies (KETs) to an optimal level of performance (Level 5 – *Optimized*), offering a structured view of gaps to be addressed for full ITS deployment.

Figure 3.1 Performance Gap Summary for Gorizia

Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The overall technology readiness score for the Gorizia is **3.37**, which places it within the **Mature** category. This indicates that smart mobility technologies are generally deployed and used in regular operations, though further optimization is required to reach full integration and continuous performance improvement. A breakdown across five thematic areas (Figure 3.1) reveals uneven levels of maturity.

- **Technical Readiness** is rated at **3.05**, placing Gorizia at the *Developing* stage. While several technologies are already embedded in operations or fully optimized, others remain limited to pilots or are absent altogether, especially in areas related to traffic and urban space management.
- **Interoperability** achieves the highest possible appraisal at **5.00**, indicating that system-wide standards, APIs, and integration tools are fully deployed and continuously improved.
- **Scalability** is rated at **4.67**, reflecting widespread system readiness for expansion. Most components are either *Optimized* or *Mature*, with only minor gaps in performance monitoring tools.
- **Sustainability Impact** is assessed at **3.33**, reflecting *Developing to Mature* performance. Environmental monitoring systems are in place, but energy and equity dimensions remain less developed.
- **User Acceptance** records the lowest score at **1.33**, highlighting that key technologies for user engagement and inclusivity are largely *Non-Existent* or in early conceptual stages.

This summary points to a well-developed ecosystem in Gorizia for technical deployment and systemic interoperability. However, for the city to transition toward full-scale, inclusive smart mobility, strategic attention

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

must be paid to user-centered design, social impact tracking, and the digital management of physical transport infrastructure.

Due to the qualitative nature of the appraisal process and the compensatory effect embedded in the aggregation of scores, the summarized results may not fully capture the mobility performance across different domains. Therefore, the overall performance gap must be interpreted with caution. To provide a more accurate and informative picture, the report offers a detailed analysis at the level of each assessment dimension.

The following two sub-sections provide a more detailed analysis across the assessed dimensions—first focusing on technical readiness as the core dimension, followed by an examination of cross-cutting enablers, covering interoperability, scalability, sustainability, and user acceptance.

3.1.3 Technical Readiness

With relatively high score for Technical Readiness (3.05) Gorizia shows moderate-to-high maturity, but the uptake is uneven across sub-criteria (Figure 3.2).

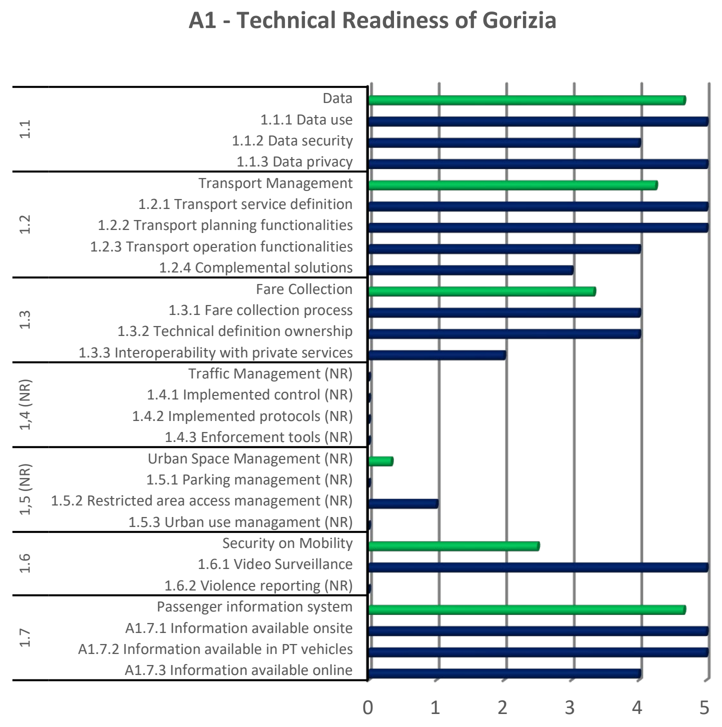
Gorizia demonstrates a **high degree of technical readiness** in the domain of **data-related enablers (A1.1)** for smart mobility, with all three assessed indicators reflecting *Mature* to *Optimized* stages of development. **Data use** has reached the *Optimized* level (score 5), reflecting that **IoT sensors for mobility data collection** are not only fully deployed but are also **operational, continuously improved, and integrated into daily practices**. This indicates that Gorizia has moved well beyond pilots or isolated deployments, establishing an infrastructure capable of supporting real-time monitoring and data-driven mobility services. **Data privacy**, also at the *Optimized* level (score 5), is supported by the use of **role-based access control systems**, suggesting a **fully functional governance mechanism** is in place for managing data access across different user profiles. **Data security** is rated at the *Mature* level (score 4), meaning that **SSL encryption and database protection mechanisms** are widely deployed and operating in real-world conditions. However, the fact that the system has not yet reached full optimization suggests that **while secure data flows are ensured**, further improvements—such as more dynamic threat detection—could still enhance resilience.

The **transport management dimension (A1.2) in Gorizia** demonstrates a solid foundation, with technologies ranging from *Developing* to *Optimized* levels of maturity. This reflects a fairly advanced operational environment, particularly in terms of **service definition and planning**, while some aspects of **transport operations** remain under development. **Transport service definition** has reached the *Optimized* level (score 5), as evidenced by the implementation of **standard-based multimodal transport definitions** (e.g. GTFS, NeTEx). This confirms that **data formats and service structuring are fully harmonized**, enabling effective integration of multimodal services and interoperability across platforms—an essential feature for scalable and user-friendly mobility systems. **Transport planning functionalities** are also at the *Optimized* stage (score 5), associated to the use of **GIS-based transport planning tools**. These means that the tools are embedded into planning routines and decision-making processes, supporting the **mapping, simulation, and optimization of transport networks**. The high maturity level suggests their **routine application** in planning interventions, route changes, or capacity expansions. **Transport operation functionalities** are currently at the *Mature* level (score 4). While **fleet tracking and scheduling software** is operational in real-world settings, the system has not yet reached full optimization. This indicates that **while real-time operational control exists**, additional features—such as predictive analytics, automated incident response may still be lacking or only partially deployed. Finally, **complemental solutions**, particularly the use of **route optimization algorithms**, are apprised at the *Developing* stage (score 3). This means that **such tools are likely used within pilot segments or in limited operational areas**, but not yet adopted system-wide. There may be room for greater automation and real-time integration with traffic or demand data to fully exploit their potential.

The **fare collection ecosystem (A.1.3)** in Gorizia demonstrates varying levels of technological maturity across its components, reflecting **a partially consolidated system** with a room for integration and scaling—particularly in relation to private sector interoperability. The **fare collection process** is at a *Mature* level (score 4), supported by the use of **contactless fare payment systems**. This indicates that such systems are **deployed in real-world settings and integrated into daily operations**, offering a streamlined and efficient payment experience for public transport users. However, the system has not yet reached full optimization, suggesting potential for **enhanced user interface, faster validation, or expanded device compatibility**. The **technical definition ownership**, referring to the digital and structural setup for multimodal fare collection, is also assessed at a *Mature* stage (score 4). This is enabled by an **Integrated Digital Ticketing system for Multimodal Payment**, which implies that different transport modes can be accessed using a unified fare medium. Although integration exists, **comprehensive multimodal interoperability (including fare capping or account-based ticketing)** may still be under development, hence not yet fully optimized. The greatest gap in this area lies in the **interoperability with private services**, such as shared mobility operators or intercity travel providers. The use of **interoperable open-loop payment systems** (e.g., credit card or mobile wallet integration) is only at the *Emerging* level (score 2), indicating **limited testing or early-stage deployment**. This limits user flexibility and **restricts seamless cross-provider journeys**, which is increasingly important in MaaS (Mobility-as-a-Service) environments.

Figure 3.2 Technical Readiness of Gorizia

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

0 – Non-Existent/The technology **does not exist** yet;

1 – Initial/Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;

2 – Emerging/Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.

3 – Developing/Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.

4 – Mature/Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.

5 – Optimized/Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

NR – technology not relevant for the pilot

Smart technologies for **Traffic Management (A1.4)** in Gorizia are **non-existent**, **not even at the conceptual level.** There is no evidence of planning, piloting, or referencing of solutions such as **adaptive traffic signal control**, **communication protocols for vehicle routing (e.g., VANETs)**, or **automated enforcement systems** in existing discussion or moreover plans, strategies or documents. This indicates that **no development has yet been initiated**, and **no conceptual groundwork has been laid** to support the evolution of intelligent traffic control and enforcement functionalities. As such, this dimension represents a clear gap and starting point for future capacity building and planning efforts.

Similar the **Urban Space Management (A1.5)** dimension in Gorizia is at an **initial to non-existent level**, indicating that digital tools and technologies to manage urban mobility zones and access are either missing or remain at the earliest stages of conceptualization. Technologies such as **parking occupancy sensors** and **urban mobility management platforms** are **non-existent**, with no indication of development or deployment. The only exception is a minimal indication of conceptual awareness for **geo-fencing and restricted access control**, suggesting some early-stage discussions or references may exist, though no technical preparations or pilot initiatives have been launched. Overall, this area reveals substantial room for foundational investment and planning to enable digital urban space regulation.

The **Security on Mobility** (A1.6) displays a mixed level of development. **CCTV surveillance** is fully **optimized** (level 5), indicating that video surveillance systems are extensively implemented and continuously maintained across mobility-relevant areas. This suggests robust infrastructure for monitoring public spaces and enhancing safety. However, **crowd movement analytics dashboards**, intended for advanced incident detection and violence reporting, are entirely **non-existent**. No evidence exists of their deployment or even conceptual discussion. The contrast between the advanced use of traditional surveillance and the absence of intelligent analytics highlights an opportunity to enhance proactive security capabilities.

The **Passenger Information System (A1.7)** in Gorizia is at a highly developed stage. Both **real-time mobility information available onsite** (e.g. at stops, terminals, and hubs) and **within public transport vehicles** have reached the **optimized** level (5), indicating full implementation and continuous operational use. These services ensure that passengers have timely and accurate updates on transit schedules and arrivals, enhancing travel efficiency. Additionally, **real-time mobility information via web and mobile apps** is evaluated as **mature** (level 4), meaning that these platforms are widely adopted but may still lack full system-wide integration or real-time optimization features. This robust combination of physical and digital information access represents one of the strongest aspects of Gorizia's smart mobility.

Table 3.2 summarizes the uptake of KETs for smart mobility in Gorizia. A fair number of technologies are at the desired level implying full deployment at the municipality level or even full optimization.

Table 3.2 Uptake of KETs for smart mobility in Gorizia

Source: SMARTMOBAIR Gap Analysis Results

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	Emerging / Developing (Level 2–3)	Non-Existent / Conceptual (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• **IoT sensors for mobility data collection** • **Role-based access control systems** • **SSL encryption & database security** • **Standard-based multimodal transport definitions (GTFS, NeTEx)** • **GIS-based transport planning tools** • **Fleet tracking & scheduling software** • **Contactless fare payment systems** • **Integrated digital ticketing for multimodal payment** • **Real-time info onsite (stops, terminals)** • **Real-time info in vehicles** • **Real-time info via web & mobile apps** • **CCTV surveillance**	• **Interoperable open-loop payment systems** • **Route optimization algorithms**	• Adaptive traffic signal control • Communication protocols (e.g., VANETs) • Automated enforcement systems • Parking occupancy sensors • Urban mobility management platforms • Geo-fencing & restricted access control • Crowd movement analytics dashboards

The categorization of Key Enabling Technologies (KETs) according to their maturity levels serves as a foundation for strategic planning within the SMARTMOBAIR framework. Technologies assessed as being at the highest levels of maturity—**Fully Deployed or Optimized (Levels 4–5)**—should be **leveraged and sustained**. This entails maintaining current systems, ensuring their long-term operability, and enhancing performance through advanced functionalities and continuous feedback mechanisms. In these cases, the focus should shift towards performance optimization, expansion of coverage, and ensuring interoperability with other urban mobility systems such as Mobility-as-a-Service (MaaS) platforms.

Technologies evaluated at **Emerging or Developing levels (Levels 2–3)** represent areas where foundational elements are in place, yet broader integration and scalability remain to be achieved. For these, the recommended course of action is to **scale up and integrate**. Efforts should target extending pilot applications into full-scale deployment, supported by dedicated funding, institutional coordination, and iterative testing. These technologies warrant particular attention in upcoming planning cycles, as they can have substantial impact once fully embedded into the urban mobility ecosystem.

Conversely, technologies identified as **Non-Existent or Conceptual (Levels 0–1)** require the most urgent strategic attention. These are typically absent from current planning or exist only in preliminary conceptual forms, without any tangible development or pilot activity. For this category, the proposed course of action is to **initiate and strategize**, beginning with feasibility assessments, stakeholder consultations, and alignment with broader urban development and sustainability goals. These foundational steps are necessary to create the enabling conditions for future deployment, including securing funding, defining technical specifications, and building institutional readiness.

In the context of the SMARTMOBAIR pilot in Gorizia, which aims to enhance digitalization and operational efficiency of public transport services through the deployment of ITS and MaaS-ready tools, the uptake of relevant Key Enabling Technologies (KETs) presents a mixed landscape. While several components critical to real-time passenger information and AVM are in place or at an advanced level of maturity, a subset of relevant KETs remains at early stages of development. Based on the gap assessment results 14 KETs are apprised as relevant for the pilot (black and bold in Table 3.2) and they fall either in developed/optimized or emerging/developing level.

Technologies assessed at the **emerging or developing level (levels 2–3)**—such as *interoperable open-loop payment systems* and *route optimization algorithms*—are operational in limited contexts or exist as early prototypes. These require **scaling up** and **contextual adaptation** to move from isolated implementations toward system-wide functionality. Their gradual advancement is key for increasing system intelligence and preparing for MaaS convergence at the municipality level.

Several technologies assessed at **mature or optimized levels (4–5)**—notably *real-time mobility information systems*, *fleet tracking*, *contactless fare collection*, and *IoT-based data acquisition*—can be **leveraged immediately** to demonstrate early pilot success and support user acceptance. These components should serve as the technological foundation upon which further integration and innovation can be built.

Among the KETs assessed, those at a **non-existent or merely conceptual stage (levels 0–1)** include *automated enforcement systems*, *urban mobility management platforms*, and *communication protocols for vehicle routing*, which are essential for broader integration, interoperability, and operational optimization of ITS solutions. Although these technologies are **not strictly required to implement the pilot** in its current scope, their absence may become increasingly problematic in the post-pilot phase, especially when aiming to achieve seamless multimodal integration and real-time coordination across systems. As such, these critical KETs should be **strategically initiated and developed** in parallel to pilot activities to avoid future deployment bottlenecks.

In sum, while the pilot is well-supported by a baseline of functional technologies, its long-term success and regional scalability depend on **strategic attention to critical KETs currently at low maturity levels**. Addressing these gaps proactively ensures that the pilot acts not merely as a local intervention, but as a stepping stone toward **full ITS deployment and MaaS integration** across the Municipality of Gorizia.

3.1.4 Cross-Cutting Enablers for Smart Mobility

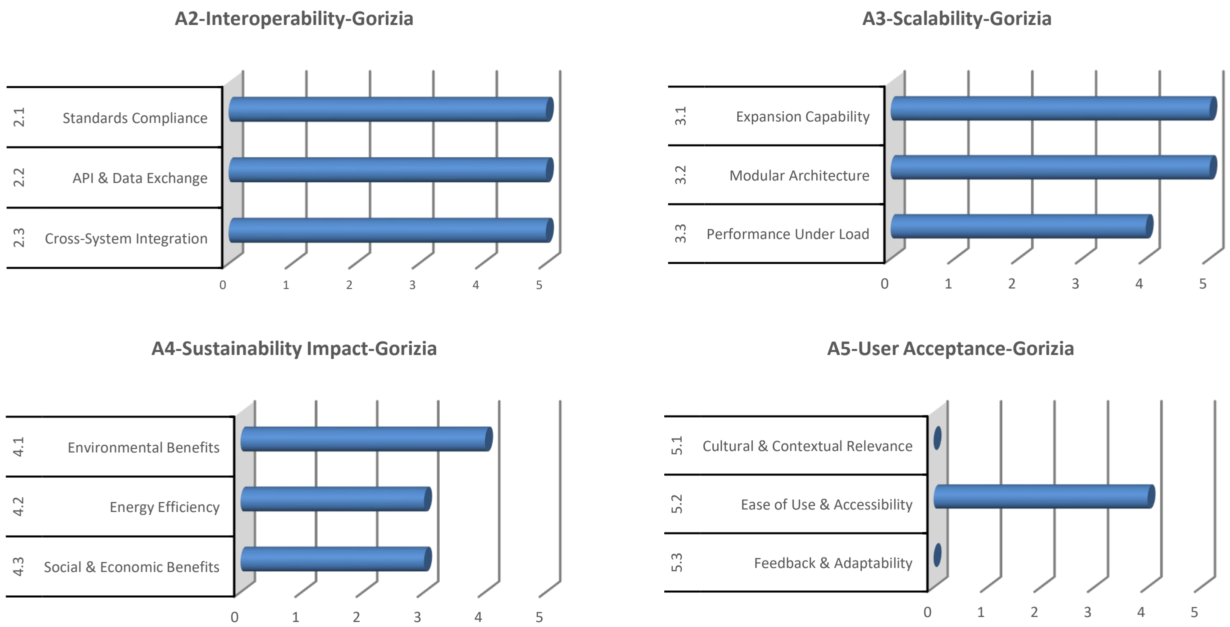
Figure 3.3 offers visualization of the cross-cutting enablers (Interoperability, Scalability, Susitanability Impact and User Acceptance) maturity for the Gorizia extracted from the GAT.

Gorizia demonstrates an **Optimized** level of maturity (score 5.0) in the domain of **interoperability** (A2), suggesting that technologies are fully implemented and continuously improved. All three sub-criteria—**Standards Compliance**, **API & Data Exchange**, and **Cross-System Integration**—have reached the highest level of technological maturity. The use of GTFS, NeTEx, and DATEX II standards ensures seamless communication between different systems and data formats. Secure API management platforms and integrated transport network data systems support real-time operations, indicating a highly interoperable smart mobility environment.

Scalability (A3) is assessed at a **Mature to Optimized** level (average score 4.67), reflecting widespread adoption with elements of ongoing improvement. Technologies such as **Cloud-based system scaling platforms** and **Modular ITS architecture software** have achieved the **Optimized** stage (score 5), indicating full deployment and operational use that can accommodate system expansion and functional upgrades. **Performance under Load**, evaluated at the **Mature** level (score 4), suggests that while load balancing and monitoring are actively used, some optimization potential remains to ensure reliable service during peak usage.

Sustainability Impact (A4) dimension shows a **Developing to Mature** level of technological maturity (average score 3.33). **Environmental Benefits**, supported by the deployment of air quality and CO_2 monitoring systems, are at the **Mature** level (score 4), suggesting real-world application but not yet full optimization. **Energy Efficiency** and **Social & Economic Benefits** are both at the **Developing** stage (score 3), indicating operational pilots or partial deployment of energy optimization systems and equity-focused mobility planning tools. Further integration and system-wide scaling would be necessary to transition toward optimized use.

Figure 3.3 Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Gorizia
Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:
- **0 – Non-Existent/**The technology **does not exist** yet;
- **1 – Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- **2 – Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- **3 – Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- **4 – Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- **5 – Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

User Acceptance (A5) represents the most critical gap in Gorizia's smart mobility ecosystem, with an overall maturity level of **Emerging to Non-Existent** (average score 1.33). **Ease of Use & Accessibility** is rated as **Mature** (score 4), indicating that user interface and design considerations have been significantly addressed. However, **Cultural & Contextual Relevance** and **Feedback & Adaptability**—supported by language localization systems and sentiment analysis tools, respectively—are rated as **Non-Existent** (score 0). This lack of adaptation to diverse user needs and absence of feedback mechanisms poses a serious constraint for future deployment and acceptance of advanced ITS solutions.

In summary Gorizia demonstrates strong performance in interoperability and scalability, with systems fully deployed and continuously improved. Sustainability shows moderate maturity, with environmental monitoring in place but limited progress on energy and socio-economic metrics. User acceptance remains a major weakness—despite accessible interfaces, there is no support for cultural adaptation or user feedback, which may hinder broader adoption of smart mobility solutions.

3.1.5 Recommendations for Bridging the Smart Mobility Technology Gap in Gorizia

This section builds directly on the findings of the preceding analysis to provide structured recommendations for addressing the smart mobility technology gap in Gorizia. Drawing from the maturity assessment of Key Enabling Technologies (KETs) and the appraisal of cross-cutting enablers—including interoperability, scalability, sustainability impact, and user acceptance—the recommendations aim to guide the territory from a partially optimized landscape toward a more integrated and inclusive smart mobility ecosystem.

The analysis revealed a relatively strong level of technical readiness—particularly in digital public transport services such as real-time information systems, automatic vehicle monitoring, and integrated fare collection. These tools are actively used across the pilot area, which spans the municipalities of Turriaco and Sagrado. However, the uptake of enabling technologies remains uneven: while data standards and operational tools are well developed, major gaps persist in areas such as digital traffic management, urban space coordination, and user-centric services. Notably, the city's weakest dimension is user acceptance, reflecting a lack of feedback systems, accessibility tools, and localized user interfaces.

To address these issues, the recommendations are structured according to the three-tiered maturity framework applied in the SMARTMOBAIR gap analysis:

- technologies at **initial** levels requiring strategic initiation,
- those at **emerging** stages needing scale-up and integration, and
- **mature or optimized** systems where efforts should focus on consolidation and future-proofing.

This approach allows the recommendations to target both pilot-specific implementation needs and broader territorial transformations needed for long-term ITS and MaaS readiness.

3.1.5.1 Initial-Level Technologies: Strategic Initiation

Several Key Enabling Technologies (KETs) remain at a non-existent or conceptual stage in Gorizia. These include adaptive traffic signal control, communication protocols, parking occupancy sensors, urban mobility management platforms, and crowd analytics. Although not immediately required for pilot implementation, their absence poses limitations for future interoperability, enforcement, and spatial coordination.

Priority actions include:

- **Initiate pilot planning for adaptive signal control** and smart intersection management, especially near commuter corridors and sensitive pedestrian areas.
- **Develop conceptual frameworks for digital enforcement systems** like (speed-cameras or Illegal parking detectors) even if short-term deployment is not feasible.
- **Prepare technical specifications for parking occupancy monitoring**, which could inform both access control and MaaS integration.

- **Launch a feasibility study on urban mobility platforms**, identifying the conditions for connecting space management tools.
- **Introduce analytics pilots for crowd detection and incident management**, leveraging the strong CCTV foundation already in place.

These early interventions will ensure that foundational systems are in place to support multi-dimensional coordination and long-term ITS expansion.

3.1.5.2 Emerging/Developing Technologies: Scaling and Integration

Technologies like route optimization algorithms and interoperable open-loop payments are currently at prototype or pilot stages. Their advancement is critical to improving operational efficiency and enabling frictionless multimodal travel within a MaaS ecosystem.

Recommended next steps:

- **Expand open-loop payment pilots** in partnership with public transport operator (TPL-FVG) and regional authorities to support seamless ticketing across mobility providers.
- **Scale route optimization algorithms** beyond internal pilots, integrating them into AVM and planning systems to support real-time service adjustments and energy savings.
- **Define a MaaS interoperability roadmap**, ensuring that developing systems align with the future regional platform planned for 2025.
- **Improve internal data sharing frameworks**, standardizing formats and APIs across local actors to facilitate system convergence.

Integrating these technologies into existing assets will reinforce Gorizia's role as a MaaS-ready testbed and enhance the performance of public transport operations.

3.1.5.3 Mature/Optimized Technologies: Consolidation and Future-Proofing

Core technologies—such as real-time passenger information, contactless fare systems, and data security mechanisms—are already mature or optimized. To preserve and enhance their value, efforts should focus on performance monitoring, user transparency, and cross-system integration.

Recommended actions include:

- **Maintain continuous improvement cycles** for real-time information systems, introducing predictive functionalities (e.g., delay forecasting, dynamic scheduling).
- **Leverage fare and trip-planning data** to inform service optimization and pricing strategies that balance demand and equity.
- **Embed user data protections** (e.g., encryption and role-based controls) into municipal mobility policies to ensure GDPR-compliance across expanding platforms.
- **Establish a user-facing dashboard** to collect service feedback, travel behavior data, and incident reports in real time.
- **Coordinate with regional authorities** to ensure that optimized local systems feed directly into the Province-wide MaaS infrastructure, without duplication.

These efforts will help anchor existing strengths into a system that is resilient, user-focused, and aligned with broader regional innovation goals.

3.1.5.4 Strategic summary

This section outlines the key strategic priorities emerging from the technology gap assessment and corresponding recommendations, providing guidance for phased and context-sensitive advancement of smart mobility in the territory.

In summary, bridging the smart mobility technology gap in Gorizia requires both consolidation of advanced public transport tools and proactive investment in underdeveloped domains such as traffic management, space regulation, and user engagement. The city's solid performance in interoperability and scalability creates a strong foundation, but the lack of digital enforcement systems, planning instruments, and user feedback mechanisms may constrain future integration and regional MaaS convergence. The recommended actions reflect a layered strategy that balances short-term implementation with long-term system development.

Strategic priorities for Gorizia include:

- **Initiate foundational systems** for traffic regulation, urban space management, and incident analytics to prepare for full ITS deployment;
- **Scale emerging tools** like open-loop payments and route optimization to improve operational performance and enable multimodal integration;
- **Consolidate existing public transport technologies**, ensuring stable operation, user transparency, and system-wide interoperability;
- **Strengthen data governance and institutional coordination**, building readiness for seamless integration with the forthcoming regional MaaS platform;
- **Address critical gaps in user acceptance** by embedding accessibility.

It should be emphasized that **these recommendations are intended as a flexible guide to inform strategic planning rather than as strict operational prescriptions.** The translation of these proposals into concrete plans and policies in Gorizia should consider territorial specificities, funding availability, and the broader regional framework for smart mobility development. **Close alignment with future regional initiatives, including Mobility-as-a-Service integration efforts, will be key to ensuring coherence and long-term impact.**

3.2 Municipality of Koper (Slovenia)

3.2.1 Territorial context

MESTNA OBČINA KOPER
COMUNE CITTA DI CAPODISTRIA

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

Due to its compact and walkable layout, the population density in this area is relatively high, with an estimated 4,000–5,000 inhabitants per km^2, higher than the municipality-wide average. While the total area of the historical center is approximately 1 km^2, the overall Municipality of Koper spans a more diverse urban and rural mix. Traffic peaks typically occur in the morning (7:00–10:00) and afternoon (14:00–17:00), reflecting commuter and freight movement patterns.

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

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

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

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

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

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

The solution builds upon an existing technology developed by "Palisada sistemi"[11], which has been successfully deployed in Slovenia and is now adapted for the specific needs and regulatory environment of Koper.

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

3.2.2 Performance Gap Summary

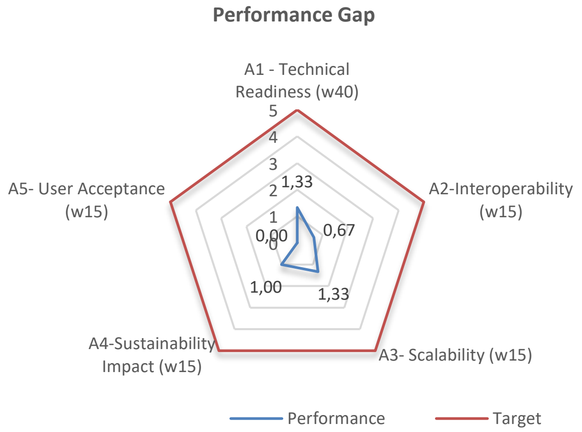
The performance gap analysis for Koper (Figure 3.4) highlights a considerable distance from the theoretical benchmark of full optimization (score 5.0), with an overall appraisal as **Initial** (Score **0.92**). This indicates that while certain foundational elements may exist, the deployment of advanced Key Enabling Technologies (KETs) across critical dimensions remains very limited.

The **technical readiness** is apprised as **Emerging** (1.18) reflects early-stage activity, where selected technologies—such as digital fare systems or planning tools—may be tested or partially applied, but without broader system-wide implementation.

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

Figure 3.4 Performance Gap summary for Koper

Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The **user acceptance** dimension is **Non-Existent.** It is important to note that, does not imply an absence of user-facing functionalities or efforts, but rather the lack of integration of advanced technologies—such as UI/UX optimization, multilingual access systems, or user feedback analytics—that would elevate the experience toward smart mobility standards.

Interoperability, is characterized as **Non-Existent to Initial** (0.67), pointing to low engagement with data standards, secure APIs, and integration protocols.

By contrast, **scalability**, is at **Emerging** stage (1,33), and shows some early progress, likely through modular system planning or cloud-based infrastructure considerations. However, institutional readiness to support broader deployment appears to be lacking.

Sustainability,is also rated as **Emerging** (1.0), indicates recognition of environmental and social impacts but without implementation of KETs such as air quality sensors, energy optimization tools, or impact modelling.

Given the **qualitative nature of the appraisal** and the **compensatory effect among dimensions**, aggregated scores such as the overall appraisal level may not fully capture the actual performance or readiness of the system. Therefore, it is essential to move beyond the aggregated score and provide a **more detailed dimension-level analysis**, which follows in the two subsequent sub-sections.

3.2.3 Technical Readiness

With a composite score of **1.18**, the city of Koper currently demonstrates a **low level of technical readiness** for smart mobility deployment, placing it in the **Emerging stage**, where technologies are either still in controlled testing environments or conceptual development phases. Koper presents a fragmented landscape with few KETs deployed in practice as observable from Figure 3.5.

The **data-related enablers (A1.1)** show **limited maturity**. While **IoT sensors for mobility data collection** and **SSL encryption and database security** are both apprised as **Emerging (level 2)**, there is **no evidence** of implementation or even conceptual discussion for **role-based access control systems** (score 0), suggesting **an absence of data privacy mechanisms** necessary for structured and secure smart mobility ecosystems.

In the area of **Transport Management (A1.2)**, readiness remains at a basic stage. Transport planning functionalities based on GIS tools and operations based on software solutions are apprised as **Initial** (level 1)**,** indicating their presence in planning discussions or early-stage concepts, without real-world deployment. Complementary services embedding **route optimization algorithms** and **standard-based multimodal transport definitions** are rated **Non-Existent,** pointing to a lack of digital structuring of transport services.

The **fare collection ecosystem (A1.3)** is **undeveloped**, with **all three indicators apprised as Non-Existent**. There is currently no infrastructure or conceptual activity around **contactless fare systems**, **multimodal digital**

ticketing, or **interoperable open-loop payment systems**. This absence limits Koper's potential for seamless and integrated user experiences e.g. within MaaS concept.

The picture for **traffic management (A1.4)** is more varied. While **implemented control** based on **adaptive traffic signal control** is apprised as **Initial** (level 1)**,** both **communication protocols** and **automated enforcement systems** are in **Developing** stage (level 3)**.** This suggests pilot-level activity or early operational testing, which—despite being localized—represents a comparative strength

Urban Space Management (A1.5) shows signs of higher maturity. **Geo-fencing and restricted access control** and **urban mobility management platforms** are each apprised as **Mature** (at level 4)**,** indicating they are deployed in real-world settings and integrated into mobility governance processes. However, **parking occupancy sensors** are at **Initial stage (1)**, showing room for improvement in real-time space utilization monitoring.

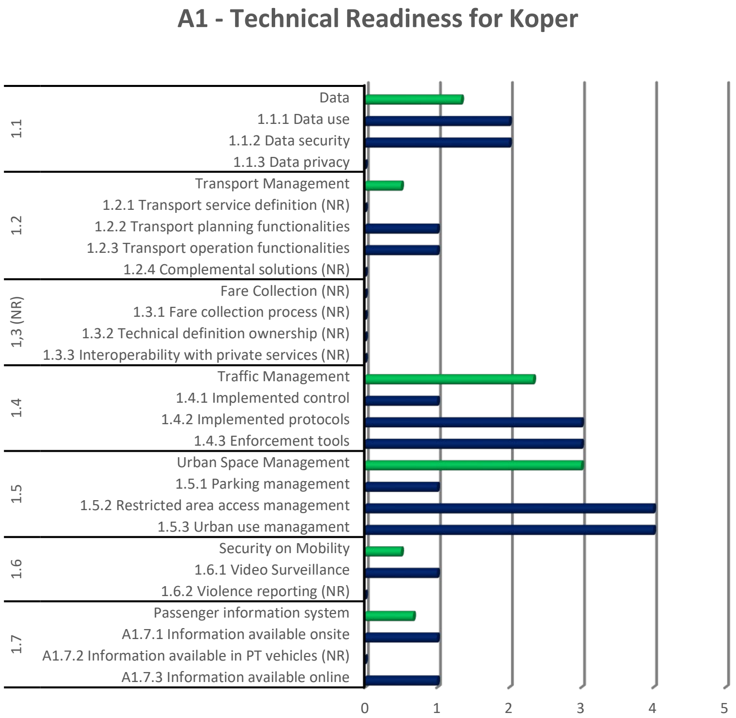
The **Security on Mobility (A1.6)** dimension remains underdeveloped. **CCTV surveillance** is at **Initial level** (1)**,** and **crowd movement analytics dashboards** are **Non-Existent.** This limits the ability to respond proactively to mobility-related safety challenges or unusual events in public space.

Finally, in the area of **Passenger Information Systems (A1.7)**, Koper currently has very limited capabilities. Both **real-time information at stops** and **online platforms** are at the **Initial level** and **onboard real-time information systems** are **absent**.

Table 3.6 summarizes the uptake of KETs for smart mobility in Koper. Several technologies are nonexistent or in the conceptual phase.

Figure 3.5 Technical Readiness of Koper

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

0 – Non-Existent/The technology **does not exist** yet;

1 – Initial/Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;

2 – Emerging/Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.

3 – Developing/Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.

4 – Mature/Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.

5 – Optimised/Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

NR – technology not relevant for the pilot

Technologies evaluated at **Optimized or Deployed** levels (Levels 4–5), such as *geo-fencing & restricted access control* and *urban mobility management platforms*, should be **leveraged and sustained**. These systems form the backbone of Koper's pilot and broader smart mobility ambitions. The recommendation is to ensure their **long-term operability**, secure their **interoperability with future ITS modules**, and invest in **continuous improvements** through feedback mechanisms and user performance data.

Technologies currently at **Emerging or Developing** stages (Levels 2–3)—notably *IoT sensors for mobility data collection*, *SSL encryption & database security*, *communication protocols*, and *automated enforcement systems*—should be targeted for **scaling up and integration**. Although present in limited capacity, these systems represent important enablers for broader ITS deployment. Priority actions include **expanding their coverage**,

aligning data standards, and embedding them into **real-time monitoring systems**, especially in light of Koper's ambition to optimize access control and regulate urban traffic through digital means.

Table 3.3 Uptake of KETs for smart mobility in Koper

Source: Gap analysis results for Koper

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	Emerging / Developing (Level 2–3)	Non-Existent / Conceptual (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• **Geo-fencing & restricted access control** • **Urban mobility management platforms**	• **IoT sensors for mobility data collection** • **SSL encryption & database security** • **Communication protocols (e.g., VANETs)** • **Automated enforcement systems**	• **Role-based access control systems** • GTFS/NeTEx-based multimodal transport definitions • **GIS-based transport planning tools** • **Fleet tracking & scheduling software** • Route optimization algorithms • Contactless fare payment systems • Integrated digital ticketing for multimodal payment • Interoperable open-loop payment systems • **Adaptive traffic signal control** • **Parking occupancy sensors** • **CCTV surveillance** • Crowd movement analytics dashboards • Real-time mobility information available in vehicles • **Real-time mobility information (onsite, in vehicles, via web/mobile apps)** • **Real-time mobility information available onsite (stops, terminals, hubs),**

The most critical technologies, however, fall within the **Non-Existent or Conceptual** category (Levels 0–1). This includes essential ITS components such as *real-time passenger information systems*, *contactless payment*, *fare integration*, *adaptive traffic signals*, and *data privacy mechanisms*. These gaps reflect either a complete absence or the existence of only early conceptual discussion, with no deployment or piloting in place. For these, the recommendation is to **initiate and strategize**. This begins with feasibility assessments, stakeholder engagement, and securing investment through national and EU-level funding instruments. Given the city's aspirations in the SMARTMOBAIR project, it is crucial that these technologies be introduced to avoid bottlenecks in scaling and ensure that pilot efforts evolve into fully operational smart mobility services.

In summary, while Koper demonstrates early progress in urban access management and control technologies, the broader ITS landscape remains fragmented. A **strategic mix of consolidation, scaling, and foundational investment** is recommended to enable integrated and sustainable smart mobility deployment in the future.

In the context of the SMARTMOBAIR pilot in Koper—focused on enhancing traffic regulation and stationary vehicle control in the historic city center—the readiness of relevant Key Enabling Technologies (KETs) is mixed, with a small cluster of technologies showing immediate applicability, while others remain in early stages or conceptual phases, based on the assessment results 14 KETs are apprised as associated with the pilot (black and bold in Table 3.6)

Core components such as **geo-fencing and restricted access control** and **parking occupancy sensors** are at a **mature level (Level 4)**, indicating they are already implemented and capable of supporting the pilot's main goals. These technologies underpin the ability to regulate vehicle entry, improve pedestrian safety, and reduce congestion especially around Kosovel Square, a sensitive urban zone with high foot traffic and constrained infrastructure.

Other related technologies—such as **adaptive traffic signal control**, **communication protocols for vehicle routing**, and **automated enforcement systems**—are at the **developing level (Level 3)** or below. These could provide valuable support functions for managing vehicle flow around restricted zones and ensuring compliance but are not currently deployed to their full potential. Although they might not impede the early implementation of the pilot for future upgrades and upscale these technologies should be envisioned as crucial.

Several supporting enablers, however, remain at **low maturity levels**. For example, **urban mobility management platforms**, **real-time mobility information systems**, and **crowd movement analytics** are either **non-existent or only in conceptual phases (Levels 0–1)**. While not critical for the current scope of the pilot, these gaps could limit the pilot's scalability, monitoring capabilities, and responsiveness to dynamic urban conditions.

A particularly important gap is found in **data privacy and security infrastructure**, which currently lacks adequate deployment. As the pilot includes automated license plate recognition (ALPR) and digital monitoring tools, the absence of role-based access control and encryption mechanisms may present barriers to secure and compliant operation—especially if expanded in the future.

In summary, the KETs most relevant to the Koper pilot's implementation are in place or in progress, providing a credible basis for short-term success. However, for sustained impact and long-term regulatory control, investment in digital infrastructure, enforcement automation, and secure data management will be necessary. Addressing these issues proactively will strengthen the pilot's contribution to more controlled, efficient, and citizen-friendly mobility in the city's historic core.

3.2.4 Cross-Cutting Enablers for Smart Mobility

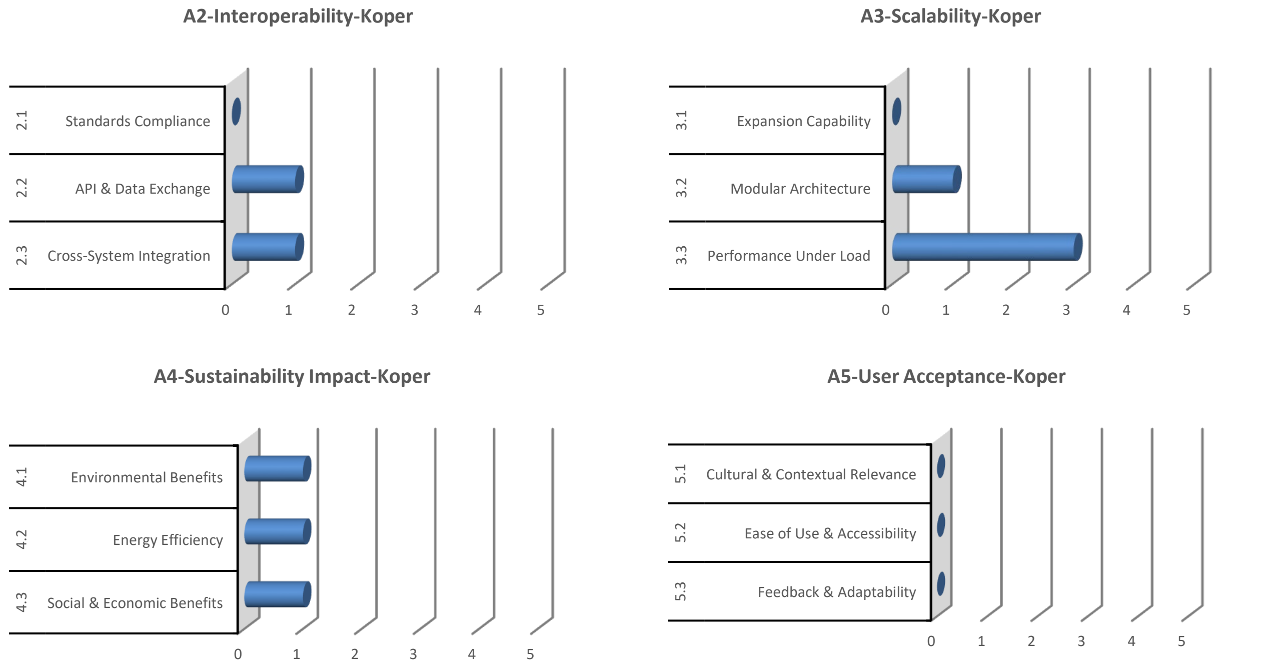
Koper's performance across the broader Cross-Cutting smart mobility enablers—**interoperability, scalability, sustainability impact, and user acceptance**—remains limited, with the overall assessment reflecting early-stage development across all domains (Figure 3.7).

Interoperability (A2) is assessed at a **Non-Existent to Initial** level (score: 0.67), indicating the absence or conceptual maturity of supporting systems for data exchange and cross-platform integration. The city has **no current implementation** of **GTFS, NeTEx, or DATEX II-based standards**. **API and data exchange capabilities**, as well as cross-system integration platforms, are at the **Initial** stage, with some basic references or plans in place but no practical deployment.

Scalability (A3) is rated at the **Emerging** level (score: 1.33). While there is **no indication** of deployment for **cloud-based scaling platforms** (Non-Existent level), modular ITS architectures have reached the **Initial** stage, suggesting early conceptualization. The only relatively advanced sub-dimension is **Performance Under Load**, which stands at the **Developing** level, indicating that some functionalities for monitoring and managing system performance are already being tested in real-world settings.

Sustainability Impact (A4) is uniformly at the **Initial** level (score: 1.00), with all three sub-criteria—**Environmental Benefits**, **Energy Efficiency**, and **Social & Economic Benefits**—at the same stage. While the presence of such topics in policy discussions may exist, there is **no operational deployment** of technologies such as **air quality monitoring**, **energy optimization tools**, or **equity-focused planning instruments**.

Figure 3.6 *Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Koper*
Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:
- 0 – **Non-Existent/**The technology **does not exist** yet;
- 1 – **Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- 2 – **Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- 3 – **Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- 4 – **Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- 5 – **Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

User Acceptance (A5) is at a **Non-Existent** level (score: 0.00), marking it as the most critical gap in Koper's digital mobility ecosystem. **No supporting technologies**—such as **language localization**, **accessible UI/UX**, or **feedback and sentiment analysis tools**—are in place or even conceptually referenced. This complete absence of user-centric infrastructure poses a barrier to inclusive and responsive smart mobility development.

In summary, Koper's cross-cutting enablers for smart mobility technologies remain at a conceptual or very early implementation stage. While isolated initiatives point to a modest uptake in system monitoring capabilities, the broader ecosystem currently lacks the technological maturity required to support scalable, interoperable, and citizen-focused ITS deployment. Strategic efforts are needed to build foundational capabilities across these four domains and ensure systematic readiness for future mobility transformations.

3.2.5 Recommendations for Bridging the Smart Mobility Technology Gap in Koper

The technology gap assessment conducted for the Municipality of Koper highlights both strengths and limitations in the current application of digital technologies to urban mobility. While certain systems—such as geofencing and access control—are well-developed, many other Key Enabling Technologies (KETs) remain at early stages of maturity or are not yet deployed. This results in a fragmented ecosystem with limited interoperability, low levels of real-time information, and underused potential for data-driven planning.

The recommendations below are structured around the assessed maturity levels of different technologies, and with some reflection on the specific characteristics of Koper. They are designed to support a gradual but strategic transition toward a more integrated and user-responsive smart mobility system. While the ongoing pilot in the historic center—aimed at improving access regulation through geofencing and ALPR technologies—offers a valuable platform for testing and integration, these recommendations address the wider city context and long-term urban mobility needs.

The gap analysis conducted for Koper reveals a mixed readiness landscape: while the city has taken notable steps in regulating access and piloting geo-fencing solutions, most enabling technologies for smart mobility remain at conceptual or pilot stages. The system is fragmented, with a limited foundation for interoperability, real-time responsiveness, and user inclusion. Given the historic core's complexity, tourist pressure, and ambitions outlined in the updated SUMP and SMARTMOBAIR project, the following recommendations are proposed. They are structured across three maturity levels of technology uptake, reflecting both specific territorial needs and broader system-level transformations required.

3.2.5.1 Initial-Level Technologies: Laying the Foundation

Many critical enablers in Koper are either non-existent or only in the early conceptual stage. These include user-facing digital services, privacy and data security, fare integration, and real-time passenger information systems. The lack of these basic services hampers both compliance and user experience in the access-regulated zones.

To address these foundational gaps:

- **Introduce simple digital user notifications**, such as web- or app-based alerts for access permissions, parking availability, or delivery windows in restricted areas.
- **Conduct feasibility studies for contactless fare and ticketing integration**, particularly as the city considers broader MaaS strategies within its updated SUMP.
- **Build internal capacity and standards for data protection and encryption**, prioritizing role-based access control systems to safeguard ALPR and mobility platform data.
- **Engage stakeholders in pilot design and early-stage procurement planning**, ensuring that upcoming investments align with long-term mobility goals.

These preparatory actions will help prevent future scalability bottlenecks and ensure that essential layers of digital mobility are not overlooked in infrastructure-focused efforts.

3.2.5.2 Emerging Technologies: Scaling and Integration

A number of technologies in Koper are already at the pilot or limited operational stage, including automated enforcement, IoT sensors, communication protocols, and modular ITS tools. However, these remain isolated or underused.

Key actions should include:

- **Expand IoT sensor coverage and link it to real-time monitoring dashboards**, enabling better situational awareness and dynamic management of restricted zones.
- **Integrate enforcement and parking systems with the mobility platform**, especially in adjacent spillover areas around the historic core.
- **Standardize data collection formats** and move toward open, interoperable protocols (e.g., GTFS, NeTEx), enabling future linkage with regional and national platforms.
- **Strengthen internal coordination** through joint technical and urban planning working groups to ensure cross-departmental ownership of pilot outcomes.

These efforts should be tied to iterative evaluation processes, creating a feedback loop that informs scaling decisions and policy adaptations.

3.2.5.3 Mature Technologies: Consolidation and Strategic Optimization

Geofencing and urban mobility management platforms represent Koper's most mature technological assets and form the operational base of the current SMARTMOBAIR pilot. However, their long-term value will depend on integration, stability, and adaptability.

To leverage these strengths:

- **Secure long-term funding and institutional support** for the urban management platform, with clearly defined administrative responsibilities.
- **Ensure the platform supports future ITS modules**, such as environmental monitoring, performance alerts, and adaptive access policies.
- **Develop it as a public-facing interface**, offering residents transparency and a channel for information and feedback—especially as regulation becomes more digitalized.
- **Use the platform as a testbed** for future experimentation with dynamic access control and integration of sustainability indicators.

3.2.5.4 Strategic summary

This section outlines the key strategic priorities emerging from the technology gap assessment and corresponding recommendations, providing guidance for phased and context-sensitive advancement of smart mobility in the territory.

In conclusion, Koper demonstrates an initial foundation for smart mobility development, particularly through access regulation and urban mobility management pilots. However, broader ITS system integration remains limited, with many enabling technologies at early or conceptual stages. Strategic efforts will need to build upon the existing pilot base while progressively strengthening digital infrastructure, interoperability, and user engagement.

Strategic priorities for Koper include:

- **Laying the groundwork** by addressing foundational gaps in user information, data privacy, and integrated fare systems;
- **Scaling and integrating pilot-stage technologies**, especially in enforcement, sensor deployment, and data standardization;
- **Consolidating mature systems** such as geofencing and mobility platforms to serve as stable backbones for future ITS modules;
- **Institutionalizing innovation** through coordination mechanisms, cross-departmental planning, and sustained technical capacity;
- **Aligning digital upgrades with broader policy goals**, including the SUMP revision and climate-neutral mobility ambitions.

It should be emphasized that **these recommendations are intended as strategic guidance rather than prescriptive measures.** Their successful implementation will require careful adaptation to the specific territorial context of Koper, including prioritization based on local needs, available resources, and alignment with regional and national mobility strategies. **A phased, context-sensitive approach will be essential to ensure that the recommended actions are realistic, feasible, and sustainable over the long term.**

3.3 The City of Niš (Serbia)

3.3.1 Territorial Context

The City of Niš, Serbia's third-largest city, acts as a key regional hub in the southeast with population of 182.797 (2022). The area of the city covers 596.71 km² and includes five municipalities, which contain 68 suburban and rural settlements.

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

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

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

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

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

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

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

Geospatial coverage focuses on major urban corridors in Niš, particularly in the municipalities of Medijana, Palilula, and Pantelej, where population density and service demand are highest.

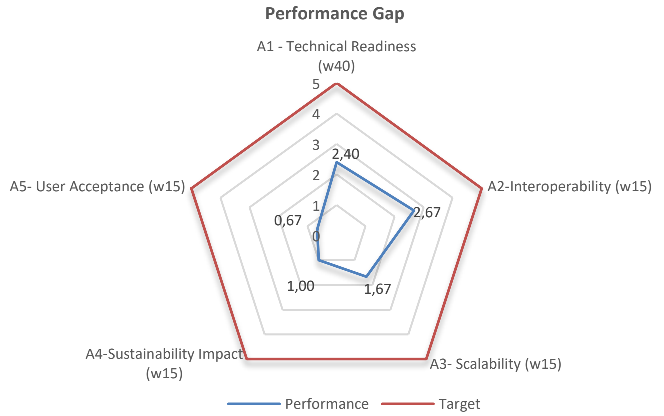
Ljubljana is referenced as exemplar city for its comprehensive real-time passenger information system, seamless smart card integration, and effective multimodal coordination via the Urbana card. Passengers in Ljubljana benefit from accurate arrival data accessible through mobile apps, station displays, and web platforms, enhancing predictability and reducing waiting times.

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

3.3.2 Performance Gap Summary

The performance gap analysis for Niš reveals moderate progress toward the benchmark of full optimization (score 5.0), with an overall appraisal level **Emerging** (1.86**.** This reflects the presence of several operational technologies, yet with important limitations in consistency, integration, and user-oriented design.

***Figure 3.7** Performance Gap summary for Niš*
Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The **technical readiness** at **Developing** stage (score 2.40) suggests that multiple Key Enabling Technologies (KETs)—such as secure data management, fleet tracking, and real-time passenger information systems—are already operational. However, significant gaps remain in advanced functionalities, such as integrated ticketing systems, vehicle-to-vehicle communication protocols, and dynamic route optimization.

Interoperability, apprised as **Developing** (2.67) indicates that standards compliance and system integration are progressing, with some APIs and network-level solutions already in use. This dimension shows relatively strong alignment with ITS deployment pathways but still lacks the level of cross-system integration needed for seamless operation.

Scalability, at **emerging level** (score 1.67) demonstrates early architectural planning, such as the use of modular ITS components and cloud-based scaling platforms. However, the lack of performance monitoring systems limits the potential for robust and resilient expansion. Similarly, **sustainability impact** is at **initial level** with score of 1.00 , reflects the presence of environmental monitoring systems but highlights critical gaps in energy efficiency and socio-economic impact assessment.

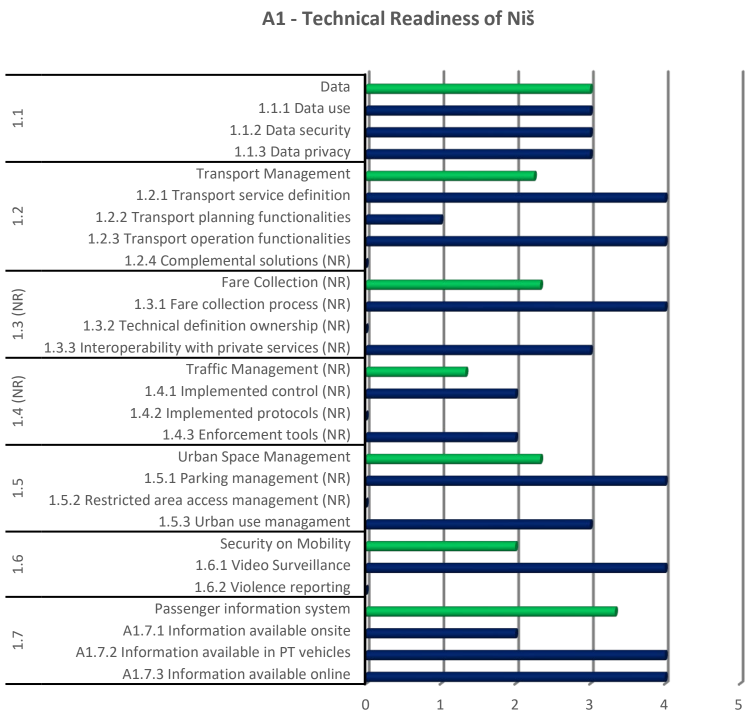
The **user acceptance** dimension is particularly underdeveloped, with an appraisal level **Non-Existent to Initial** (score 0.67) . This indicates minimal deployment of user-centered KETs, such as adaptable feedback mechanisms or inclusive UX design, which are essential for long-term engagement and service personalization.

Given the **qualitative nature of the appraisal** and the **compensatory effect among dimensions**, aggregated scores may not fully reflect the strengths and weaknesses observed in specific areas. Therefore, it is essential to move beyond the overall score and proceed to the **dimension-level analysis**, which follows in the next two sub-sections.

3.3.3 Technical readiness

With an overall score of **2.40**, Niš demonstrates a **Developing level of technical readiness**, suggesting that many key enabling technologies (KETs) have moved beyond the conceptual phase and are now operational in pilot settings or early deployments. The uptake is uneven, with several domains showing strong foundations and others requiring substantial advancement (Figure 3.9).

Figure 3.8 Technical Readiness of Niš
Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

- **0 – Non-Existent/**The technology **does not exist** yet;
- **1 – Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- **2 – Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- **3 – Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- **4 – Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- **5 – Optimised/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.
- **NR – technology not relevant for the pilot**

Data-related technologies (A1.1) are all assessed at the **Developing level** (score 3)**.** This includes **IoT sensors for mobility data collection**, **SSL encryption and database security**, and **role-based access control systems**. These results indicate that data collection and protection mechanisms are in place and have seen some degree of real-world deployment, though not yet citywide integration or continuous optimization. In Niš this is mostly applied in the bus public transport system. Niš thus possesses an emerging infrastructure for data-driven mobility management, with potential to scale.

In the domain of **Transport Management (A1.2)**, there is a mix of maturity levels. **Transport service definition** (based on GTFS, NeTEx) and **fleet tracking & scheduling software** are both **Mature** (score 4)**,** suggesting they are already widely deployed across the city. Conversely, **GIS-based planning tools** remain at the **Initial stage** (score 1)**,** meaning that while such tools may be referenced in plans, they are not yet actively used for spatial analysis or network optimization. The **use of route optimization algorithms** is **non-existent** reflecting a complete absence of automation in strategic transport planning and vehicle routing. The development and operation of GIS infrastructure in the City of Niš falls under the general jurisdiction of the City Administration for Common Affairs and Information-Communication Technologies - Department for ICT. Currently, the GIS is set to generally support digital services and has not yet been upgraded to meet the specific needs of transport and mobility planning. Its further adaptation and enhancement for mobility-related applications will require strengthened interdepartmental coordination and collaborative efforts between ICT, transport, and urban planning stakeholders.

The **fare collection system (A1.3)** shows a similar contrast. While **contactless fare payment systems** are **Mature** (score 4) and **interoperable open-loop payment systems (e.g. via credit card or wallet)** are at a **Developing stage** (score 3), the **technical definition for multimodal payment** integration is still **non-existent** (score 0)**.** This implies that the city has modernized payment options but lacks full structural coordination across modes for seamless fare integration. It is also important to note that the public transport system in Niš is exclusively based on bus services, which currently represent the backbone of urban mobility. Consequently, this mode serves as the principal platform for the ongoing deployment of smart mobility solutions.

Traffic Management (A1.4) is unevenly developed. **Adaptive signal control** and **automated enforcement systems** are at the **Emerging level** (score 2)—validated in limited real-world applications, but not widely adopted. **Communication protocols for vehicle routing (e.g., VANETs)** remain **non-existent**, underscoring the absence of real-time vehicle-infrastructure coordination.

In **Urban Space Management (A1.5)**, **parking occupancy sensors** and **urban mobility management platforms** are evaluated as **Mature** (score 4) and **Developing** (score 3) respectively, indicating that Niš has a relatively robust foundation for digital space monitoring. However, **geo-fencing for access control** remains at the **Initial level** (score 1)**,** suggesting it is still conceptual and not deployed in practice.

Security on Mobility (A1.6) shows partial advancement. **CCTV surveillance** is **Mature** (score 4) and widely deployed, offering good coverage for public space monitoring. However, the **use of crowd movement analytics for violence detection and response** is **non-existent (score 0)**, limiting the potential for predictive security functions.

Passenger Information Systems (A1.7) perform strongly. Both **real-time mobility information in public transport vehicles** and **via web/mobile apps** are at a **Mature level** (score 4)**,** indicating full deployment and consistent use by passengers. **Onsite information systems** (e.g., at stops and terminals) are at the **Developing stage** (score 2)**,** suggesting presence in limited areas or with partial real-time capabilities. This indicates an advanced information environment, particularly for digitally connected users, while highlighting the potential to enhance infrastructure-based services, such as smart bus stops equipped with real-time displays and connectivity features.

Table 3.3 summarizes the uptake of Key Enabling Technologies (KETs) for smart mobility in Niš, grouped by maturity level as assessed through the SMARTMOBAIR Gap Analysis Tool. The classification distinguishes between fully operational systems, technologies under early deployment or testing, and those still at a conceptual or non-existent stage.

Table 3.4 Uptake of KETs for smart mobility in Niš

Source: SMARTMOBAIR Gap analysis results

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	**Emerging / Developing** (Level 2–3)	**Non-Existent / Conceptual** (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network or system)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• **Standard-based multimodal transport definitions (GTFS, NeTEx)** • **Fleet tracking & scheduling software** • Contactless fare payment systems • Parking occupancy sensors • **Real-time mobility information available in PT vehicles** • **Real-time mobility information via web & mobile apps** • **CCTV surveillance**	• **IoT sensors for mobility data collection** • **SSL encryption & database security** • **Role-based access control systems** • Interoperable open-loop payment system (e.g. via credit card or wallet) • Adaptive traffic signal control • Automated enforcement systems • **Urban mobility management platforms** • **Real-time mobility information available onsite (stops, terminals, hubs)**	• **GIS-based transport planning tools** • Route optimization algorithms • Integrated digital ticketing for multimodal payment • Communication protocols (e.g., VANETs) • Geo-fencing & restricted access control • **Crowd movement analytics dashboards**

Niš demonstrates a solid foundation for smart mobility, with key technologies like **fleet tracking**, **contactless fare payment**, and **real-time PT information** already **deployed or optimized**. These should be **leveraged and maintained** to support ongoing operations and enable integration with future ITS modules.

Technologies at **emerging or developing** levels—such as **IoT sensors**, **adaptive traffic control**, and **data security**—should be **scaled up and integrated**. These components form a critical layer for improving service quality and preparing the system for city-wide application.

Critical gaps remain in **non-existent or conceptual** technologies, including **GIS-based transport planning**, **integrated fare systems**, **geo-fencing**, and **crowd analytics**. These require urgent strategic attention to **initiate and plan** for future deployment. Targeted actions, including feasibility assessments, stakeholder coordination, and alignment with urban planning priorities, will be essential to close these gaps and ensure the long-term viability of Niš's smart mobility ecosystem.

Based on the technology gap assessment in Niš, **13 KETs are identified as relevant for the SMARTMOBAIR pilot** (bold and black in Table 3.3). These include enablers of key functionalities such as GPS vehicle tracking, GIS-based public transport mapping, API-enabled system communication, smart fare collection, and real-time passenger information systems.

Several of these KETs are already operational and support the pilot's implementation. For instance, **fleet tracking & scheduling software** and **contactless fare payment systems** are assessed as **Mature** (Level 4), indicating they are widely deployed and form a strong technological baseline. Similarly, **real-time mobility information via web and mobile apps** is also at a **Mature** level, providing reliable support for passenger communication.

However, other critical enablers remain at lower stages of maturity. **GIS-based transport planning tools**, key to spatial optimization in the pilot, are at the Conceptual level (Level 1), while **API management platforms** and **urban mobility management platforms** are only Developing (Levels 2–3), limiting system integration and operational coordination. Technologies such as **role-based access control systems**, **route optimization algorithms**, and **data security protocols** are either in early development or remain conceptual, pointing to broader digital infrastructure gaps.

In summary, the SMARTMOBAIR pilot in Niš is supported by a strong cluster of KETs that are either fully deployed or operational in real-world settings, providing a solid technological foundation for pilot implementation. Key enablers such as **fleet tracking & scheduling**, **contactless fare collection**, and **real-time passenger information systems** demonstrate mature readiness and can be leveraged immediately. At the same time, several KETs essential for integrated and scalable ITS functionality—such as **GIS-based planning**, **route optimization**, and **urban mobility management platforms**—remain at earlier stages of development. Addressing these gaps through targeted investment and system integration will be critical to unlocking the full potential of the pilot and positioning Niš for broader deployment of smart mobility services. The city is well-positioned to build on its existing assets and use the pilot to move towards a more efficient, connected, and user-responsive public transport system.

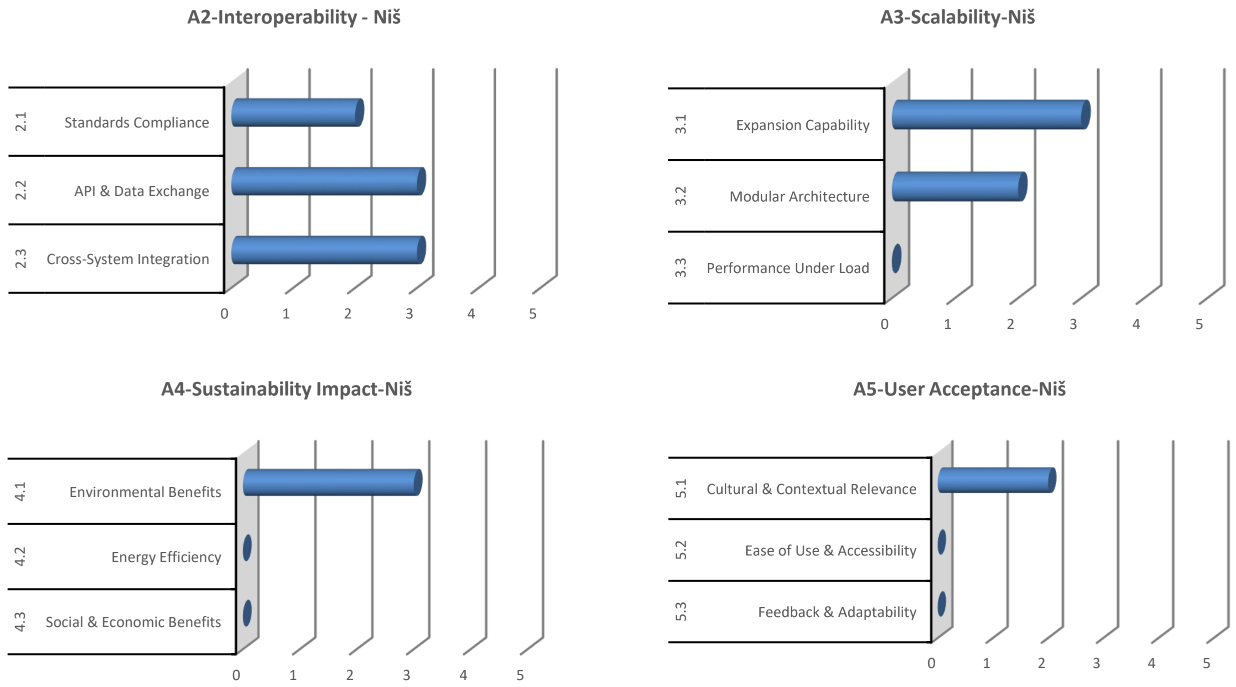
3.3.4 Cross-cutting enablers for smart mobility

The cross-cutting enablers—**Interoperability (A2), Scalability (A3), Sustainability Impact (A4), and User Acceptance (A5)**—complement the broader picture of smart mobility readiness in Niš. While Technical Readiness reflects the implementation of key digital systems, these enablers highlight the city's capacity to integrate, expand, sustain, and align with user expectations, all of which are important for system-wide adoption. Assessment results for these enablers is presented in Figure 3.10.

Interoperability (A2) is the most advanced among the four domains, with an average score of **2.67**, corresponding to an **Emerging to Developing** level of maturity. API & Data Exchange and Cross-System Integration are at the **Developing** level (score 3), indicating real-world operational use in limited contexts, such as pilot environments or specific subsystems (bus subsystem in Niš). Standards Compliance, rated **Emerging** (score 2), suggests partial use of GTFS, NeTEx, or DATEX II, not yet city-wide. The current foundation is promising, but further alignment of data standards is required to unlock full-scale interoperability.

Figure 3.9 Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Niš

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

- 0 – **Non-Existent/**The technology **does not exist** yet;
- 1 – **Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- 2 – **Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- 3 – **Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- 4 – **Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- 5 – **Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

Scalability (A3) registers a **Developing** maturity level (score 1.67). Expansion Capability, driven by cloud-based platforms (score 3), indicates some operational application in pilots or limited deployment zones. Modular Architecture (score 2) is **Emerging**, showing that component-based ITS design is still in early-stage trials. Performance Under Load, however, remains **Non-Existent** (score 0), signaling an absence of system stress testing or performance monitoring under real-world conditions. This imbalance suggests readiness to scale but highlights potential technical risk when moving toward full deployment.

Sustainability Impact (A4) is assessed as **Non-Existent** (score 0), the lowest score across all domains. None of the enabling technologies—environmental sensors, EV optimization tools, or equity-based impact models—have been initiated, indicating a complete absence of environmental or social performance monitoring. As Niš aims to increase digitalization and mobility system integration, this gap could become a critical blind spot if left unaddressed. However, after revision of the available sources regarding the environmental sensing it is important to note that The City of Niš has an established network of environmental monitoring stations that measure air quality indicators such as PM_{10}, NO_2, and O_3, in line with national legislation on environmental protection[12]. While these sensors are operational and provide real-time data, they are not yet systematically integrated into the city's smart mobility or traffic management systems. Nevertheless, the available data have been used in sporadic studies—such as those applying the COPERT methodology[13][14]—to estimate transport-related emissions. Given their real-world deployment and partial use in mobility-related analysis, the appropriate appraisal of the Key Enabling Technology Air Quality Sensors & CO_2 Monitoring Systems should be at the Developing level, rather than Non-Existent. This correction is included in Figure 3.9.

User Acceptance (A5) is rated at an **Initial to Emerging** stage (score 0.67). Cultural and Contextual Relevance (score 2) suggests early consideration of localization and inclusivity, though practical applications remain limited. The existing capacities relate to the existence of Multilingual Mobility Platforms with the possibility to embed Inclusive Digital Interfaces as explained by the local smart fare collection system operator, SWG member. Both Ease of Use and Feedback & Adaptability remain **Non-Existent** (score 0), indicating no evidence of user-centric design or feedback loops in current smart mobility development. This dimension requires urgent attention to ensure adoption and responsiveness as systems are deployed.

3.3.5 Recommendations for Bridging the Smart Mobility Technology Gap in Niš

This section builds on the detailed gap assessment of Niš's smart mobility ecosystem. The analysis revealed a public transport network with important foundations—such as real-time information systems, contactless fare payment, and GPS-based fleet tracking—already in place and supporting the SMARTMOBAIR pilot. However, the city's broader digital infrastructure remains fragmented. Key enablers for integrated planning, automation, and user engagement are underdeveloped or entirely absent, and the cross-cutting enablers—especially sustainability and user acceptance—show substantial gaps.

To address this, the recommendations follow the three-tiered maturity framework applied in the SMARTMOBAIR assessment: (1) technologies at **initial levels** that require strategic initiation, (2) those at **emerging or developing stages** needing scale-up and integration, and (3) **mature systems** that should be consolidated and optimized. This structured approach is intended to guide Niš in transforming its pilot success into a broader, user-oriented and system-integrated smart mobility framework.

3.3.5.1 Initial-Level Technologies: Strategic Initiation

A number of important technologies in Niš remain in a conceptual or non-existent phase. These include route optimization algorithms, integrated digital ticketing, geo-fencing, and GIS-based transport planning tools. Their absence undermines efforts to improve efficiency, spatial accessibility, and multimodal coordination.

Recommended actions:

- **Initiate the development of a GIS-based mobility layer**, enabling spatial analysis for network planning and service optimization, in coordination with the ICT and urban planning departments.
- **Define technical specifications for route optimization**, starting with a feasibility study to assess application potential in daily operations and future demand-responsive transport.

[12] **Law on Air Protection** (*Official Gazette of the Republic of Serbia*, Nos. 36/2009, 10/2013, and 26/2021)

[13] COPERT is a software tool developed by the European Environment Agency (EEA) for calculating air pollutant emissions from road transport. It is widely used across Europe for compiling emission inventories and supports the estimation of emissions at various scales, including urban areas

[14] Živković, P., Tomić, M., Ayed, S., Milutinović, B., & Vukić, M. (2017). An assessment of the traffic-related emissions in the city on Niš. *Facta Universitatis, Series: Working and Living Environmental Protection*, 87-92.

- **Lay groundwork for integrated fare systems**, ensuring future compatibility with multimodal payment platforms at regional and national levels.
- **Design a phased pilot for geo-fencing and dynamic access control**, particularly in high-congestion or sensitive zones.
- **Introduce planning for user feedback loops** and adaptive interfaces to support inclusive digital mobility environments.

3.3.5.2 Emerging Technologies: Scaling and Integration

Technologies such as open-loop fare systems, automated enforcement, IoT sensors, and adaptive traffic signals are already in early-stage deployment but remain disconnected from the city's broader ITS and mobility strategies.

Next steps for scaling and integration:

- **Strengthen API and data exchange platforms** to improve system interoperability between fare collection, vehicle tracking, and passenger information tools.
- **Expand the deployment of adaptive signal control**, prioritizing congested intersections and corridors with high public transport usage.
- **Integrate IoT sensor data into a central dashboard**, enabling real-time monitoring of traffic and service reliability.
- **Enhance the utility of smart fare systems** by embedding multilingual and accessible interfaces, especially to improve ease of use and user acceptance.
- **Coordinate enforcement technologies** with urban space management systems, creating an ecosystem for regulation, monitoring, and feedback.

3.3.5.3 Mature Technologies: Consolidation and Optimization

Several technologies deployed in Niš—including fleet tracking, contactless payment, and real-time information via mobile platforms—are assessed as Mature. These provide a strong basis for the SMARTMOBAIR pilot and future smart mobility services.

Consolidation measures include:

- **Formalize system maintenance and update cycles** for mature tools like GPS tracking and real-time passenger information.
- **Enhance backend analytics** to support operational adjustments and strategic planning using data collected through mature systems.
- **Ensure administrative responsibility and funding continuity** for already deployed smart mobility solutions, particularly those used in pilot corridors.
- **Link smart bus stop** (piloted in SMARTMOBAIR) with the real-time data platform to display live service information on-site, ensuring access for all users, including those without mobile devices..
- **Leverage data from contactless fare and vehicle tracking systems** to model peak demand, inform route restructuring, and improve overall system performance.

3.3.6 Strategic Summary

This section outlines the key strategic priorities emerging from the technology gap assessment and corresponding recommendations, providing guidance for phased and context-sensitive advancement of smart mobility in the territory.

In conclusion, Niš has laid a promising foundation for digital transformation in public transport, but the full potential of its ITS ecosystem remains untapped. The city needs to **strategically expand from isolated deployments toward a more integrated and user-oriented approach,** guided by realistic implementation steps and interdepartmental coordination.

Strategic priorities for Niš include:

- **Initiate planning and testing** for key missing technologies such as GIS-based transport tools, route optimization, and multimodal fare integration;
- **Scale and connect emerging tools**, ensuring that APIs, smart sensors, and enforcement systems support coordinated and interoperable services;
- **Consolidate and maintain mature assets**, such as GPS-based fleet tracking and real-time information systems, as stable pillars of smart mobility;
- **Link planning, operations, and user services** into a cohesive data-driven system to enhance decision-making;
- **Integrate user-centric design and sustainability monitoring**, closing gaps in feedback, accessibility, and environmental performance.

By advancing along these lines, Niš can transition from pilot-based modernization to city-wide smart mobility innovation—ensuring improved service quality, stronger user engagement, and readiness for future regional and national mobility frameworks.

It should be emphasized that **the recommendations provided serve as strategic guidance and should not be interpreted as prescriptive action plans.** Their effective operationalization in Niš will depend on the careful adaptation to the city's territorial conditions, financial and human resource availability, and strategic priorities. Integration with local, national and regional smart mobility frameworks will be critical to ensuring that future planning, investments, and policy decisions are realistic, targeted, and sustainable.

3.4 The Municipality of Novo Sarajevo (Bosnia and Herzegovina)

3.4.1 Territorial Context

The Municipality of Novo Sarajevo, located within the Sarajevo metropolitan area, is one of the most densely populated urban units in Bosnia and Herzegovina. With an area of just 9.9 km^2 and a population of approximately 64,814 residents, the municipality exhibits an average density of 6,370 inhabitants per km^2, presenting significant spatial constraints for mobility infrastructure development and urban planning.

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

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

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

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

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

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

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

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

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

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

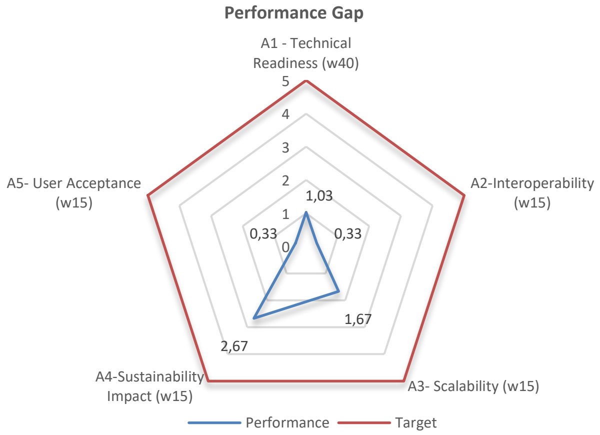
3.4.2 Performance Gap Summary

The performance gap appraisal for Novo Sarajevo indicates a diverse landscape of development across the assessed dimensions (Figure 3.11), with an overall appraisal level as **Emerging** (Score 1.43**)**. This suggests that while certain technologies relevant to smart mobility have been introduced, the integration of advanced Key Enabling Technologies (KETs) remains limited or uneven.

The **technical readiness** dimension is at **Developing** stage (score 1.69) and reflects the presence of several implemented solutions, such as real-time passenger information, fleet tracking, and contactless payment systems. At the same time, other sub-dimensions—such as integrated ticketing, communication protocols, and route optimization—remain at a conceptual or non-deployed stage.

***Figure 3.10** Performance Gap summary for Novo Sarajevo*

Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The **interoperability** dimension, rated as **Non-Existent to Initial** (score 0.33)**,** shows that systems for standard compliance, data exchange, and network-level integration are largely undeveloped from a KET deployment perspective. This may not reflect broader institutional or operational capacities but signals that specific enabling technologies aligned with smart mobility standards have not yet been prioritized.

In terms of **scalability** apprised as **emerging** (score 1.67), Novo Sarajevo shows some use of modular architectures and cloud-based platforms, though performance monitoring capabilities appear to be absent.

Sustainability impact, is seen as **Developing** (2.67)**,** is comparatively more advanced, particularly concerning environmental KETs such as air quality and energy efficiency monitoring, while socio-economic modelling tools are not currently in use.

The **user acceptance** dimension, at **0.33 (Non-Existent to Initial)**, suggests that key technologies for user interface localization, accessibility, and feedback integration have not been implemented at this stage. This does not preclude the existence of user engagement or communication mechanisms but reflects the current lack of advanced tools supporting these functions in a smart mobility context.

As with all cases, it is important to emphasize that this assessment is based on the deployment of specific KETs relevant to smart mobility transformation. Given the **qualitative nature of the appraisal** and the **compensatory effect across dimensions**, overall scores should not be interpreted as direct indicators of overall mobility performance. Therefore, the following two sub-sections provide additional dimension-level analysis.

3.4.3 Technical readiness

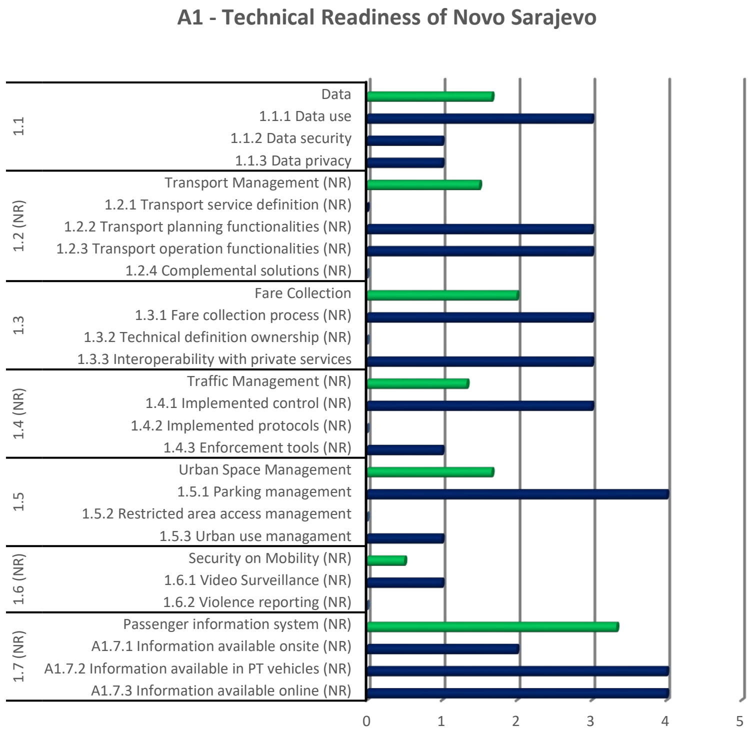
Novo Sarajevo's overall technical readiness is characterized by a **score of 1.69**, placing the territory within the **Emerging to Developing** range. This implies that while several technologies have reached operational testing in limited contexts, many remain at the conceptual level or are only beginning to emerge in early implementation efforts (Figure 3.12). The assessment reveals notable differences across domains, with a few components demonstrating functional pilots, and others not yet present in policy or planning frameworks.

Data-related technologies (A1.1) reflect varied levels of maturity. *IoT sensors for mobility data collection* are assessed at the **Developing level (score 3)**, indicating that real-world testing has occurred and operational pilots are in place. In contrast, both *SSL encryption & database security* and *role-based access control systems* remain at the **Initial level (score 1)**. This suggests that while discussions or references to secure data governance exist, they have not yet materialized into concrete implementation.

Transport Management (A1.2) shows some promising elements. *GIS-based transport planning tools* and *fleet tracking & scheduling software* are each evaluated at the **Developing level (score 3)**, signifying ongoing pilots or partial use in operational settings. However, the absence of *Standard-based multimodal transport definitions* and *route optimization algorithms*, each rated at **Non-Existent (score 0)**, indicates that critical foundational tools for service integration and efficiency remain entirely undeveloped.

Figure 3.11 Technical Readiness of Novo Sarajevo

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

0 – Non-Existent/The technology **does not exist** yet;

1 – Initial/Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;

2 – Emerging/Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.

3 – Developing/Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.

4 – Mature/Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.

5 – Optimised/Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

NR – technology not relevant for the pilot

Fare Collection (A1.3) presents a similar duality. The use of *contactless fare payment systems* and *interoperable open-loop payment systems (e.g., credit cards or wallets)* is assessed at the **Developing level (score 3)**, meaning that pilot usage or segmented deployment is underway. However, the absence of a *digital ticketing framework for multimodal services* (**score 0**) limits potential integration and user convenience.

In the area of **Traffic Management (A1.4)**, two subcomponents—*adaptive traffic signal control* and *automated enforcement systems*—have reached the **Developing level (score 3 and score 1 respectively)**. However, *communication protocols for vehicle routing*, essential for dynamic and responsive systems, are entirely **absent (score 0)**, with no evidence of conceptualization or planning.

Urban Space Management (A1.5) shows a stronger performance in *parking management*, which has reached the **Mature level (score 4)**. This indicates that *parking occupancy sensors* are widely deployed and operational in real-world settings. In contrast, *geo-fencing & restricted access control* remains **Non-Existent (Le 0)**, and *urban mobility management platforms* are at the **Initial level (score 1)**—suggesting early discussions but no tangible development.

Security on Mobility (A1.6) is currently underdeveloped. *CCTV surveillance* is at the **Initial level (score 1)**, with limited presence or plans in place. More advanced technologies such as *crowd movement analytics dashboards* are assessed at **Non-Existent (score 0)**, indicating no conceptual or operational progress in this area.

Finally, **Passenger Information Systems (A1.7)** reveal a mixed level of advancement. *Real-time information in public transport vehicles* and *via web and mobile apps* are each rated at the **Mature level (score 4)**, reflecting widespread real-world deployment and integration into daily operations. However, *onsite information systems* (e.g., digital displays at terminals and stops) are only at the **Emerging level (score 2)**, indicating limited or pilot-level implementation.

Table 3.4. summarizes the uptake of KETs for smart mobility in Novo Sarajevo.

Table 3.5 Uptake of KETs for smart mobility in Novo Sarajevo

Source: SMARTMOBAIR Gap analysis results

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	Emerging / Developing (Level 2–3)	Non-Existent / Conceptual (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• **Parking occupancy sensors** • Real-time mobility information available in PT vehicles • Real-time mobility information via web & mobile apps	• **IoT sensors for mobility data collection** • GIS-based transport planning tools • Fleet tracking & scheduling software • Contactless fare payment systems • **Interoperable open-loop payment system (e.g. via credit card or wallet)** • Adaptive traffic signal control •	• **SSL encryption & database security** • **Role-based access control systems** • Standard-based multimodal transport definitions (GTFS, NeTEx) • Route optimization algorithms • Integrated digital ticketing for multimodal payment • Communication protocols (e.g., VANETs) • Automated enforcement systems • **Geo-fencing & restricted access control** • **Urban mobility management platforms** • CCTV surveillance • Crowd movement analytics dashboards

Technologies evaluated at the **Optimized or Deployed levels (Levels 4–5)** in Novo Sarajevo—such as real-time mobility information systems available online and in vehicles, as well as parking occupancy sensors—should be **leveraged and sustained**. These elements offer a strong starting point for building visible user-facing services and anchoring future ITS deployments. The recommendation is to maintain their operability, enhance their interoperability with upcoming modules (e.g., data platforms, payment systems), and gradually improve user responsiveness through performance monitoring and feedback mechanisms.

Technologies currently at the **Emerging or Developing stages (Levels 2–3)** include IoT-based mobility data collection, fleet tracking, GIS-based transport planning tools, contactless fare collection, and adaptive traffic signal control. These indicate limited real-world deployment or operation in pilot settings. For these, the recommendation is to **scale up and integrate**. Their progression is essential to unlock real-time operations, demand-responsive planning, and system-wide optimization. Particular emphasis should be placed on strengthening data infrastructure, connecting silos, and ensuring these technologies serve broader urban mobility goals beyond isolated applications.

The most critical technologies fall within the **Non-Existent or Conceptual category (Levels 0–1)**. This includes foundational enablers such as SSL-based data security, role-based access control, integrated digital ticketing, communication protocols (e.g., VANETs), urban mobility management platforms, and advanced enforcement tools. Despite being central to the long-term viability of smart mobility systems, these technologies are currently either absent or only referenced at a conceptual level. The recommendation is to **initiate and strategize** their development—beginning with pilot frameworks, institutional dialogue, and alignment with strategic mobility planning. Their absence may not prevent pilot-level success but will ultimately limit the city's capacity to scale, coordinate, and sustain ITS deployments in the future.

In summary, while Novo Sarajevo presents an encouraging mix of developing and operational technologies in selected areas, the overall smart mobility ecosystem remains fragmented. A dual-track approach—combining the **leveraging of mature systems** and **strategic activation of missing enablers**—will be critical to move from pilot success toward integrated and resilient urban mobility solutions.

In the context of the SMARTMOBAIR pilot in Novo Sarajevo, which focuses on enhancing micromobility monitoring through the deployment of stationary traffic measuring devices and a digital platform for tracking e-scooter and e-bike use, seven Key Enabling Technologies (KETs) have been identified as directly relevant (black and bold in Table 3.4). The appraisal of these technologies reflects a **developing but still limited technical foundation**, with important distinctions between those required for the pilot's immediate functionality and those that will be more critical as the solution evolves toward full-scale ITS deployment in Sarajevo.

Among the core technologies supporting the pilot, **IoT sensors for mobility data collection** are the most advanced, currently at the **Developing** stage (Level 3). This suggests that sensor-based data gathering is already operational in some contexts and can be effectively integrated into the planned pilot area. As these sensors will form the basis for real-time micromobility tracking, their current level of maturity supports successful pilot implementation, although system-wide optimization will be needed in the long term.

In contrast, key data governance components—**SSL encryption & database security** and **role-based access control systems**—are currently at the **Initial** stage (Level 1). While their absence may not hinder the basic operation of the pilot, they are essential for ensuring secure and ethical data handling, especially if the monitoring platform is to scale beyond the pilot zone or include sensitive user information. Strengthening these systems would not only enhance compliance with data protection standards but also increase public trust in the deployed technologies.

Urban mobility management platforms, which could serve as the digital interface for analyzing, visualizing, and acting upon collected micromobility data, are similarly at an **Initial** stage (Level 1). For the pilot's scope—focused on data collection and awareness-raising—this may be sufficient. However, to transition toward evidence-based planning and regulatory integration, further development of such platforms will be necessary.

Technologies like **geo-fencing and restricted access control** are not immediately essential for the pilot's core objectives but have been identified as relevant for future phases, particularly if the city aims to introduce spatial restrictions or enforce micromobility rules in real-time. Currently, these systems are also at an **Initial** level (Level 1), suggesting that strategic planning should begin to prepare for their gradual integration.

Parking occupancy sensors—though not central to the pilot's micromobility focus—have reached a **Mature** level (Level 4), reflecting an existing digital capacity that may be leveraged for broader urban space management. This can provide useful synergies in future iterations of the pilot, especially in multimodal contexts.

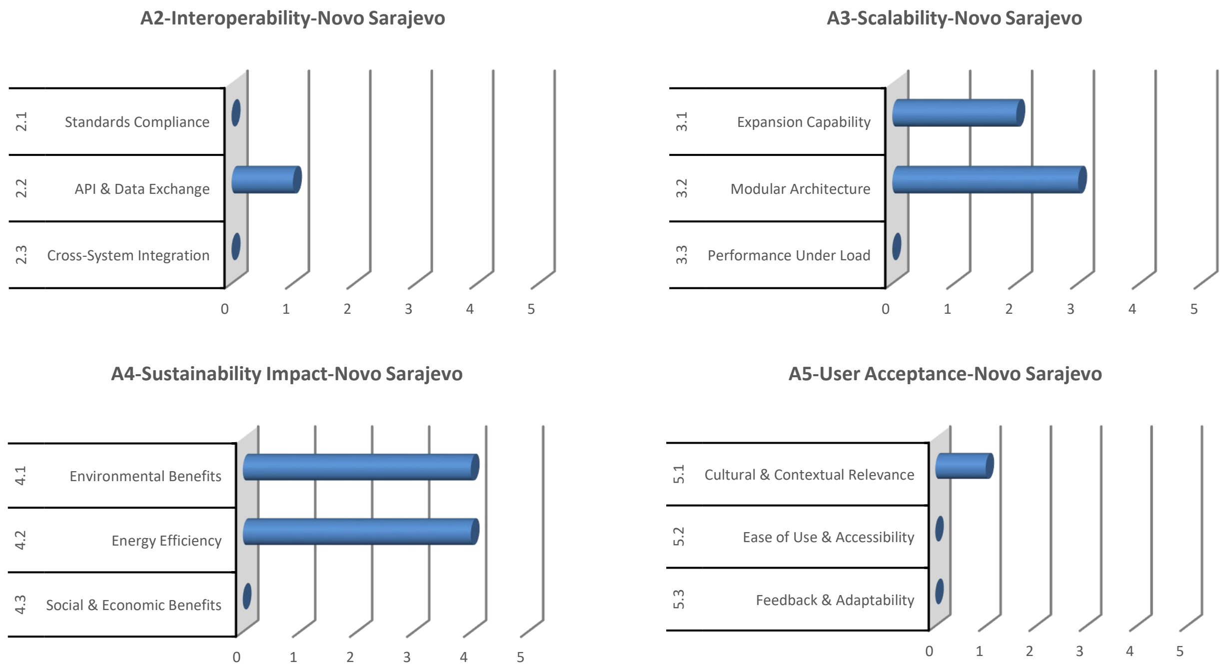
Finally, **interoperable open-loop payment systems** are currently at the **Developing** level (Level 3). While not directly linked to the pilot's immediate objectives, their inclusion points to foresight in aligning with future MaaS frameworks, should e-scooter or e-bike sharing schemes be introduced in Sarajevo.

In sum, **the pilot in Novo Sarajevo is supported by a modest but functionally sufficient technological base**, particularly with regard to sensor deployment and data collection. However, further efforts are needed to strengthen foundational digital infrastructure—especially in terms of data security and system integration—if the city is to scale this pilot into a fully operational smart mobility solution. By distinguishing between what is essential for the current implementation and what will be necessary for long-term ITS readiness, this phased approach offers a realistic and achievable pathway forward.

3.4.4 Cross-Cutting Enablers for Smart Mobility

System and Societal Enablers for Smart Mobility—namely **Interoperability (A2)**, **Scalability (A3)**, **Sustainability Impact (A4)**, and **User Acceptance (A5)**—represent critical capabilities that enable the long-term integration, expansion, and citizen responsiveness of ITS solutions. In Novo Sarajevo, the appraisal of these dimensions reveals a fragmented enabling landscape, with key technologies either at conceptual stages or under early development (Figure 3.12).

Figure 3.12 Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Novo Sarajevo
Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:
- **0 – Non-Existent/**The technology **does not exist** yet;
- **1 – Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- **2 – Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- **3 – Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- **4 – Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- **5 – Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

Interoperability (A2) is assessed at a *Non-Existent to Initial* level (average score 0.33). Two of the three sub-criteria—Standards Compliance (GTFS, NeTEx, DATEX II) and Cross-System Integration—are at Level 0, indicating that no relevant technologies or supporting frameworks are in place. The only partial progress is noted in API and Data Exchange (Level 1), where the use of secure API management platforms is at a conceptual stage. The lack of interoperability enablers suggests that any future integration with broader urban systems or external mobility providers will face substantial limitations.

Scalability (A3) demonstrates slightly higher maturity, with an overall *Emerging to Developing* level (score 1.67). The use of cloud-based platforms for system expansion is currently at the *Emerging* stage (Level 2), suggesting controlled environment testing or very limited deployment. Modular ITS architecture is at the *Developing* level (Level 3), indicating early operational use, likely within pilot settings. However, performance monitoring tools remain *Non-Existent* (Level 0), signaling a gap in ensuring system resilience under increased load or expanded service scope.

Sustainability Impact (A4) is currently the most advanced among the four enabling domains, with an overall *Developing to Mature* level (score 2.67). Environmental Benefits and Energy Efficiency are each at the *Mature* stage (Level 4), reflecting the presence of air quality sensors and energy optimization technologies in real-world use. This suggests that, at least in part, the city is deploying ITS tools that align with environmental goals. However, Social and Economic Benefits remain *Non-Existent* (Level 0), with no platforms or models available to address equity, accessibility, or economic inclusion—key elements for a just mobility transition.

User Acceptance (A5) remains a significant challenge, with an average score of *Non-Existent to Initial* (0.33). Ease of Use and Feedback & Adaptability technologies—such as accessible UI/UX design and user feedback systems—are entirely absent (Level 0). Cultural and Contextual Relevance is at the *Initial* stage (Level 1), reflecting only early-stage consideration for language localization or user adaptation. The lack of basic user-facing features may hinder the adoption of smart mobility services, especially in a pilot focused on behavioral and cultural change, such as micromobility adoption.

In summary, while Novo Sarajevo shows promising use of environmental monitoring tools, the broader enabling framework necessary to support integration, growth, and public engagement in smart mobility remains underdeveloped. Strategic investment and institutional focus are needed to address gaps in interoperability, modularity, and citizen-centered design to ensure that early pilot activities translate into sustainable, scalable ITS deployments.

3.4.5 Recommendations for Bridging the Smart Mobility Technology Gap in Novo Sarajevo

This section builds on the detailed gap assessment of Novo Sarajevo's smart mobility ecosystem. The analysis highlights that while the municipality has functioning urban mobility systems—particularly in terms of public transport services and parking management—the deployment of advanced **Key Enabling Technologies (KETs)** for smart mobility remains limited. Initial operational capabilities exist in areas such as real-time passenger information and parking occupancy monitoring, yet broader systems for interoperability, integrated planning, digital enforcement, and user-centric services have not been fully developed or systematically applied. It is important to note that the scope of this assessment focuses specifically on the uptake of advanced KETs relevant to smart urban mobility transformation, and does not evaluate the overall functionality of existing mobility services.

The recommendations are closely aligned with the SMARTMOBAIR pilot implemented in Novo Sarajevo, which focuses on monitoring micromobility flows (e-scooters and e-bikes) through the deployment of stationary measuring devices and a dedicated digital application. While the pilot introduces important new tools for data-driven planning and micromobility management, the broader analysis reveals that several supporting technologies and cross-cutting enablers remain underdeveloped.

To address the identified development areas, the recommendations are structured along the three-tiered maturity framework applied in the SMARTMOBAIR gap analysis: (1) technologies at **initial levels** requiring strategic initiation, (2) those at **emerging or developing stages** needing scale-up and integration, and (3) **mature systems** requiring consolidation and optimization. This structured approach supports both the immediate success of the pilot and the broader evolution of Novo Sarajevo toward a more integrated, data-driven urban mobility ecosystem.

3.4.5.1 Initial-Level Technologies: Strategic Initiation

Several Key Enabling Technologies (KETs) in Novo Sarajevo are currently at the conceptual or non-existent stage. These include digital security systems, multimodal digital ticketing, urban mobility management platforms, crowd analytics, and communication protocols for vehicle coordination.

Recommended actions:

- Develop a data security and governance framework, ensuring SSL encryption, role-based access control, and GDPR compliance as foundational elements for future mobility platforms.
- Initiate planning for an integrated digital ticketing platform, aligned with potential future multimodal mobility services.

- Launch a pilot concept for an urban mobility management platform, linking real-time parking, micromobility, and public transport data streams.
- Explore feasibility studies for geo-fencing and automated enforcement systems, particularly targeting areas with pedestrian and micromobility conflicts.
- Begin early planning for user feedback and accessibility features, embedding inclusive design principles into future mobility services.

3.4.5.2 Emerging Technologies: Scaling and Integration

Some technologies, including IoT-based mobility data collection, GIS planning tools, adaptive traffic control, and open-loop fare systems, have moved beyond conceptual stages and are operational at a limited scale. Their broader integration and scaling are necessary for comprehensive smart mobility development.

Next steps for scaling and integration:

- Expand the deployment and interconnection of IoT sensors, supporting real-time monitoring of micromobility flows and pedestrian traffic.
- Strengthen the use of GIS tools for transport planning, enabling more data-driven infrastructure development and service design.
- Scale up adaptive traffic control, prioritizing intersections and corridors with high multimodal traffic demand.
- Consolidate contactless fare and open-loop payment systems to enhance user convenience and prepare for future Mobility-as-a-Service (MaaS) integration.

3.4.5.3 Mature Technologies: Consolidation and Optimization

Real-time mobility information systems (both in vehicles and via mobile/web apps) and parking occupancy sensors are already deployed and operational, providing an important foundation for immediate service improvements.

Consolidation measures include:

- Ensure consistent maintenance and performance monitoring for real-time information systems and parking infrastructure to sustain service reliability.
- Integrate parking and mobility data into a public-facing dashboard, improving transparency and supporting multimodal trip planning.
- Use existing mature technologies as anchor points for the gradual development of more complex ITS ecosystems.
- Promote visibility and accessibility of digital mobility services, encouraging greater public trust and adoption.

3.4.6 Strategic Summary

In conclusion, Novo Sarajevo demonstrates important early steps toward digitalization in mobility, particularly through real-time information services and sensor-based monitoring. However, the deployment of advanced smart mobility KETs remains at an early stage and requires a strategic and phased approach to ensure broader integration and user-centered growth. Strengthening core digital enablers, fostering system interoperability, and embedding inclusive design principles will be crucial for scaling early successes into a sustainable urban mobility transformation.

Strategic priorities for Novo Sarajevo include:

- Initiate essential digital enablers such as secure data management, multimodal ticketing systems, and urban mobility management frameworks.
- Scale and integrate emerging technologies, particularly IoT-based monitoring, GIS planning tools, and adaptive traffic management systems.
- Consolidate mature real-time information and parking management systems, enhancing reliability and user engagement.
- Establish cross-system interoperability and centralized data governance structures, preparing for future integration opportunities.
- Strengthen user-centric approaches, embedding accessibility, feedback mechanisms, and cultural localization into future smart mobility services.

It should be emphasized that **these recommendations are intended as a strategic guide and not as prescriptive measures.** Their successful translation into operational plans, roadmaps, or policy documents will require careful adaptation to the specific territorial context of Novo Sarajevo. This includes consideration of local priorities, financial and human resource availability, and alignment with broader cantonal and national mobility and digitalization strategies. **A phased and context-sensitive approach will be essential to ensure that the recommended actions are realistically implementable and sustainable over the long term.**

3.5 Municipality of Rethymno (Crete)

3.5.1 Territorial context

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

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

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

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

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

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

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

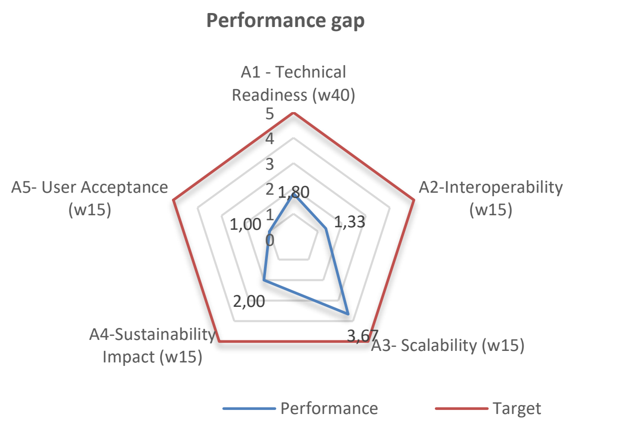
Exemplar solution is Ülemiste City in Tallinn, Estonia[15]. It has smart parking stations for personal bikes with Bikeep's secure, tech-enabled bike parking infrastructure. This system combines physical security with digital access and monitoring, promoting cycling by ensuring safe and convenient parking in a busy urban innovation district.

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

3.5.2 Performance Gap Summary

The appraisal for Rethymno indicates varying levels of technological deployment across the smart mobility dimensions (Figure 3.14), with an overall appraisal level **Emerging** (Score 1.92)**.** This reflects early to moderate integration of Key Enabling Technologies (KETs), with notable strengths in core digital infrastructure and scalability readiness, and more limited activity in integrated transport services and user-centered features.

Figure 3.13 Performance Gap summary for Rethymno
Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The **technical readiness** dimension, is apprised as **Emerging** (score 1.80) with strong implementation of data-related technologies—such as IoT-based data collection, encryption, and access control—but limited deployment of other KETs..

Interoperability, rated **Initial** (1.33) reflects that the use of secure API platforms and initial system integration measures, though formal alignment with open standards (e.g. GTFS, NeTEx) has not yet been adopted.

The **scalability** dimension is apprised as **Mature** (score 3.67)**,** indicating a high level of technical preparedness for wider deployment. This is evidenced by the availability of cloud-based

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

expansion infrastructure and active performance monitoring systems, though modularity remains at a more basic stage. This represents one of the most advanced areas in the current appraisal.

Sustainability impact, is at **2.00 Developing level** (score 2,0) and shows that environmental and energy-efficiency KETs have been partially integrated, while social and economic impact tools are not currently deployed.

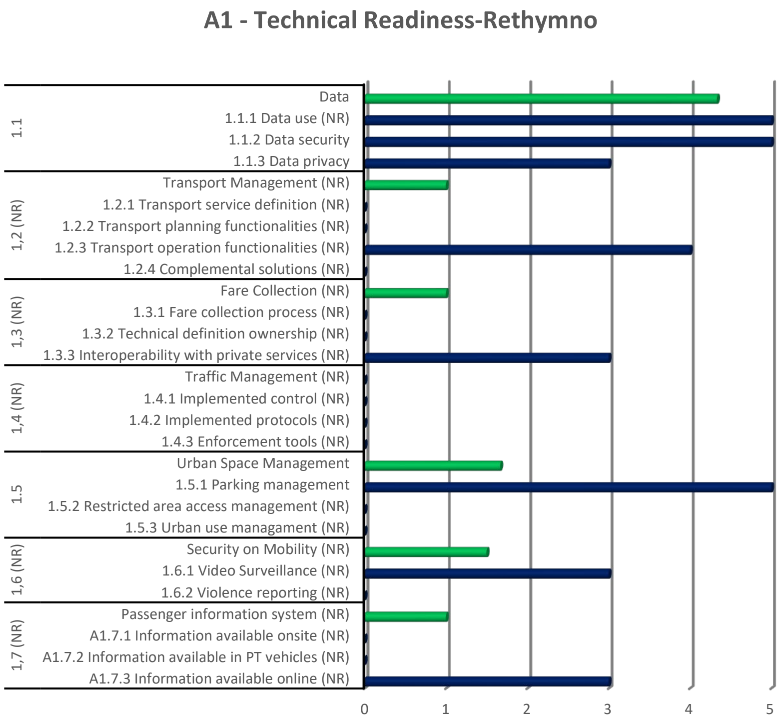
User acceptance is Emerging, with a score of 1.00 and indicates that early-stage features supporting localization, accessibility, and feedback are in place, though more advanced tools for user experience design and engagement are yet to be introduced.

As with all territories, it is important to emphasize that this assessment reflects the deployment of technologies relevant to smart mobility transformation, rather than general urban mobility performance. Due to the **qualitative nature of the appraisal** and the **compensatory relationship among dimensions**, overall scores may not fully represent performance in specific areas. Therefore, the following sub-sections offer a more detailed, dimension-by-dimension analysis to support targeted interpretation and further discussion.

3.5.3 Technical readiness

Figure 3.14 Technical Readiness of Rethymno

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

- **0 – Non-Existent/**The technology **does not exist** yet;
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- **5 – Optimised/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.
- **NR – technology not relevant for the pilot**

With a composite score of 1.8, Rethymno's **Technical Readiness** reflects an overall ***emerging stage of maturity* for smart mobility technologies.** This indicates that while certain key enabling technologies (KETs) have entered real-world deployment, many components remain in early developmental or conceptual phases, influencing the municipality's current capacity for comprehensive ITS implementation.

Data-related enablers (A1.1) represent one of the strongest areas for Rethymno. *IoT sensors for mobility data collection* and *SSL encryption & database security* have both reached the **Optimized level (5)**, suggesting full deployment, continuous improvement, and integration into operational workflows. *Data privacy*, supported by role-based access control systems, is evaluated at the **Developing level (3)**, indicating limited real-world deployment and suggesting that the mechanisms are applied in pilot segments or in partial scope. This strong foundation in data collection and security could serve as a foundation for broader smart mobility deployment.

Transport management (A1.2), however, exhibits considerable gaps. While *fleet tracking and scheduling software* is at a **Mature level (4)**—reflecting wide deployment and routine use—other aspects remain at the **Non-Existent level (0)**. These include *Standard-based multimodal transport definitions*, *GIS-based transport planning tools*, and *route optimization algorithms*. The absence of such foundational tools impedes systematic multimodal integration and limits the potential for dynamic route management, demand forecasting, or infrastructure planning.

Fare collection systems (A1.3) are also underdeveloped. *Interoperable open-loop payment systems* are at the **Developing level (3)**, which implies limited deployment or piloting without full integration. Meanwhile, *contactless fare payment* and *integrated digital ticketing* remain **non-existent (0)**, suggesting that public transport payment systems are not currently digitized or integrated, which represents a barrier for user convenience.

Traffic management (A1.4) is entirely undeveloped, with all three apsects and KETs—*adaptive traffic signal control*, *communication protocols for vehicle routing*, and *automated enforcement systems*—assessed at the **Non-Existent level (0)**. There is no indication of planning, piloting, or deployment activities in this area, highlighting a gap in intelligent control and enforcement capabilities.

Urban space management (A1.5) presents a mixed picture. *Parking occupancy sensors* have reached the **Optimized level (5)**, indicating well-established technology with routine use in Rethymno. However, *geo-fencing & restricted access control* and *urban mobility management platforms* remain at the **Non-Existent level (0)**. This imbalance suggests that while parking regulation has received investment, other components for integrated spatial regulation of mobility are missing.

Security on mobility (A1.6) is moderately developed. *CCTV surveillance* is at the **Developing level (3)**, indicating use in limited areas or operational pilots. On the other hand, *crowd movement analytics dashboards* remain **non-existent (0)**, reflecting a lack of investment in advanced and proactive incident detection.

Finally, **Passenger Information Systems (A1.7)** are underdeveloped. *Real-time information via web and mobile apps* is assessed at the **Developing level (3)**, indicating partial deployment. However, no real-time information is available onsite at terminals or in vehicles, with both indicators remaining at **Non-Existent level (0)**. This limits the effectiveness of passenger communication and may affect trust in public transport services.

In summary, Rethymno exhibits strong potential in data security and parking monitoring but lacks the foundational technologies required for integrated smart mobility. While select systems are well-developed, the overall profile remains fragmented. Strategic interventions should target the initiation and scaling of transport management tools, passenger-facing systems, and digital fare solutions to moves towards a cohesive and sustainable ITS framework.

Table 3.5 summarizes the uptake of KETs for smart mobility in Rethymno further showing the current state of maturity.

Technologies evaluated at the **Optimized or Deployed levels (Levels 4–5)** in Rethymno — **including IoT sensors for mobility data collection, SSL encryption and database security, parking occupancy sensors, and fleet tracking and scheduling software — should be leveraged and sustained.** These elements provide essential operational foundations for mobility monitoring, security, and parking management. The recommendation is to maintain their stability, progressively integrate them with emerging modules (e.g., real-time user information systems), and build structured feedback loops to ensure service optimization and responsiveness.

Table 3.6 Uptake of KETs for smart mobility in Rethymno

Source: SMARTMOBAIR Gap analysis results

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	Emerging / Developing (Level 2–3)	Non-Existent / Conceptual (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• IoT sensors for mobility data collection • **SSL encryption & database security** • **Parking occupancy sensors** • Fleet tracking & scheduling software	• **Role-based access control systems** • Interoperable open-loop payment systems • CCTV surveillance • Real-time mobility information via web & mobile apps	• Standard-based multimodal transport definitions (GTFS, NeTEx) • GIS-based transport planning tools • Route optimization algorithms • Contactless fare payment systems • Integrated digital ticketing for multimodal payment • Adaptive traffic signal control • Communication protocols (e.g., VANETs) • Automated enforcement systems • Geo-fencing & restricted access control • Urban mobility management platforms • Real-time mobility information available onsite • Real-time mobility information in PT vehicles • Crowd movement analytics dashboards

Technologies currently at the Emerging or Developing stages (Levels 2–3) include role-based access control systems, interoperable open-loop payment systems, CCTV surveillance, and real-time mobility information available via web and mobile applications. These indicate real-world operationalization, often in pilot or limited environments. For these, the recommendation is to scale and consolidate. Strengthening their deployment, expanding coverage, and ensuring interoperability with existing systems will be critical to enable more seamless, user-centered mobility services and to unlock the full value of early smart mobility investments.

The most critical technologies fall within the Non-Existent or Conceptual category (Levels 0–1). This group includes key enablers such as standard-based multimodal transport definitions (GTFS, NeTEx), GIS-based transport planning tools, integrated digital ticketing, adaptive traffic signal control, urban mobility management platforms, and real-time information systems available onsite or in vehicles. Their absence reflects major foundational gaps that could restrict future scaling and integration efforts. **The recommendation is to initiate structured feasibility studies, pilot concepts, and strategic prioritization of these technologies within broader urban and regional mobility planning frameworks.**

In summary, while Rethymno has demonstrated encouraging operational capacities in selected domains — particularly in data collection, parking management, and information security — the overall smart mobility ecosystem remains fragmented. A phased development strategy, focusing both on leveraging existing operational elements and systematically activating missing enablers, will be essential to transition toward an integrated, user-responsive, and resilient smart mobility system.

In the context of the SMARTMOBAIR pilot in Rethymno—which focuses on Smart parking stations for personal bikes a modest but functionally important foundation exists. Notably, only **three KETs were marked as relevant for the pilot**, representing the smallest number among all SMARTMOBAIR territories (black and bold in Table 3.5).

Parking occupancy sensors, which enable congestion detection and parking regulation in critical urban corridors, have reached the **Optimized** level of maturity (score 5). This indicates that these systems are not only fully implemented but also continuously maintained and integrated into existing operational workflows. Similarly,

SSL encryption and database security, essential for safeguarding the traffic data collected by pilot systems, are also at the **Optimized** level (score 5), demonstrating the municipality's readiness to manage digital information securely. The third technology—**role-based access control systems**—which ensures differentiated access to the monitoring dashboard and supports secure administrative management, is assessed at the **Developing** stage (score 3). This suggests that while initial implementation may exist, broader integration and routine use are still in progress.

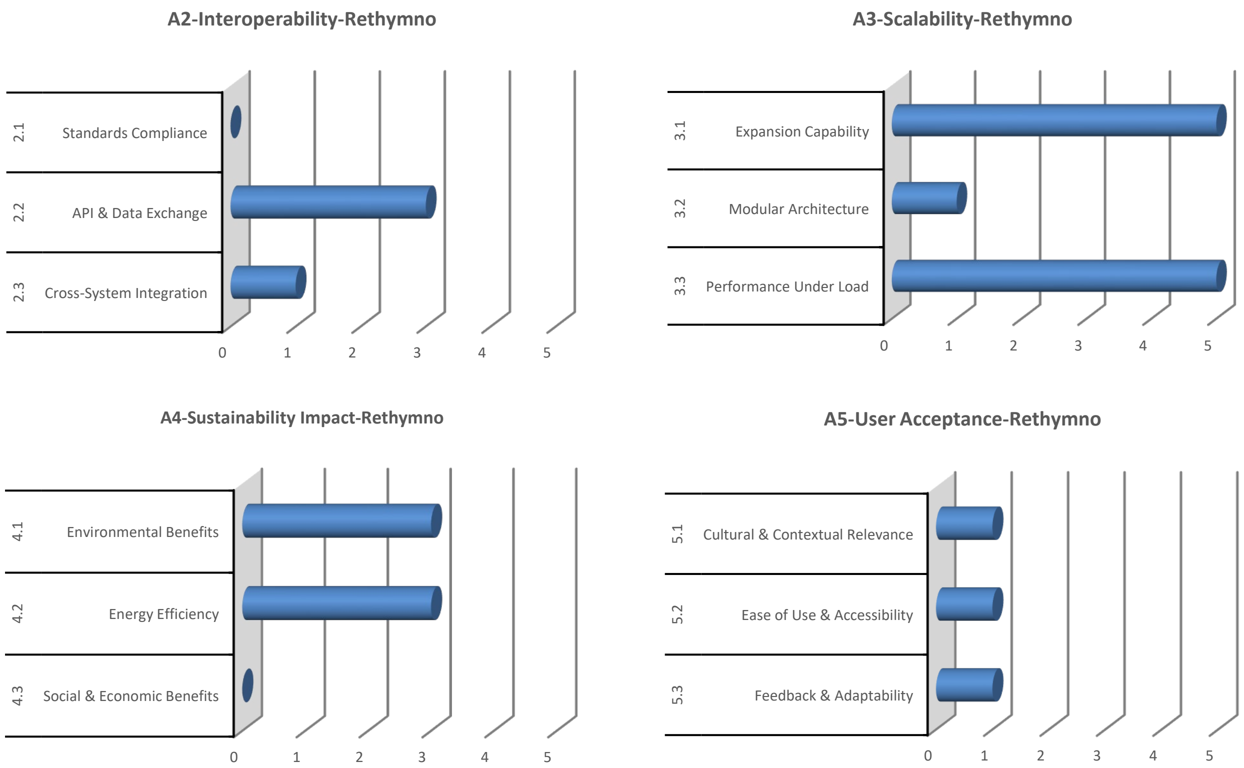
Although the number of pilot-relevant technologies is low, their advanced maturity levels in core areas provide a foundation for achieving the immediate objectives of the pilot. However, the absence of broader ITS enablers may pose limitations for scaling the solution beyond its current scope. Therefore, while the pilot is technically feasible with the existing components, its long-term success will require strategic planning to expand and connect these systems into a wider digital mobility framework at the city level.

3.5.4 Cross-Cutting Enablers for Smart Mobility

The enabling dimensions of **Interoperability**, **Scalability**, **Sustainability Impact**, and **User Acceptance** were assessed to complement the overall picture of smart mobility readiness in Rethymno. Compared to the more comprehensive and infrastructure-oriented domain of technical readiness, these four dimensions highlight the maturity of cross-system integration, growth potential, environmental and social impact, and alignment with user expectations—each essential for ensuring the viability and acceptance of ITS solutions at scale. Results for the Rethymno are presented in Figure 3.16. The graphs are directly extracted from the GAT for Rethymno.

Figure 3.15 Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Rethymno

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

- 0 – **Non-Existent/**The technology **does not exist** yet;
- 1 – **Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
- 2 – **Emerging/**Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
- 3 – **Developing/**Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
- 4 – **Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- 5 – **Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

Interoperability (A2) in Rethymno is assessed at an **Emerging to Developing** stage (score: 1.33). The use of standardized transport data formats—**GTFS, NeTEx, and DATEX II**—remains at a **Non-Existent** level (score 0), suggesting that foundational mechanisms for cross-system compatibility have not yet been adopted. **API & Data Exchange** is rated **Developing** (score 3), indicating that **secure API management platforms** may be used within limited or project-specific environments but are not integrated into a city-wide architecture. **Cross-System Integration**, supported by **transport network data integration systems**, is still **Initial** (score 1), showing minimal efforts toward real-time interconnectivity across mobility subsystems.

Scalability (A3) emerges as the strongest of the four domains, rated at a **Mature** level (score: 3.67). Both **Expansion Capability** and **Performance Under Load** have reached the **Optimized** level (score 5), supported by **cloud-based system scaling platforms** and **load balancing and system performance monitoring tools**. These high scores indicate that the city's digital backbone can handle growing data volumes and increased user demands without system degradation. However, **Modular Architecture**, represented by **modular ITS architecture software**, remains at the **Initial** stage (score 1), suggesting that while the overall system is robust, the flexibility to upgrade or replace subsystems independently is limited. This asymmetry may create bottlenecks during future ITS scaling phases.

Sustainability Impact (A4) is rated as **Developing** (score: 2.00), showing early but fragmented efforts across environmental and social dimensions. **Environmental Benefits** (score 3) are likely enabled by technologies such as **air quality sensors and CO_2 monitoring systems**, which are partially deployed. **Energy Efficiency** (also score 3) reflects the early-stage adoption of **smart grid-integrated EV charging infrastructure** and **vehicle energy optimization tools**. In contrast, **Social & Economic Benefits** are **Non-Existent** (score 0), indicating that enablers like **equity-focused mobility data platforms** or **transport economic impact models** are missing, reducing the municipality's ability to evaluate inclusive and equitable mobility outcomes.

User Acceptance (A5) remains the most underdeveloped area, rated at an **Initial to Emerging** stage (score: 1.00). All three sub-dimensions—**Cultural & Contextual Relevance**, **Ease of Use & Accessibility**, and **Feedback & Adaptability**—are at the **Initial** level (score 1). This implies that technologies such as **language localization and translation systems**, **accessible UI/UX design principles**, and **user feedback collection & sentiment analysis tools** are only being considered in preliminary terms, with no evidence of piloting or deployment. The absence of mature, user-oriented design mechanisms is likely to hinder long-term adoption and satisfaction with ITS services.

In summary, cross-cutting enablers of smart mobility in Rethymno present uneven maturity. Scalability performs strongest, with Optimized infrastructure for expansion and system performance, though limited by Initial modularity. Sustainability Impact is Developing, with partial deployment of environmental and energy-efficiency tools, but lacking any social equity focus. Interoperability remains weak, with standards compliance and system integration still Non-Existent or at Initial levels. User Acceptance is the least developed, with all sub-dimensions rated Initial, indicating only preliminary consideration of accessibility and feedback. Strategic efforts are needed to align these enablers with existing technical readiness and unlock the full potential of ITS deployment.

3.5.5 Recommendations for Bridging the Smart Mobility Technology Gap in Rethymno

This section builds on the detailed gap assessment of Rethymno's smart mobility ecosystem. The analysis reveals that while the municipality has made substantial progress in deploying certain digital systems—particularly in data collection, parking management, and cloud-based scalability infrastructure—broader Key Enabling Technologies (KETs) necessary for integrated smart mobility remain underdeveloped. It is important to highlight that this assessment focuses specifically on the deployment of advanced KETs and cross-cutting enablers relevant to smart mobility transformation, not on the overall performance of Rethymno's urban mobility system, which is supported by a functioning public transport network and a strong tourism-driven urban dynamic.

The recommendations take into account the SMARTMOBAIR pilot implemented in Rethymno, which focuses Smart parking stations for personal bikes. While the pilot benefits from a mature data infrastructure, broader systemic gaps—particularly in transport management tools, interoperability standards, and user-centric design—could limit its scalability and long-term impact without targeted interventions.

To guide strategic advancement, the recommendations are structured according to the three-tiered maturity framework used in the SMARTMOBAIR assessment: (1) technologies at **initial levels** requiring strategic initiation, (2) those at **emerging or developing stages** needing scale-up and integration, and (3) **mature systems** requiring consolidation and optimization.

3.5.5.1 Conceptual Technologies: Strategic Initiation

A significant number of foundational KETs in Rethymno remain at the conceptual or non-existent stage, particularly in transport management, fare systems, and user information services.

Recommended actions:

- Initiate feasibility studies for **GIS-based transport planning tools** and **route optimization algorithms** to strengthen multimodal planning and dynamic management capabilities.
- Define a technical roadmap for **contactless fare payment** and **integrated ticketing** development, aligned with future MaaS integration opportunities.
- Explore piloting of **adaptive traffic signal control** and **communication protocols** to prepare the infrastructure for intelligent traffic management.
- Launch early-stage planning for **urban mobility management platforms** to consolidate parking, micromobility, and public transport monitoring into a unified system.
- Incorporate basic **real-time information systems** onsite at terminals and vehicles to enhance passenger communication and service trust.

3.5.6 Emerging Technologies: Scaling and Integration

Several technologies in Rethymno, including real-time web/mobile apps, interoperable open-loop payment systems, and CCTV surveillance, are operational at a limited scale but require broader integration to deliver full benefits.

Next steps for scaling and integration:

- Strengthen **open API frameworks** and progressively align with **open data standards** (e.g., GTFS, NeTEx) to enhance interoperability across mobility services.
- Expand **real-time information availability** beyond mobile/web apps, embedding information points at transport hubs, park-and-ride facilities, and key urban corridors.
- Scale **CCTV-based mobility monitoring** to support traffic flow analysis, safety initiatives, and congestion management in high-demand areas.
- Enhance integration between **IoT-based mobility sensors**, **parking systems**, and the **GIS-based mobility dashboard** to enable holistic management of urban space.

3.5.6.1 Mature Technologies: Consolidation and Optimization

Some systems in Rethymno—such as IoT sensors, SSL encryption for traffic data, parking occupancy sensors, and cloud infrastructure for scalability—have reached mature or optimized stages. Consolidation efforts are needed to maximize their contribution to city-wide smart mobility development.

Consolidation measures include:

- Maintain and enhance the performance of **data security** systems and **traffic monitoring infrastructure** through continuous updates and system health monitoring.
- Promote **cross-platform interoperability** by linking parking occupancy data, congestion analytics, and e-mobility data into a unified dashboard.
- Develop a **performance evaluation framework** for existing ITS assets, introducing key performance indicators (KPIs) linked to traffic flow, environmental benefits, and user satisfaction.
- Use the existing cloud scalability infrastructure to progressively pilot **modular upgrades** of ITS components, improving flexibility for future system expansion.

3.5.7 Strategic Summary

This section outlines the key strategic priorities emerging from the technology gap assessment and corresponding recommendations, providing guidance for phased and context-sensitive advancement of smart mobility in the territory.

In conclusion, Rethymno exhibits strong progress in foundational areas of smart mobility—particularly in data collection, parking monitoring, and digital scalability—supported by a clear strategic vision. However, gaps in transport management, user-centered services, and interoperability standards require targeted attention to fully realize the city's ambitions for integrated and sustainable urban mobility. Building on the strengths of the SMARTMOBAIR pilot and aligning further developments with regional and national smart mobility frameworks will be key to achieving long-term impact.

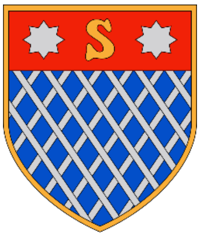
Strategic priorities for Rethymno include:

- Initiate planning and piloting for missing transport management, fare integration, and real-time passenger information systems.
- Scale and integrate emerging mobility monitoring and communication technologies across broader city areas.
- Consolidate mature systems by embedding them into unified data management and mobility planning platforms.
- Strengthen interoperability by adopting standardized data formats and open APIs for future MaaS readiness.
- Embed performance monitoring and user-centered design principles into future ITS development.

It should be emphasized that **these recommendations are intended as strategic guidance rather than prescriptive measures.** Their translation into operational plans, roadmaps, or policy documents should be adapted to the territorial realities of Rethymno, considering local priorities, resource availability, and broader development strategies. In the context of Rethymno's strong tourism sector and dynamic urban environment, mobility should be planned and invested in as a core dimension of sustainable growth—not only as a response to transport needs, but as an integral part of strategic overall development. Recognizing that mobility demand arises from and supports tourism, education, commerce, and community life, **smart mobility initiatives should be treated as a strategic priority alongside other key sectors. A phased and context-sensitive approach will be essential to ensure that mobility investments contribute meaningfully to Rethymno's long-term urban resilience and quality of life.**

3.6 The Municipality of Shkodra (Albania)

3.6.1 Territorial context



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

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

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

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

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

Geospatial coverage of the pilot will include selected access routes and arterial roads leading into and out of the city of Shkodra.

Athens (Greece) is selected as exemplar city. Athens has implemented an advanced real-time public transport information system, offering live bus tracking.[16] While Athens serves as a strong reference for ITS development, pilot in Shkodra focuses on a more foundational application: introducing GPS tracking and passenger counting technologies.

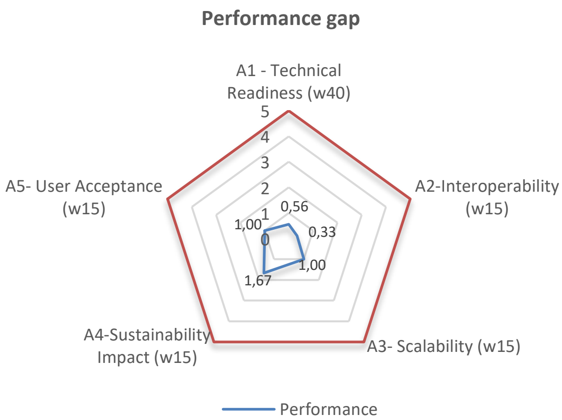
Expected benefits include Improved efficiency and reliability of public bus services; Better planning through real-time operational data; Enhanced passenger satisfaction; Data-driven long-term transport planning and Foundation for broader ITS adoption in Albania.

3.6.2 Performance Gap Summary

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

The appraisal of Shkodra highlights early-stage deployment of smart mobility-related dimensions (Figure 3.17), with an overall appraisal level as **Initial** (Score 0.82). This reflects the presence of a few conceptual and pilot-level applications of Key Enabling Technologies (KETs), while many core systems remain either under development or not yet prioritized for implementation.

***Figure 3.16** Performance Gap summary for Shkodra*
Source: SMARTMOBAIR Gap Analysis results



Note: *The "Target" level (Level 5) represents an ideal state of full technology optimization and system-wide integration, as defined by the SMARTMOBAIR Gap Analysis methodology. It serves as a theoretical benchmark for comparison purposes and does not necessarily reflect a target formally set by the local administration.*

The **technical readiness** dimension is at **Initial** level (score of 0.56), indicates foundational efforts in areas such as data security, route optimization, parking occupancy, and real-time information display, though most transport management, fare systems, and traffic control components remain at the conceptual or non-existent level.

Interoperability, appraised as **Non-Existent to Initial** (score 0.33)**,** shows very limited activity in terms of standards compliance, secure data exchange, or system-level integration, suggesting that cross-platform and institutional coordination through digital infrastructure is still at a very early stage.

Scalability is seen as **Emerging** with a score of 1.00, which points to a basic technical setup that includes elements like modular architecture and system monitoring tools, though not yet operationalized in wider urban contexts.

A similar level of progress is noted in **sustainability impact** (**1.00 – Emerging**), where Shkodra demonstrates early adoption of energy-efficiency-related KETs, while environmental monitoring and socio-economic impact tools are not currently present. The **user acceptance** dimension, rated at **1.00 (Emerging)**, reflects early steps toward building a more user-oriented approach through language localization, accessibility principles, and user feedback mechanisms, though these remain relatively simple in design and scope.

This appraisal is based exclusively on the deployment of smart mobility-related KETs and should not be interpreted as a comprehensive judgment of urban mobility performance. Given the **qualitative nature of the assessment** and the **compensatory relationship among dimensions**, the aggregated score may not fully capture existing strengths or limitations. To support more targeted interpretation, the next two sub-sections provide a **dimension-level breakdown** of the results.

3.6.3 Technical readiness

Shkodra demonstrates a **low level of technical readiness** for smart mobility development, with an overall score of **0.56**, placing it at the **Initial stage** of maturity. This indicates that most enabling technologies are either at a very early stage of planning or remain at the conceptual phase, with limited implementation activity to date (Figure 3.18).

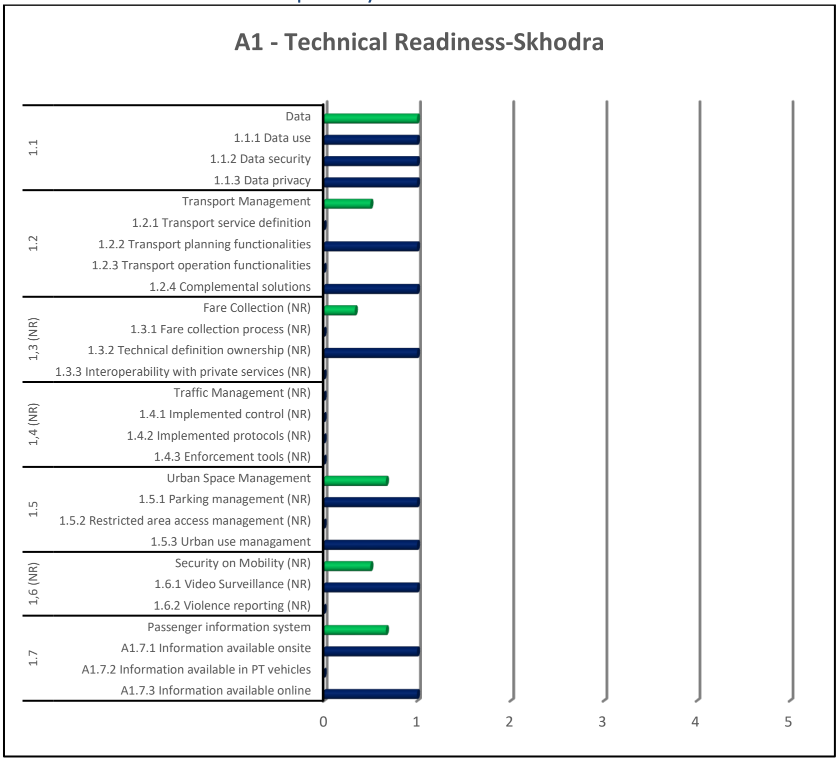
Data (A1.1) readiness is uniformly assessed at the **Initial level (score 1)** across all three sub-criteria—data use, data security, and data privacy. IoT sensors, SSL encryption protocols, and role-based access control systems are referenced in preliminary plans or discussions, but real-world application remains limited. These elements have yet to move beyond early-stage consideration or isolated preparatory steps.

Transport Management (A1.2) reflects a similarly early stage of development. While there is some indication of planned use of GIS-based planning tools and route optimization algorithms (Initial level each), critical enablers such as standardized transport definitions (e.g., GTFS, NeTEx) and fleet tracking systems are currently **absent from practice**, suggesting no implmentation activity has been initiated in these areas.

In the domain of **Fare Collection (A1.3)**, an integrated digital ticketing system is acknowledged at the conceptual level, but other essential components such as contactless fare systems and interoperable open-loop payment platforms are not yet addressed in current frameworks (**score 0**). At present, fare collection is conducted exclusively in cash, paid directly to the conductor or bus driver. This reflects the broader national context, as no public transport systems in Albania currently operate with e-ticketing or digital fare options. However, recent feasibility studies—mostly at the national or regional level—have started to explore potential models for digital fare integration, though no pilot projects have yet been implemented in Shkodra. **Traffic Management (A1.4)** remains **undeveloped**, with all three key technologies—adaptive traffic signal control, vehicle routing communication protocols, and automated enforcement tools—rated as **Non-Existent**. There is no evidence of piloting or planning to date, marking this as an area for strategic capacity-building.

Figure 3.17 Technical Readiness of Shkodra

Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:

0 – Non-Existent/The technology **does not exist** yet;
1 – Initial/Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
2 – Emerging/Prototype tested/The technology has been **tested in a controlled environment** (e.g., simulations or laboratory trials), but there has been no real-world application.
3 – Developing/Operational in pilots/The technology has been **tested in real-world conditions, but in a limited scope**—such as within a pilot project or a single segment of the transport system.
4 – Mature/Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
5 – Optimised/Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.
NR – technology not relevant for the pilot

For **Urban Space Management (A1.5)**, Shkodra shows early attention to parking management and urban mobility coordination platforms, each rated at the **Initial level**. However, digital tools for restricted area access such as geo-fencing are currently not in place, indicating the need for foundational development.

Security on Mobility (A1.6) is limited, with basic CCTV infrastructure considered (**score 1**) but no activity yet regarding advanced analytics for crowd movement or incident reporting.

Finally, the **Passenger Information System (A1.7)** is in the earliest stages of development. Real-time information provision—both onsite and via online platforms—is acknowledged conceptually, while in-vehicle systems are currently **non-existent**. This limits the city's ability to offer timely and user-oriented mobility updates.

Table 3.6 summarizes uptake of KETs for smart urban mobility in Shkodra.

Since in Shkodra, all assessed Key Enabling Technologies (KETs) are currently at the **Initial or Conceptual stage (Level 0–1)**, indicating that digital solutions for smart mobility have not yet been piloted or implemented and implying that **Initiate and Strategize** is the course of action. While this reflects a significant readiness gap, it also positions Shkodra to benefit from the 'latecomer advantage': the ability to learn from the experiences of more advanced cities and adopt already-proven technologies without the cost of legacy system upgrades.

To move forward, the municipality should **focus on initiating foundational steps**, including feasibility assessments, stakeholder engagement, and awareness campaigns. These efforts can lay the groundwork for selecting priority areas, attracting external funding, and gradually introducing scalable ITS components aligned with local needs. Strategic planning now will help ensure that future investments are targeted, coherent, and responsive to Shkodra's broader urban mobility goals.

Table 3.7 Uptake of KETs for smart mobility in Shkodra

Source: SMARTMOBAIR Gap analysis results

Note: KETs relevant for the pilot solution are in black and bold

Deployed / Optimized (Level 4–5)	**Emerging / Developing** (Level 2–3)	**Non-Existent / Conceptual** (Level 0–1)
Technologies fully implemented, used city-wide, and in some cases continuously improved	*Technologies tested in a controlled environment or in limited real world conditions (pilots, part of a network)*	*Technologies either not present or only conceptual (no real-world implementation or planning yet)*
• na	• na	• **IoT sensors for mobility data collection** • **SSL encryption & database security** • **Role-based access control systems** • **Standard (e.g. GTFS, NeTEx) -based multimodal transport definitions** • **GIS-based transport planning tools** • **Fleet tracking & scheduling software** • **Route optimization algorithms** • Contactless fare payment systems • Integrated Digital Ticketing for Multimodal Payment • Interoperable open-loop payment system (e.g. via credit card or wallet) • Adaptive traffic signal control • Communication protocols like for e.g. vehicle routing protocols within VANETs • Automated enforcement systems • Parking occupancy sensors • Geo-fencing & restricted access control • **Urban mobility management platforms** • CCTV surveillance • Crowd movement analytics dashboards • **Real-time mobility information available onsite (stops, terminals, hubs),** • **Real-time mobility information available in vehicles** • **Real-time mobility information via web & mobile apps**

In the context of the SMARTMOBAIR project, the pilot in Shkodra is set to lay the groundwork for the city's digital transformation in mobility planning and monitoring. Focusing on the implementation of a modular traffic data monitoring system, the pilot aims to enable evidence-based planning and proactive traffic control. The KETs identified as relevant for the pilot (black and bold in Table 3.6)—**IoT sensors for mobility data collection**, **SSL encryption and database security**, **role-based access control systems**, **urban mobility management platforms**, and **real-time passenger information tools**—reflect a strong ambition to introduce foundational ITS components.

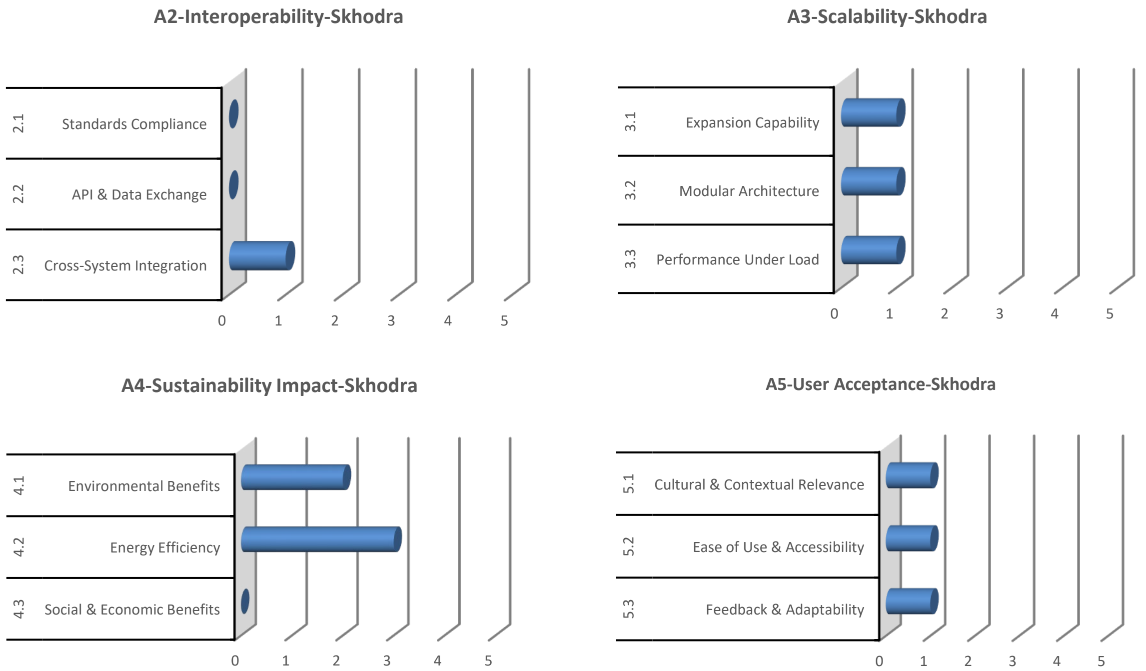
While these KETs are currently **at the Initial stage (score 1)**, meaning they exist primarily in conceptual or planning documents, their selection demonstrates clear alignment with core smart mobility functions. This includes data-driven transport planning, secure system operation, and user-facing service information—all critical for managing public transport and improving mobility efficiency in the urban core.

To ensure this trajectory, the pilot should be positioned as a **capacity-building instrument**—a practical step that enables institutional learning, stakeholder coordination, and technical validation. This approach will help Shkodra transform early concepts into tangible systems and set basis for evidence-based mobility governance.

3.6.4 Cross-Cutting Enablers for Smart Mobility

The cross-cutting dimensions of **Interoperability**, **Scalability**, **Sustainability Impact**, and **User Acceptance** were assessed to complement the analysis of technical readiness in Shkodra. While technical maturity reflects the presence of core systems and technologies, these cross-cutting enablers provide insights into the city's readiness to integrate, expand, sustain, and align smart mobility solutions with user needs. Results from GAT for these dimensions are presented in Figure 3.18.

Figure 3.18 Maturity Assessment of Cross-Cutting Enablers for Smart Mobility in Shkodra
Source: SMARTMOBAIR Gap Analysis Results



Note on the levels:
- **0 – Non-Existent/**The technology **does not exist** yet;
- **1 – Initial/**Concept only (early stage),/The technology is **in the concept stage**—there are discussions, early ideas, or references in planning documents, but no development has started;
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- **4 – Mature/**Deployed widely/The technology is **adopted across the entire city** and integrated into the overall transport system.
- **5 – Optimized/**Fully optimized & continuously improved/the technology is **in full deployment** and optimization—fully implemented, operational, and undergoing continuous improvements.

Interoperability (A2) is rated at a **very low Initial stage (score: 0.33)**, indicating that the foundational capacities for digital integration remain largely unestablished. No evidence was found of **standard-based compliance** (e.g. GTFS, NeTEx, DATEX II) or the use of **secure API management platforms** (both at level 0). Only **Cross-System Integration**, supported by transport network data integration systems, shows an Initial level of conceptual consideration (score 1). Without these core enablers, the prospects for seamless data sharing, modular platform development, and system-wide ITS coordination remain limited.

Scalability (A3) is uniformly rated at the **Initial stage (score: 1.00)**. All three enablers—**Cloud-based system scaling**, **Modular ITS architecture**, and **Load balancing & system performance monitoring**—are present only in early discussions or planning intentions, with no implementation or piloting recorded. This indicates that while the municipality may acknowledge the importance of scalable architecture, the operational groundwork has yet to be laid. For ITS systems to grow beyond pilot boundaries, this foundation will need strategic investment.

Sustainability Impact (A4) shows relatively better performance, with an **overall Developing level (score: 1.67)**. Technologies contributing to **Energy Efficiency** (score 3), such as **EV charging systems and vehicle optimization tools**, appear more advanced and possibly deployed in early phases. In Shkodra, this is partially reflected in the increasing presence of electric taxis, which are widely used as a cost-efficient alternative to traditional vehicles. **Environmental Benefits** (score 2), enabled by **air quality monitoring technologies**, are partially embedded in municipal practices. However, the dimension of **Social & Economic Benefits** is rated Non-Existent (score 0), pointing to a significant gap in tools and frameworks for equity-based planning and mobility impact analysis. This suggests that while environmental ambitions are materializing, the social dimension of sustainability remains overlooked.

User Acceptance (A5) is also at the **Initial stage (score: 1.00)**. All three indicators—**Cultural & Contextual Relevance**, **Ease of Use & Accessibility**, and **Feedback & Adaptability**—are appraised at level 1. This reflects the presence of early-stage awareness of user needs, possibly within project proposals or strategic objectives, but without concrete user-facing tools or participatory mechanisms in place. Enhancing these aspects is critical to foster citizen engagement and promote inclusive adoption of smart mobility services.

In summary, while Shkodra's enabling environment for smart mobility remains at an early stage, there are encouraging signs in sustainability-related efforts and a clear conceptual awareness across all four domains.

3.6.5 Recommendations for Bridging the Smart Mobility Technology Gap in Shkodra

This section builds on the detailed gap assessment of Shkodra's smart mobility ecosystem. The analysis indicates that while the municipality has basic urban mobility services in place, the deployment of advanced **Key Enabling Technologies (KETs)** for smart mobility is at an early conceptual stage. The focus of this assessment is specifically on the readiness and uptake of KETs relevant to smart mobility transformation, not on the general performance of existing transport services. Initial efforts in sustainability-related technologies and modular system design show promise; however, core capacities in data governance, interoperability, system integration, and user engagement require significant development.

The recommendations take into account the SMARTMOBAIR pilot implemented in Shkodra, which aims to establish a modular traffic data monitoring system to support evidence-based urban mobility planning. The pilot provides an opportunity to build foundational digital infrastructure and institutional capacities, setting the groundwork for future ITS deployment and multimodal integration. Following the three-tiered maturity framework used in the SMARTMOBAIR gap analysis, the recommendations are structured to address (1) technologies at **initial levels** requiring strategic initiation, (2) those at **emerging stages** needing scale-up and integration, and (3) **mature systems** requiring consolidation and optimization.

3.6.5.1 Initial-Level Technologies: Strategic Initiation

Most Key Enabling Technologies (KETs) in Shkodra remain at a conceptual or non-existent stage, requiring strategic action to initiate development pathways.

Recommended actions:

- Launch feasibility studies and concept development for **GIS-based planning tools**, **fleet tracking systems**, and **route optimization algorithms** to build data-driven transport planning capacities.
- Initiate planning for **integrated digital ticketing systems** and **contactless fare collection** to enable future multimodal coordination.
- Develop a **data governance and security framework**, ensuring early adoption of SSL encryption, role-based access controls, and privacy standards.
- Pilot conceptual designs for **adaptive traffic control** and **geo-fencing mechanisms**, focusing on areas with seasonal congestion or safety concerns.
- Introduce planning for **user-oriented information systems**, particularly real-time mobility information for terminals and vehicles.

3.6.5.2 Emerging Technologies: Scaling and Integration

Certain technologies, particularly those related to sustainability monitoring and modular system design, are at an emerging stage but have not yet been operationalized city-wide.

Next steps for scaling and integration:

- Expand the modular ITS architecture piloted under SMARTMOBAIR into adjacent mobility domains such as parking management and pedestrian monitoring, building on the same data collection and dashboard framework tested during the pilot.
- Strengthen **cloud-based scalability infrastructure**, ensuring that initial data systems are ready for broader future deployment.
- Enhance the integration of **IoT sensors** with planned urban mobility dashboards, enabling dynamic monitoring of traffic flows.
- Develop pilot projects that integrate sustainability monitoring with transport planning, particularly air quality sensors and vehicle energy efficiency tools.

3.6.5.3 Mature Technologies: Consolidation and Optimization

While no KETs are fully mature or optimized yet in Shkodra, preliminary steps in sustainability (energy efficiency measures) and conceptual system architecture provide a foundation for future consolidation.

Recommended consolidation measures:

- Formalize a **performance monitoring framework** for early sustainability-related initiatives, linking mobility data to environmental impact tracking.
- Embed **modular and scalable system design principles** into all upcoming mobility projects to future-proof infrastructure investments.
- Initiate early-stage **user engagement strategies**, including awareness-raising, feedback channels, and inclusive design guidelines, to foster user acceptance and adaptability.

3.6.5.4 Strategic Summary

This section outlines the key strategic priorities emerging from the technology gap assessment and corresponding recommendations, providing guidance for phased and context-sensitive advancement of smart mobility in the territory.

The technology gap assessment for Shkodra highlights that while conceptual frameworks and early modular systems will be established through the SMARTMOBAIR pilot, broader deployment of advanced KETs for smart mobility needs to be strategically planned. Initial efforts in traffic data monitoring and system modularity provide a valuable foundation for future development. Moving forward, strategic investment, stakeholder coordination, and gradual system integration will be essential to expand from pilot-level initiatives toward a more comprehensive smart mobility ecosystem.

Strategic priorities for Shkodra include:

- Initiate foundational digital mobility systems, focusing on data governance, transport planning tools, and user information services.
- Scale and integrate emerging modular ITS infrastructure into broader mobility domains beyond traffic monitoring.
- Consolidate preliminary sustainability efforts by embedding environmental monitoring and system performance tracking.
- Build cross-system interoperability and data-sharing frameworks to prepare for future multimodal integration.
- Foster early user engagement and inclusive service design to promote acceptance and long-term adoption.

It should be emphasized that these recommendations are intended as strategic guidance rather than prescriptive measures. Their operationalization should be carefully adapted to the local priorities, resource availability, and national development strategies of Shkodra. The focus on building **core digital infrastructure for public transport and traffic monitoring through the SMARTMOBAIR pilot represents a strong starting point.** To maximize its impact, **future planning should ensure that system development remains scalable, interoperable, and progressively oriented toward broader smart mobility integration, including potential Mobility-as-a-Service (MaaS) applications**.

4 Cross-Territorial Comparison and Strategic Insights for ADRION Smart Mobility Development

This chapter synthesizes findings across the six SMARTMOBAIR pilot territories—Koper, Gorizia, Niš, Novo Sarajevo, Rethymno, and Shkodra—to highlight **shared patterns, common gaps and strengths**, and strategic development opportunities. The comparison focuses on the uptake of Key Enabling Technologies (KETs) for smart mobility within their respective territorial contexts, offering **a broader perspective on regionally relevant priorities and potential directions for coordinated action**.

It should be reminded that, although the analysis is grounded in a common set of indicators, the values reflect each territory's own appraisal based on its local understanding and priorities. The comparison therefore **does not represent full cross-territorial assessment or benchmarking**, but rather a synthesis of locally grounded perspectives on readiness and development needs. Moreover, the presence or absence of particular KETs should be understood in light of contextual factors—such as city size, institutional capacity, and the scope of mobility systems—which naturally shape the uptake and relevance of specific technologies. The aim is not to rank the territories, but to surface meaningful insights that can guide strategic planning within the SMARTMOBAIR framework.

4.1 Common Patterns Across Territories

The identification of common patterns across the pilot territories follows the same analytical structure applied at the territorial level. First, shared observations regarding the technical readiness of KETs are presented. This is followed by an assessment of cross-cutting enablers, including interoperability, scalability, sustainability impact, and user acceptance, which shape the maturity and integration potential of smart mobility systems across the ADRION region.

4.1.1 Technical readiness

The following table summarizes the technical readiness levels for key smart mobility technologies across the six pilot territories assessed. Each KET is evaluated using a six-point scale, where 0 indicates non-existent deployment and 5 reflects optimized, fully operational systems. The assessment reveals a predominance of low to mid-level maturity across most technologies, with a significant share of technologies evaluated at non-existent, initial, or emerging stages. Only a limited number of technologies—mainly related to traffic monitoring, IoT-based data collection, and real-time information provision—reach mature or optimized deployment levels in certain territories. This distribution highlights both the early development phase of many smart mobility systems and the presence of strategic entry points for future scaling and integration efforts.

Table 4.1 Technical Readiness of Smart Mobility KETs Across Territories

Source: SMARTMOBAIR Technology Gap Assessment

Domain	Sub-domain	Key Enabling Technology (KET)	Gorizia	Koper	Niš	N. Sarajevo	Rethymno	Shkodra
A1.1 Data (w25)	A1.1.1 Data use	IoT sensors for mobility data collection	5	2	3	3	5	1
	A1.1.2 Data security	SSL encryption & database security	4	2	3	1	5	1
	A1.1.3 Data privacy	Role-based access control systems	5	0	3	1	3	1
A1.2 Transport Management (w15)	A1.2.1 Transport service definition	Standard (e.g. GTFS, NeTEx) -based multimodal transport definitions	5	0	4	0	0	0
	A1.2.2 Transport planning functionalities	GIS-based transport planning tools	5	1	1	3	0	1
	A1.2.3 Transport operation functionalities	Fleet tracking & scheduling software	4	1	4	3	4	0
	A1.2.4 Complemental solutions	Route optimization algorithms	3	0	0	0	0	1
A 1.3 Fare Collection (w15)	A1.3.1 Fare collection process	Contactless fare payment systems	4	0	4	3	0	0
	A1.3.2 Technical definition ownership	Integrated Digital Ticketing for Multimodal Payment	4	0	0	0	0	1
	A1.3.3 Interoperability with private services	Interoperable open-loop payment system (e.g. via credit card or wallet)	2	0	3	3	3	0
A1.4 Traffic Management (w15)	A1.4.1 Implemented control	Adaptive traffic signal control	0	1	2	3	0	0
	A1.4.2 Implemented protocols	Communication protocols like for e.g. vehicle routing protocols within VANETs	0	3	0	0	0	0
	A1.4.3 Enforcement tools	Automated enforcement systems	0	3	2	1	0	0
A1.5 Urban Space Management (w10)	A1.5.1 Parking management	Parking occupancy sensors	0	1	4	4	5	1
	A1.5.2 Restricted area access management	Geo-fencing & restricted access control	1	4	0	0	0	0
	A1.5.3 Urban use management	Urban mobility management platforms	0	4	3	1	0	1
A1.6 Security on Mobility (w10)	A1.6.1 Video Surveillance	CCTV surveillance	5	1	4	1	3	1
	A1.6.2 Violence reporting	Crowd movement analytics dashboards	0	0	0	0	0	0
A1.7 Passenger information system (w10)	A1.7.1 Information available onsite	Real-time mobility information available onsite (stops, terminals, hubs),	5	1	2	2	0	1
	A1.7.2 Information available in PT vehicles	Real-time mobility information available in vehicles	5	0	4	4	0	0
	A1.7.3 Information available online	Real-time mobility information via web & mobile apps	4	1	4	4	3	1

Legend: 0 – Non-Existent Deployment; 1 – Initial Stage (conceptual or early discussions); 2 – Emerging Stage (tested in controlled environment, no real world application);3 – Developing Stage (operational in pilots, limited but real-world areas); 4 – Mature Stage (operational and functional city-wide); 5 – Optimized Stage (fully deployed, continuously improved)

4.1.1.1 Shared strengths in Technical Readiness

The identification of shared strengths in Technical Readiness is based on the operational deployment of KETs across the six pilot territories. Deployment is considered from the Developing Stage (Level 3) upwards, meaning that the technology is operational in pilots or limited real-world conditions. This reflects a **practical threshold for smart mobility readiness, recognizing that true implementation begins once technologies move beyond conceptualization and laboratory testing into live urban environments.**

A KET is considered a shared strength if it achieves real-world deployment (Level 3–5) in multiple territories, generally covering around half of the observed cases, and without widespread non-existence (absence of critical mass of zero scores). This approach emphasizes technologies that are already delivering practical value and can serve as foundations for regional scaling and further innovation.

Applying this perspective, the following KETs emerge as shared strengths:

- **IoT-based traffic and mobility data collection (A1.1.1)**: IoT sensor systems have achieved operational deployment in four out of six territories, with no widespread non-existence recorded. While maturity levels vary, from pilot-scale applications to fully optimized deployments, the consistent real-world use of these technologies signals a robust foundation for building dynamic, data-driven mobility services.
- **Data security and privacy measures (A1.1.2)**: SSL encryption and database security technologies are deployed in four out of six territories, with no territories lacking basic implementation. Although the degree of sophistication varies, the widespread existence of functional data security infrastructures is a critical enabler for further digitalization of mobility services.
- **Real-time mobility information via web and mobile applications (A1.7.3)**: Real-time traveler information systems accessible via web or mobile apps have been deployed in four territories, without significant gaps. Variations exist in the depth and integration of information provided, but the widespread operational presence of these services establishes a strong basis for user-centered smart mobility development.

Localized strength:

- **Urban mobility management platforms (A1.5.2)**: Operational deployment of urban mobility management platforms is evident in three territories, while in the remaining territories the concept remains at an emerging or developing stage, often limited to partial functionality or early-stage planning. Although geographically concentrated, these platforms offer practical tools for regulating access control, parking, and urban logistics, and can serve as models for broader regional application.

The technological foundations outlined above suggest several ITS solution areas that are particularly viable for further development across the ADRION territories:

- **Real-time traffic monitoring and management systems**: These systems use sensor networks and digital platforms to monitor traffic flows, detect incidents, and dynamically optimize urban mobility conditions. *Such systems primarily support transport planners and traffic management operators by enabling more responsive regulation of vehicle movements, congestion mitigation, and incident response.*
- **User-centered information services**: Digital platforms that provide real-time updates regarding transport options, routing alternatives, service delays, and parking availability, delivered through web portals, mobile applications, or in-vehicle information systems. *These services are principally designed to enhance the experience of end users — including citizens, commuters, and visitors — by facilitating informed, flexible, and efficient travel choices.*
- **Urban access control and mobility management platforms**: Integrated systems that digitally regulate vehicular access to designated urban areas, manage parking supply and logistics flows, and implement

dynamic restrictions through tools such as geo-fencing and digital permitting. *These platforms primarily serve city authorities and transport planners by enabling the strategic regulation of urban traffic and stationary mobility, while indirectly improving urban space accessibility and environmental quality for citizens.*

These solution areas offer strategic entry points for strengthening smart mobility capacities across the region and progressively preparing the territories for higher levels of service integration, scalability, and eventual transition toward Mobility-as-a-Service (MaaS) ecosystems. Real-world implementations of similar smart mobility solutions in cities such as Barcelona, Helsinki, and London demonstrate their potential benefits for traffic efficiency, traveler experience, and urban sustainability.

4.1.2 Shared Gaps in Technical Readiness

The identification of shared gaps is based on the absence of operational deployment (below Level 3) of Key Enabling Technologies (KETs) across the six pilot territories. A KET is considered a shared gap if it remains at the Non-Existent, Initial, or Emerging Stage (Levels 0–2) in at least half of the observed cases, or if critical absence (Level 0) is observed across a majority of territories. This approach highlights areas where smart mobility capacities are still conceptual, experimental, or not yet translated into real-world operational systems, thus indicating priority fields for strategic investment and development.

Applying this methodology, several shared gaps emerge:

- **Integrated fare management systems**: Technologies supporting contactless fare payment (A1.3.1), integrated digital ticketing (A1.3.2), and interoperable open-loop payment systems (A1.3.3) remain largely absent or at conceptual stages across the majority of territories. The lack of real-world deployment significantly limits opportunities for seamless multimodal integration and user-centered mobility services.
- **Dynamic traffic control and advanced traffic management technologies**: Adaptive traffic signal control systems (A1.4.1) and communication protocols for vehicle-infrastructure interaction (A1.4.2) are at non-existent or very early stages in most territories. Without these functionalities, the ability to dynamically manage traffic flows, prioritize sustainable transport modes, and reduce congestion remains constrained.
- **Predictive and crowd movement analytics**: Technologies related to crowd movement analytics dashboards (A1.6.2) are almost entirely non-existent across all observed territories. This critical gap limits the capacity for real-time monitoring of pedestrian flows and the design of responsive, safe, and adaptive urban spaces.
- **Multimodal transport planning and open data standards**: The adoption of standard multimodal transport data definitions (A1.2.1, e.g., GTFS, NeTEx) remains limited. Without these foundations, the development of integrated public transport services, journey planning applications, and interoperable smart mobility ecosystems is severely restricted.
- **Comprehensive real-time passenger information systems**: While some progress exists in web- and app-based real-time information, the deployment of real-time passenger information systems at stops, hubs, and inside vehicles (A1.7.1, A1.7.2) remains fragmented and underdeveloped across the majority of territories, impacting the overall quality and accessibility of public transport services.

Overall, these gaps illustrate persistent structural weaknesses in the smart mobility ecosystems of the ADRION territories. They highlight the need for coordinated investments, capacity building, and strategic innovation to bridge foundational technological deficits and enable a progressive transition toward integrated, resilient, and user-centered mobility systems.

4.1.3 Cross-Cutting Enablers Patterns

In addition to the core technical readiness of smart mobility solutions, the effective deployment and long-term success of smart mobility ecosystems depend heavily on a set of cross-cutting enablers. These enablers — encompassing interoperability, scalability, sustainability impact, and user acceptance — represent transversal factors that influence the integration, resilience, and societal acceptance of technological innovations.

This section presents the results of the cross-territorial assessment of cross-cutting enablers, focusing on their current levels of maturity across the six SMARTMOBAIR pilot territories: Gorizia, Koper, Niš, Novo Sarajevo, Rethymno, and Shkodra. The assessment was conducted using the Gap Analysis Tool developed within the SMARTMOBAIR project, based on a qualitative appraisal approach structured along a standardized ladder of development and maturity levels. This ladder ranges from 0 (non-existent deployment) to 5 (optimized deployment), where the numeric values serve as technical references for positioning the stage of development, rather than as quantitative scores.

Table 4.2 summarizes the technical readiness appraisal of key cross-cutting enablers, organized into four thematic areas: interoperability (A2), scalability (A3), sustainability impact (A4), and user acceptance (A5).

Table 4.2 Cross-territorial comparison of Cross-Cutting Enablers for Smart Mobility

Source: SMARTMOBAIR Technology Gap Results

Domain	Sub-domain	KETs	Gorizia	Koper	Niš	N. Sarajevo	Rethymno	Shkodra
A2-Interoperability (w15)	A2.1 Standards Compliance	GTFS, NeTEx, DATEX II-based compliance	5	0	2	0	0	0
	A2.2 API & Data Exchange	Secure API management platforms	5	1	3	1	3	0
	A2.3 Cross-System Integration	Transport network data integration systems	5	1	3	0	1	1
A3- Scalability (w15)	A.3.1 Expansion Capability	Cloud-based system scaling platforms	5	0	3	2	5	1
	A 3.2 Modular Architecture	Modular ITS architecture software	5	1	2	3	1	1
	A 3.3 Performance Under Load	Load balancing & system performance monitoring	4	3	0	0	5	1
A4-Sustainability Impact (w15)	A4.1 Environmental Benefits	Air Quality Sensors & CO_2 Monitoring Systems	4	1	3	4	3	2
	A4.2 Energy Efficiency	Smart Grid-Integrated EV Charging & Vehicle Energy Optimization	3	1	0	4	3	3
	A4.3 Social & Economic Benefits	Equity-Focused Mobility Data Platforms & Economic Impact	3	1	0	0	0	0
A5- User Acceptance (w15)	A5.1 Cultural & Contextual Relevance	Language localization & translation systems	0	0	2	1	1	1
	A5.2 Ease of Use & Accessibility	Accessible UI/UX design principles	4	0	0	0	1	1
	A5.3 Feedback & Adaptability	User feedback collection & sentiment analysis tools	0	0	0	0	1	1

Legend: 0 – Non-Existent Deployment; 1 – Initial Stage (conceptual or early discussions); 2 – Emerging Stage (tested in controlled environment, no real world application);3 – Developing Stage (operational in pilots, limited but real-world areas); 4 – Mature Stage (operational and functional city-wide); 5 – Optimized Stage (fully deployed, continuously improved)

The appraisal of cross-cutting enablers across the six SMARTMOBAIR pilot territories reveals several patterns. While the maturity of enablers varies considerably across territories, certain common trends emerge. Interoperability-related enablers generally show **relatively** higher stages of development, with multiple territories advancing toward pilot or operational deployment. User acceptance enablers also display early signs of structured engagement; though operational maturity remains limited. In contrast, scalability and sustainability impact enablers consistently lag behind, with most territories remaining at conceptual or emerging stages of development.

These patterns suggest that while technical integration and user-centered approaches are beginning to be addressed, the scaling of solutions and their alignment with broader sustainability objectives require further strategic focus. The following paragraphs provide a more detailed analysis of each thematic area.

4.1.3.1 Interoperability

Some progress in interoperability has been achieved, with three of six territories showing some deployment in real-world settings, particularly related to KET **A2.2 (API & Data Exchange)**. The introduction of modular ITS architectures and limited standardized data handling demonstrates that foundational capacities for interoperable smart mobility are starting to emerge. Although comprehensive interoperability is not yet widespread, these early deployments provide a critical basis for future integration efforts.

At the same time, major interoperability gaps persist, with a majority (four of six territories) remaining below the threshold of real-world deployment. Notably, KET **A2.1 (Standards Compliance)** and **A2.3 (Cross-System Integration)** show little operationalization across the observed territories. The absence of such interoperability frameworks limits the ability to create seamless user journeys and cross-system connectivity.

Overall, the pattern observed indicates that while basic interoperability is beginning to be addressed through modular approaches and initial data exchange initiatives, fully integrated, real-time, and multimodal interoperability remains underdeveloped across the region. Progress tends to be confined to specific systems or domains, without systemic horizontal integration across broader urban mobility environments.

This trend highlights the importance of scalability as the next critical enabler to be considered, focusing on challenges and opportunities associated with extending pilot-based deployments into more comprehensive and sustainable smart mobility networks.

4.1.3.2 Scalability

Some deployment in real-world settings related to scalability is observed in two of six territories, primarily associated with KET **A3.1 (Expansion Capability)**. Efforts to design modular system architectures capable of limited expansion or replication beyond pilot areas demonstrate important preliminary experiences for future scaling.

However, scalability remains a shared gap, with a majority (four of six territories) still operating below the threshold of real-world deployment. KET **A3.2 (Modular Architecture)** and **A3.3 (Performance Under Load)** in particular show limited attention in project design and implementation. The absence of scalability frameworks risks confining smart mobility innovations to isolated, non-replicable initiatives.

The overall tendency indicates that scalability considerations are only marginally present. While individual pilots demonstrate technical potential, strategic frameworks for systematic scaling remain undeveloped.

4.1.3.3 Sustainability Impact

Operational deployment reflecting sustainability impact considerations is visible in only one of six territories, mostly linked to KET **A4.1 (Environmental Benefits)**. Although individual projects incorporate sustainability goals at a general level, systematic approaches to integrating and measuring sustainability outcomes are rare.

Sustainability-related enablers show significant shared gaps, with five of six territories remaining at the non-existent or conceptual stages. Particularly, KET **A4.2 (Energy Efficiency)** and **A4.3 (Social & Economic Benefits)** are underdeveloped or absent in operational contexts. This limits the broader strategic contribution of smart mobility projects to urban sustainability transitions.

Overall, sustainability impact remains the least developed cross-cutting enabler across the observed territories. Although recognized as a policy goal, its operationalization into measurable frameworks within smart mobility pilots remains very limited and fragmented.

The next dimension, user acceptance, provides further insight into the social readiness of smart mobility solutions and the degree of active engagement with end users during deployment processes.

4.1.3.4 User Acceptance

Some deployment addressing user acceptance is observed in three of six territories, particularly related to KET **A5.1 (Cultural & Contextual Relevance)** and **A5.2 (Ease of Use & Accessibility)**. These initiatives reflect an emerging focus on integrating user feedback mechanisms and participatory processes into pilot design and implementation.

Nevertheless, important gaps remain, with three of six territories still operating below the threshold of real-world deployment regarding structured user engagement. Limited deployment is observed for KET **A5.3 (Feedback & Adaptability)**, with user-centered approaches often peripheral rather than systematically embedded into project planning.

The overall pattern suggests that while user acceptance is beginning to be addressed in pilot initiatives, engagement approaches remain uneven and insufficiently scaled. More systematic integration of participatory methodologies and behavioral change strategies is needed to fully realize the potential of citizen-centered smart mobility services.

4.2 Summary and recommendations from cross-territorial perspective

The **cross-territorial comparison of technical readiness reveals** a landscape characterized by **uneven development, with a limited number of KETs reaching operational deployment** while significant foundational gaps persist**. Shared strengths** are observed particularly in the deployment of **IoT-based mobility data collection systems, basic data security infrastructures, and real-time information services accessible through web and mobile applications**. These technologies demonstrate real-world operationalization (Level 3–5) in multiple territories, providing a solid starting point for future scaling and integration efforts. Urban mobility management platforms also emerge as localized strengths, with operational deployment in selected territories, although their presence remains geographically concentrated.

Conversely, **several critical gaps are consistently identified across the territories. Integrated fare management systems, dynamic traffic control technologies, predictive crowd analytics, and the adoption of standard multimodal transport data definitions** remain largely absent or confined to conceptual and experimental stages (Levels 0–2) across a majority of cases. The fragmented deployment of comprehensive real-time passenger information systems further constrains the accessibility and attractiveness of public transport services.
Overall, the pattern indicates that while early-stage operational capacities are beginning to form around data-driven services and user information provision, the broader technological baseline for integrated, multimodal, and scalable smart mobility solutions remains underdeveloped. Addressing these structural weaknesses through coordinated investment, capacity-building initiatives, and strategic innovation will be essential for enabling the progressive transition of the observed ADRION territories toward resilient, sustainable, and user-centered smart mobility systems.

Similarly, the cross-territorial analysis of **cross-cutting enablers** reveals a **pattern of partial progress accompanied by persistent structural gaps**. **While interoperability and user acceptance show early signs of**

operationalization in several territories, **scalability, user acceptance and particularly sustainability impact remain underdeveloped**, with most territories without real-world deployment. These findings highlight the need for more systematic integration of cross-cutting enablers into smart mobility planning, ensuring that future advancements are not only technically feasible but also scalable, sustainable, and inclusive. **Building on the cross-territorial comparison, the following recommendations are proposed** to guide macroregional action, supporting the coordinated development of integrated, resilient, and citizen-centered smart mobility ecosystems across the observed ADRION territories:

- **Facilitate knowledge transfer and peer learning** across territories by establishing structured mechanisms for exchanging good practices in IoT-based data collection, real-time information services, and urban mobility management.
- **Promote the harmonization of technical standards** (e.g., open data formats, interoperability protocols) to enable cross-border integration of mobility services and support the development of a coherent smart mobility ecosystem at the macroregional level.
- **Support the development of capacity-building programs** aimed at strengthening technical, institutional, and governance capacities in emerging smart mobility domains, particularly in territories with early-stage deployment.
- **Encourage alignment of national and regional funding instruments** to prioritize investment in key enablers such as integrated fare management, dynamic traffic control, sustainability monitoring, and user engagement strategies.
- **Coordinate the development of regional smart mobility strategies** that embed scalability and sustainability objectives from the outset, ensuring that pilot initiatives are designed to evolve into systemic solutions.
- **Foster the integration of sustainability impact assessment frameworks** within smart mobility planning at territorial and macroregional levels, linking mobility innovation efforts to broader climate-neutrality and resilience targets.
- **Enable the embedding of structured user engagement approaches** in smart mobility projects, moving beyond pilot-specific consultations toward systemic models of citizen participation in service design and evaluation.

The cross-territorial analysis **highlights opportunities to foster structured peer-learning processes among SMARTMOBAIR pilot territories**. Cities demonstrating mature deployment (Levels 4–5) in specific Key Enabling Technologies (KETs) can serve as knowledge hubs, supporting capacity-building among territories where these technologies remain at early development stages. Table 4.3 presents potential peer learning pathways across key smart mobility domains.

Table 4.3 Potential Peer Learning Opportunities Across Pilot Territories Based on Technical Readiness

Domain / KET Area	Potential Peer Cities	Potential Learning Cities
IoT-based Mobility Data Collection	Gorizia, Rethymno	Koper, Shkodra
Data Security (SSL Encryption)	Gorizia, Rethymno	Koper, Shkodra
Data Privacy (Role-Based Access Control)	Gorizia	Koper, Shkodra
Multimodal Transport Data Standards	Gorizia, Niš	Koper, Novo Sarajevo, Rethymno, Shkodra
GIS-Based Transport Planning	Gorizia	Koper, Niš, Rethymno, Shkodra
Fleet Tracking and Scheduling	Gorizia, Niš, Rethymno	Koper, Shkodra
Route Optimization Algorithms	Gorizia	Koper, Niš, Novo Sarajevo, Rethymno, Shkodra
Contactless Fare Payment Systems	Gorizia, Niš	Koper, Rethymno, Shkodra
Integrated Digital Ticketing	Gorizia	Koper, Niš, Novo Sarajevo, Rethymno, Shkodra
Interoperable Open-Loop Payment Systems	Gorizia	Koper, Rethymno, Shkodra
Communication Protocols (VANETs etc.)	Koper	Gorizia, Niš, Novo Sarajevo, Rethymno, Shkodra
Automated Enforcement Systems	Koper	Gorizia, Niš, Novo Sarajevo, Rethymno, Shkodra
Parking Occupancy Sensors	Niš, Rethymno	Gorizia, Koper, Shkodra
Geo-Fencing and Access Control	Koper	Gorizia, Niš, Novo Sarajevo, Rethymno, Shkodra
Urban Mobility Management Platforms	Koper	Gorizia, Novo Sarajevo, Rethymno, Shkodra
Video Surveillance (CCTV)	Gorizia, Niš	Koper, Novo Sarajevo, Shkodra
Real-Time Mobility Info Onsite	Gorizia	Koper, Rethymno, Shkodra
Real-Time Mobility Info in Vehicles	Gorizia, Niš	Koper, Rethymno, Shkodra
Real-Time Mobility Info Web/Mobile	Gorizia, Niš	Koper, Rethymno, Shkodra

It is important to note that the suggestions are made solely based on the appraisal of the KETs maturity and does not take into account territorial context as an important factor of successful policy transfer based on cross-territorial learning. The cross-territorial peer learning insights reveal some patterns regarding the distribution of technical readiness and learning potential among the SMARTMOBAIR pilot territories:

- **Gorizia** emerges as a **consistent peer mentor** across demonstrating mature or optimized deployments (Level 4–5) in multiple domains. Gorizia does not appear as a learner city in any KET, underlining its relatively advanced position within the observed cohort.
- **Niš** plays a **dual role**: it acts as a **peer mentor** in areas such as fleet tracking, contactless fare systems, parking management, and real-time user information, while also remaining a **learner** in several areas including GIS-based transport planning, route optimization algorithms, integrated digital ticketing, and advanced traffic control systems.
- **Koper** presents an **interesting selective profile**, acting as a **peer mentor specifically in geo-fencing and digital access control solutions**, while maintaining a learner status in several other technical domains. This reflects the targeted development focus observed in its pilot activities.
- **Novo Sarajevo** primarily acts as a **learner** across the assessed KETs, with some limited operational deployment (pilot-level) observed in adaptive traffic signal control. Similarly, **Rethymno and Shkodra** appear predominantly as **learner territories**, with limited instances of mature technical deployment. Both, however, demonstrate innovation potential and pilot-level engagement that, if supported through structured knowledge transfer and capacity-building initiatives, could significantly strengthen their smart mobility ecosystems.

No territory demonstrates full maturity across all KET domains, reinforcing the value of adopting a **mutual learning approach** rather than a hierarchical model of knowledge transfer, with each territory contributing to and benefiting from regional cooperation dynamics.

Building on these insights, the SMARTMOBAIR pilot actions represent important stepping stones for advancing the technical readiness and cross-cutting enabler integration across the ADRION region. By strategically linking pilot outcomes to macroregional capacity-building, standardization efforts, and coordinated investment priorities, the pilots can catalyze broader transitions toward scalable, sustainable, and user-centered smart mobility systems. Continued monitoring, knowledge exchange, and adaptive learning will be essential to maintain momentum and ensure lasting regional impact.
Unlike technical readiness, cross-cutting enablers of smart mobility do not exhibit sufficient maturity dispersion across the observed territories to enable structured peer learning pathways. In most cases, operational deployment of key enablers such as interoperability frameworks, modular system architectures, sustainability impact tools, and user engagement mechanisms remains isolated or incomplete. As a result, it is advisable that the territories seek reference to successful practices and models developed outside the investigated area, drawing from broader European or international experiences. Table 4.4 presents possible peer cities. They have been selected based on the demonstrable success of their smart mobility initiatives in achieving operational maturity, systemic integration, and measurable urban impacts.

Table 4.4 European Exemplar Cities for Cross-Cutting Enablers of Smart Mobility

Enabler	European Examples	Short Explanation
Interoperability	**Helsinki, Finland** (via MaaS Global and Whim App)	Helsinki pioneered interoperable mobility platforms integrating public and private services under a unified payment and ticketing system, setting a European benchmark for MaaS interoperability.
Scalability	**Vienna, Austria** (WienMobil platform)	Vienna has demonstrated successful scaling of integrated urban mobility services, expanding from pilot initiatives to a fully operational city-wide multimodal service network.
Sustainability Impact	**Copenhagen, Denmark** (Climate action plan and mobility integration)	Copenhagen systematically embeds sustainability objectives into ITS deployment and urban mobility planning, linking technological innovation to carbon reduction targets and urban livability.
User Acceptance	**Barcelona, Spain** (Smart City strategy and participatory mobility planning)	Barcelona emphasizes citizen engagement in shaping smart mobility services through public consultations, living labs, and participatory digital platforms, fostering higher user acceptance and adoption rates.

Drawing from these examples, the ADRION territories can adopt tailored approaches to strengthen their cross-cutting enablers, moving beyond isolated technological deployments toward integrated, scalable, sustainable, and citizen-driven smart mobility systems. Notable EU initiatives and projects that have captured and promoted these best practices include the **MaaS4EU project** (interoperability and user acceptance – Helsinki, Barcelona), **CIVITAS Initiative** (scalability – Vienna), and **GrowSmarter** (sustainability impact – Copenhagen, Barcelona). Leveraging insights from such programs can further accelerate knowledge transfer and strategic capacity building within the region. Furthermore, future actions aiming to operationalize peer learning and cross-cutting enabler development could benefit from opportunities provided under Horizon Europe WIDERA calls, particularly those supporting twinning, teaming, and excellence hubs initiatives in widening countries.

5 Concluding remarks

The technology gap assessment conducted across the six SMARTMOBAIR pilot territories reveals both emerging strengths and persistent structural gaps. While certain Key Enabling Technologies (KETs) — particularly those 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. Shared strengths are concentrated in foundational elements that support basic smart mobility functions, but comprehensive integration, interoperability, and service scalability are still limited.

The cross-territorial analysis further confirms that while early digitalization initiatives are underway, systemic smart mobility readiness — involving dynamic traffic control, integrated fare management, multimodal planning, and predictive analytics — remains fragmented. Similarly, the maturity of cross-cutting enablers such as interoperability, scalability, sustainability impact assessment, and user acceptance is low, with most territories operating below real-world deployment thresholds.

Overall, the assessment shows that the SMARTMOBAIR territories are entering a critical transition phase. Initial investments and pilot deployments have laid important foundations, but achieving a fully integrated, resilient, and citizen-centered smart mobility ecosystem will require coordinated scaling, enhanced institutional capacity, and a stronger emphasis on systemic enablers.

Based on the findings, several strategic priorities are identified to guide future action:

- **Consolidating foundational technologies**, ensuring the stability and integration of existing operational systems related to data collection, security, and real-time information services.
- **Bridging critical technology gaps**, particularly in integrated fare management, dynamic traffic control, multimodal data standardization, and predictive analytics capabilities.
- **Strengthening cross-cutting enablers**, including interoperability frameworks, modular architectures, sustainability impact monitoring tools, and structured user engagement mechanisms.
- **Fostering institutional capacity and governance readiness**, ensuring that technical deployment is supported by strong institutional frameworks and technical expertise.
- **Embedding smart mobility into broader urban and regional development strategies**, aligning digital mobility innovation with sustainability, climate neutrality, and inclusive growth objectives.

The cross-territorial analysis suggests that structured knowledge exchange could serve as a valuable mechanism for supporting the advancement of smart mobility capacities across the ADRION region. Certain pilot territories demonstrate relatively higher operational maturity in selected KETs, offering potential reference points for targeted capacity-building efforts. However, it is important to note that the observed differences in maturity levels are preliminary and context-specific, and further detailed assessments would be necessary to establish fully operational peer learning frameworks. While initial comparisons indicate that cities such as Gorizia and Niš have achieved more advanced deployment in certain domains, and that others such as Novo Sarajevo, Rethymno, and Shkodra are at earlier stages of digital transformation, the current cross-comparison does not yet provide a sufficiently robust basis for formalized cross-learning pathways. Rather, it highlights areas where mutual knowledge exchange, technical cooperation, and joint learning initiatives could be explored to strengthen regional innovation capacities. Future efforts aimed at promoting cross-territorial learning should be carefully designed, based on more detailed mappings of institutional capacities, deployment environments, and innovation ecosystems. Structured cooperation mechanisms — such as thematic working groups, twinning initiatives, or technical pilot exchanges — could provide an appropriate framework for facilitating gradual knowledge transfer while respecting the specific developmental contexts of each territory.

Given the limited operational maturity of cross-cutting enablers within the observed territories, it is advisable to look toward leading European cities as reference models. Examples such as Helsinki, Vienna, Copenhagen, and Barcelona offer valuable insights into building interoperability frameworks, scalable systems, sustainability-driven mobility planning, and user-centered service design.

Moving forward, further actions should focus on translating the identified strategic priorities into operational roadmaps tailored to each territorial context which is planned within dedicated activity of the SMARTMOBAIR project (A1.5). Particular emphasis should be placed on scaling up pilot solutions, investing in key enabling technologies that remain at conceptual or emerging stages, and systematically embedding cross-cutting enablers into smart mobility planning frameworks.

Opportunities under European knowledge transfer initiatives, including Horizon Europe WIDERA calls, offer promising pathways to support these efforts through structured capacity-building, twinning, and excellence hubs. By building on the analytical foundations established in this report, the SMARTMOBAIR territories can progressively move from isolated pilot deployments toward integrated, scalable, and resilient smart mobility ecosystems.

Another future step aligned with this report is the preparation of the **Factsheets on Adoptable Smart Mobility Technologies** (Deliverable 1.4.2), which will build further upon the assessment of pilot solutions partially addressed within this report. To support this process, a preliminary indication on the *adoptability* can be drawn from the gap analysis results. Technologies demonstrating a deployment level of 3 (Developing Stage) or higher in at least one territory, and without evidence of complete non-existence across the observed pilots, are considered particularly promising. This primary set includes IoT sensors for mobility data collection, real-time mobility information systems via web and mobile applications, parking occupancy sensors, and SSL encryption and database security platforms. In addition, an extended list of technologies emerges based on slightly more flexible criteria, where deployment may exist only in selected territories or where limited instances of non-existence are recorded. This extended set includes urban mobility management platforms, contactless fare payment systems, geo-fencing and restricted access control systems, and API-based data exchange platforms.

While the final selection of adoptable technologies will be refined in the forthcoming deliverable, this preliminary orientation highlights technological building blocks with a potential to support the implementation and scaling of pilot solutions in the next phases of the project. The finalization of the factsheets will thus complement the strategic insights developed through this report, further supporting the territories in translating their pilot initiatives into scalable and integrated smart mobility solutions.

The Deliverable 1.4.2 is also closely interconnected with the Deliverable 1.5.1 (**SMARTMOBAIR technology roadmap**) which will highlight the development and future impacts of emerging smart mobility-related technologies. Together they contribute to a coherent process aimed at supporting informed decision-making for the adoption of smart mobility technologies in the Adriatic-Ionian region. While Deliverable 1.4.2 provides a bottom-up perspective based on insights from the pilot territories, Deliverable 1.5.1 offers a top-down strategic vision of where technology is heading. Together, they form a comprehensive knowledge base. This integrated approach also ensures that technology selection for testing is grounded both in current feasibility and future relevance, maximizing the impact and sustainability of smart mobility interventions across the ADRION region.