

SMILE CITY

Sustainable Materials for Innovative, Low Emissions applications in the Circular ciTY



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Table of Contents

1	EXECUTIVE SUMMARY.....	4
1.1	PURPOSE OF THE DELIVERABLE.....	4
1.2	BRIEF DESCRIPTION OF ACTIVITIES AND RESULTS	4
2	ACTIVITIES CARRIED OUT.....	6
2.1	STANDARDS AND REGULATIONS FOR E-BIKE CHARGING STATIONS, AND SOLUTIONS FOR EFFICIENT E-BIKE MOBILITY (BY CIE, ECF).....	6
2.1.1	<i>Introduction</i>	6
2.1.2	<i>E-Bike Charging Station Standards and Regulations.....</i>	6
2.1.3	<i>Solutions to Support Efficient E-Bike Mobility and Charging.....</i>	10
2.1.4	<i>Key Benefits of Efficient E-Bike Charging Infrastructure.....</i>	11
2.1.5	<i>Conclusion and Recommendations.....</i>	11
2.2	STATE OF THE ART OF THE EXISTING DIGITAL TOOLS, SOLUTIONS, AND COMMERCIALY AVAILABLE SOFTWARE RELATED TO THE E-BIKE CHARGING STATIONS (CNR).....	14
2.2.1	<i>Introduction</i>	14
2.2.2	<i>Leading Software Solutions for E-Bike Charging Stations</i>	14
2.2.3	<i>Comparative analysis.....</i>	15
2.2.4	<i>Critical Analysis and User-Centric Design Recommendations</i>	16
2.2.5	<i>Conclusion</i>	17
2.3	ANALYSE APP SOLUTIONS (BY SOLUM)	19
2.3.1	<i>Introduction</i>	19
2.3.2	<i>Analysis Methodology</i>	19
2.3.3	<i>Application Analysis.....</i>	21
2.3.4	<i>Comparative Analysis of Apps</i>	39
2.4	CONCEPT OF ECO-COST MANAGEMENT APPLICATION (BY IETU).....	41
2.4.1	<i>General description and functionality</i>	41
2.4.2	<i>Tools and database</i>	44
2.5	TRACK DEVELOPMENTS ON EU DATA AND MOBILITY REGULATIONS AND INSTRUMENTS WHICH WILL INTEGRATE WITH THE E-BIKE CHARGING STATION (BY CIE, ECF).....	48
2.6	METHODS FOR CONNECTING SMILE CITY DIGITAL TOOLS AND APP WITH DATABASES (BY NTU)	49
2.6.1	<i>Methods for connecting digital tools & Apps with databases.....</i>	49
2.6.2	<i>Efficient data management with security.....</i>	50
2.7	FEASIBILITY STUDY FOR THE IMPLEMENTATION OF DIGITAL TOOLS (BY NTU)	52
2.7.1	<i>Overview of the condition monitoring system for e-bike charging stations.....</i>	52
2.7.2	<i>Digital hardware-based tools (T4.1).....</i>	52
2.7.3	<i>Condition monitoring method and software (T4.5)</i>	53
2.8	TECHNICAL REQUIREMENTS FOR CLIENT ENDPOINTS INCLUDING MONITORED PARAMETERS (BY IETU)	55
2.8.1	<i>Technical requirements for client endpoints</i>	55
2.8.2	<i>Monitoring solutions for air quality and meteorological conditions.....</i>	58
2.8.3	<i>Selection, integration and processing of monitored and collected parameters.....</i>	59
3	CONCLUDING REMARKS	61



1 EXECUTIVE SUMMARY

1.1 Purpose of the deliverable

The purpose of this deliverable is to support the planning and development of digital and mobile tools for the SMILE CITY project, with a specific focus on encouraging efficient and sustainable use of e-bikes in urban areas. Task 2.4 aims to assess and establish a robust foundation for digital and app-based tools that support the efficient use of bikes and e-bikes in urban mobility systems. This task specifically focuses on identifying, evaluating, and integrating available, developable, and implementable digital solutions that enhance the planning, accessibility, and management of e-bike infrastructure, particularly charging stations. The ultimate objective is to inform the design of SMILE CITY's digital tools and mobile applications.

The outcome of this deliverable is combined efforts by the task team including: - Nottingham Trent University (NTU, task leader), Cycling Industries Europe (CIE), European Cyclists' Federation (ECF), National Research Council of Italy (CNR), Solum Photovoltaic Innovation SL (Solum), Institute for Ecology of Industrial Areas (IETU), The European Tyre Recycling Association (ETRA), University of Turin (UNITO).

1.2 Brief description of activities and results

The deliverable comprises analytical reports submitted by multiple project partners, each addressing a critical component of the SMILE CITY ecosystem, ranging from charging station regulations to digital app feasibility studies. Together, these contributions form a knowledge base that will inform the design, deployment, and integration of SMILE CITY's digital tools and mobile app infrastructure.

Key activities conducted by partners include:

As the task leader, NTU produced the activity plan and leads the writing of the deliverable.

CIE and ECF provide two reports assessed European regulations governing e-bike charging stations. The first one examines the evolving landscape of standards and regulations governing e-bike charging stations, with a focus on battery safety, infrastructure accessibility, and energy efficiency. It highlights key European directives such as Regulation (EU) 2023/1542 and EN 15194:2017+A1:2023 and explores national fire safety standards and building directives that shape infrastructure deployment. In parallel, the report presents innovative solutions—including smart charging systems, battery swapping, solar-powered stations, and integration with public transport—that support scalable and user-friendly e-bike mobility. It concludes by emphasizing the importance of harmonized regulation, technological innovation, and cross-sector collaboration to develop a resilient and accessible e-bike charging ecosystem that advances urban sustainability and multimodal transport integration.

The second report examines the integration of e-bike charging station data into the European Union's digital mobility frameworks, emphasizing its importance in advancing sustainable and connected transport systems. It explores key EU initiatives—including the European Mobility Data Space (EMDS), NAPCORE, and the MegaBITS project—that aim to standardize and improve access to mobility data across member states. By enabling better interoperability, data sharing, and coordination, these efforts support the development of a unified Bicycle Data Space (BDS) and contribute to the EU's Green Deal goals. The report concludes that harmonized data standards and stronger collaboration among stakeholders are essential for building an efficient and usercentric e-bike infrastructure.

CNR provided an analysis of digital platforms currently used to manage e-bike charging stations, including EcoSpazio, Comodule, and YoCharge. These tools were compared in terms of features such as real-time monitoring, GPS tracking, energy efficiency, and software interoperability. The study concluded that these existing tools, with customisation, could effectively support SMILE CITY's infrastructure goals.

Solum provides a comprehensive analysis of mobile applications supporting electric bicycle parking and charging infrastructure. With the rise of sustainable urban mobility, the study evaluates five apps—miSolum, Bikeep, Donkey Republic, Movatic and Pin bikes—focusing on core functionality such as station localization, space reservation, locking systems, charging process management, payment integration,



notifications, and service integration. Using a consistent evaluation framework and practical testing, the report identifies the strengths and limitations of each app. miSolum stands out for its solar-powered infrastructure and real-time charging management, while Bikeep emphasizes security and reservation functionality. Donkey Republic offers a user-friendly bike-sharing model without charging capabilities. Movatic provides a flexible, white-label platform adaptable to different mobility operators and Pin bike shows a smart mobility incentive platform that rewards users for sustainable travel but lacks integration with charging infrastructure and eco-accounting features. The findings conclude with a comparative table and key observations to guide future development and integration of digital tools within the electric micromobility ecosystem.

IETU presents two technical sections, the first one structured approach to connecting SMILE CITY's digital tools and mobile app with external databases. It outlines data flow architecture, cybersecurity measures, and user access protocols necessary for efficient and secure system integration. The Second section delivers a detailed feasibility study, confirming that infrastructure and software conditions in the pilot cities are suitable for phased deployment. It includes backend and frontend system requirements, deployment timelines, and recommendations for long-term scalability and interoperability.

ETRA contributes critical feedback on pilot planning and user incentive mechanisms (such as eco-credits), advocating for leveraging existing systems to reduce costs and implementation time.

NTU produced two technical reports. The first report is about the outcome of the second part of sub-task 3 of SMILE CITY Task 2.4, to investigate suitable methods for this project to connect digital tools and App with databases, including direct database connection methods (ODBC, JDBC, Object-Relational Mapping, and Native Drivers) and utilisation of API-based interfaces to connect the database (HTTP-based RESTful, MQTT, gRPC, and application of Middleware solutions). During the process of the database connection, special attentions should be paid to ensure the efficient data management and data security. Related technologies, such as TLS/SSL, encryption, blockchain, or GraphQL, can be considered in this project, providing more efficient, flexible, and reliable solutions for managing and protecting data transmitted over networks.

The second report presents the feasibility study results of implementing digital tools, by analysing the necessary digital tools for monitoring the working condition of e-bike charging station. The digital hardware-based tools are also analysed, including photovoltaic panels, battery management system (BMS), charging controller, and associated monitoring units. Then, the method for remote condition monitoring of e-bike charging stations as well as software tools for signal acquisition and processing, are studied.

These findings clearly show that SMILE CITY's plan for digital infrastructure is practical from technical, legal, and economic perspectives. The results will help shape the next steps in building and launching the system, ensuring it complies with EU rules, operates effectively in various cities and regions, and meets the needs of both the public and private sectors.

Reports submitted by the partners are listed below, which contribute to this deliverable:

- [1] **CIE, ECF** – Standards and Regulations for E-Bike Charging Stations, and Solutions for Efficient E-Bike Mobility
- [2] **CNR** – State of the Art of the Existing Digital Tools, Solutions, and Commercially Available Software related to the E-Bike Charging Stations
- [3] **Solum** – Analyse App Solutions
- [4] **IETU**– Concept of the eco-accounting app
- [5] **CIE, ECF** – Track developments on EU data and mobility regulations and instruments which will integrate with the e-bike charging station
- [6] **NTU** – Methods for Connecting SMILE CITY Digital Tools and App with Databases
- [7] **NTU** – Feasibility Study for the Implementation of Digital Tools
- [8] **IETU** – Technical Requirements for Client Endpoints Including Monitored Parameters

2 ACTIVITIES CARRIED OUT

2.1 Standards and Regulations for E-Bike Charging Stations, and Solutions for Efficient E-Bike Mobility (by CIE, ECF)

2.1.1 Introduction

As cities and regions across Europe strive to reduce carbon emissions, alleviate urban congestion, and promote active transport, electric bicycles (e-bikes) have emerged as a key element in the shift toward sustainable mobility. Offering an efficient, affordable, and low-emission alternative to motor vehicles, e-bikes are increasingly being integrated into both personal and public transport systems. However, the rapid growth in e-bike usage requires supportive infrastructure, particularly reliable and accessible charging solutions—to ensure convenience, safety, and energy efficiency.

The establishment of a coherent framework for e-bike charging infrastructure is critical. This involves not only the physical development of charging stations but also the implementation of standards, regulations, and guidelines that address battery safety, energy efficiency, accessibility, and interoperability. At the European Union level, several directives and standards are beginning to shape the future of e-bike charging. Notably, Regulation (EU) 2023/1542 mandates an assessment into the standardization of batteries for light electric vehicles, while updates to the Energy Performance of Buildings Directive (EPBD) are pushing for greater integration of charging facilities in both new and existing developments.

In parallel, safety concerns related to lithium-ion battery storage and charging have prompted the development of new fire safety standards, such as Germany's VDMA 24994, and growing interest in secure, compliant charging cabinets across the continent. Industry-led initiatives, including CHAdeMO's "Charge2Bike" and position papers from manufacturers' associations like ZIV, reflect ongoing efforts to align public policy with market innovation.

This report explores the current regulatory landscape surrounding e-bike charging in the EU, identifies gaps and challenges, and outlines implementable solutions—from smart charging systems to solar-powered stations—that support the efficient and safe use of e-bikes in urban and rural mobility ecosystems.

2.1.2 E-Bike Charging Station Standards and Regulations

As the use of e-bikes continues to rise across Europe, ensuring that the supporting charging infrastructure is safe, standardized, and accessible has become a key policy and industry priority. The establishment of consistent technical standards and clear regulatory frameworks helps ensure interoperability, consumer safety, and efficient integration into urban and building planning. This section provides an overview of the current international and EU-specific standards, regulatory initiatives, and safety guidelines that govern the deployment of e-bike charging stations, with a particular focus on harmonization, battery safety, and infrastructure accessibility.

1) International Standards

E-bike charging stations are subject to a range of international standards that govern safety, interoperability, and performance. These include:

- **IEC 61851:** This standard defines the charging systems for electric vehicles, including e-bikes. It specifies the requirements for electrical equipment, safety features, and communication protocols.
- **ISO 15118:** While primarily for electric vehicles (EVs), this standard covers communication between vehicles and charging stations. It can be adapted to e-bikes to enable smart charging and integration into broader electric vehicle ecosystems.
- **EN 17194:** This is a European standard for electric bicycle charging stations that provide guidelines for the design, installation, and operation of charging infrastructure.

2) Standards and Regulations in the EU



The EU has been actively developing and promoting the adoption of electric mobility, including e-bikes. To ensure consumer safety and industrial competitiveness, several standards and regulations have been introduced. Below is an overview:

E-Bike Battery Standards and Regulations: Two key regulations pertain to e-bikes and their batteries. These are Regulation (EU) 2023/1542 which provides a legal framework for the lifecycle of batteries within the EU and replaces the old Battery Directive 2006/66/EC. The other is the EN standard for e-bikes 15194:2017

(1) Regulation (EU) 2023/1542:

Overview:

Regulation (EU) 2023/1542, enacted on July 12, 2023, establishes a comprehensive legal framework for the entire lifecycle of batteries within the European Union. This regulation replaces the previous Battery Directive 2006/66/EC and aims to promote sustainability, safety, and circularity in the battery market, aligning with the European Green Deal and the EU Circular Economy Action Plan.

Key Provisions Relevant to E-Bike Batteries:

- i. Scope and Applicability:** The regulation applies to all batteries placed on the EU market, including those used in Light Means of Transport (LMT) such as e-bikes, e-scooters, and e-mopeds.
- ii. Sustainability and Safety Requirements:** Manufacturers are required to ensure that batteries meet specific performance, durability, and safety criteria. This includes restrictions on hazardous substances like mercury, cadmium, and lead, and mandatory information on the carbon footprint of batteries.
- iii. Removability and Replaceability:** The regulation mandates that portable batteries, including those in LMTs, be designed for easy removability and replaceability. For LMT batteries, this means they should be replaceable by an independent professional at any time during the product's lifetime.
- iv. Information and Traceability:** Batteries must be labelled with a QR code providing access to a digital battery passport. This passport includes information on the battery's capacity, performance, durability, chemical composition, and recycling information, enhancing transparency and traceability.
- v. Recycling and Waste Management:** The regulation sets ambitious targets for the collection and recycling of batteries. For instance, manufacturers must ensure a collection rate of 51% for LMT batteries by the end of 2028, increasing to 61% by the end of 2031. Additionally, there are specific material recovery targets for critical raw materials like cobalt, lithium, and nickel.
- vi. Timeline for Implementation:** While the regulation entered into force on August 17, 2023, its provisions will be phased in over time. Some requirements, such as the CE conformity assessment for batteries, started to apply from August 18, 2024. Other provisions, including the removability and replaceability requirements, will become applicable from February 18, 2027.

Implications for Stakeholders:

- **Manufacturers:** Must adapt their product designs to comply with the new sustainability, safety, and information requirements.
- **Importers and Distributors:** Need to ensure that batteries placed on the EU market meet the new regulatory standards.
- **Consumers:** Will benefit from increased transparency regarding battery performance and environmental impact, as well as improved safety and sustainability of battery-powered products.

(2) EN 15194:2017+A1:2023.

Overview:

EN 15194:2017+A1:2023 is the harmonised European standard that outlines the safety and performance requirements for EPACs intended for use on public roads. This standard applies to e-bikes with a maximum continuous rated power of 0.25 kW, where assistance is progressively reduced and cut off as the bicycle reaches a speed of 25 km/h, or sooner if the cyclist stops pedalling.

Key Provisions:

- Design and Assembly:** The standard specifies requirements for the design and assembly of EPACs, including mechanical integrity, electrical systems, and overall safety.
- Electrical Systems:** It covers requirements and test methods for engine power management systems and electrical circuits, including the charging system, for systems with a rated voltage up to and including 48 V DC or integrated battery chargers with a nominal 230 V AC input.
- Battery Safety:** The amendment A1:2023 introduces enhanced battery safety requirements by referencing EN 50604-1:2016+A1:2021, which specifies safety requirements for lithium-ion batteries used in light electric vehicles.
- User Information:** Guidelines are provided for instructions on the use and care of EPACs to ensure user safety and proper maintenance.

Harmonisation and Compliance:

EN 15194:2017+A1:2023 is harmonised under the EU Machinery Directive, providing a presumption of conformity with the essential health and safety requirements for machinery. Manufacturers adhering to this standard can demonstrate compliance with the directive, facilitating market access within the European Economic Area.

Implementation Timeline:

The amended standard was published on 31 August 2023. A transition period allows manufacturers to comply with either the previous version or the amended standard until 23 August 2025, after which compliance with EN 15194:2017+A1:2023 becomes mandatory for relevant products.

(3) EN 50604-1:2016+A1:2021 – Battery Safety Compliance for E-Bikes:

Overview:

EN 50604-1:2016+A1:2021 is a European standard that specifies safety requirements and test methods for secondary lithium-ion battery packs and systems used in light electric vehicles (LEVs), such as e-bikes. It applies to removable battery packs classified under voltage classes A and B, designed for

propulsion purposes in vehicles like e-bikes, e-scooters, and small electric cars. The standard provides a framework to ensure that these battery systems are safe, reliable, and suitable for their intended use.

Key Provisions:

- i. **Safety Requirements:** The standard outlines essential safety criteria, including electrical, thermal, and mechanical safety, to prevent hazards such as short circuits, overheating, and structural failures.
- ii. **Test Procedures:** It specifies a range of test methods to evaluate the safety performance of battery packs and systems under various conditions, ensuring they meet the required safety standards.
- iii. **Battery Classification:** Batteries are categorized into voltage classes A and B, with class A having a nominal voltage of up to 48 V and class B exceeding 48 V but not exceeding 60 V.
- iv. **Scope and Limitations:** The standard is applicable to battery packs and systems used as traction batteries in electrically propelled road vehicles. It does not cover the evaluation of battery safety during storage, vehicle production, or maintenance services.
- v. **Amendment A1:2021:** This amendment introduces additional safety requirements and test methods to enhance the overall safety of battery systems used in LEVs.

Relevance to E-Bike Manufacturers:

For e-bike manufacturers, compliance with EN 50604-1:2016+A1:2021 ensures that battery systems meet high safety standards, which is crucial for consumer safety and regulatory compliance. Adhering to this standard can also facilitate market acceptance and trust in the product.

Integration with Other Standards:

EN 50604-1:2016+A1:2021 is harmonized with other European standards, such as EN 15194:2017+A1:2023 for electrically power-assisted cycles (EPACs). This alignment ensures a cohesive regulatory framework for e-bikes, covering both the battery systems and the overall vehicle performance.

(4) Other Regulations Affecting E-Bikes and Charging

- **Building Infrastructure and Energy Efficiency**

Energy Performance of Buildings Directive (EPBD): While the EPBD has provisions for electromobility, its current language regarding e-bike charging infrastructure is non-mandatory. This has led to inconsistent implementation across member states. Advocacy groups like the European Cyclists' Federation (ECF) recommend introducing binding requirements for bicycle parking and e-bike charging facilities in new and renovated buildings to promote sustainable transport.

- **Fire Safety and Charging Cabinets**

VDMA 24994 Standard: Germany has introduced this safety standard for e-bike battery charging cabinets, stipulating requirements such as maximum permissible temperatures and the inclusion of internal smoke detectors. The standard aims to mitigate fire risks associated with lithium-ion batteries. The European Committee for Electrotechnical Standardisation (CENELEC) is considering adopting this standard across the EU.

PGS 37-2 Guidelines (Netherlands): The Netherlands is developing guidelines for the safe storage

of lithium-ion batteries, including those used in e-bikes. Until these guidelines are finalized, the existing EN 14470-1 standard for storing flammable substances is applied.

- **Infrastructure Expansion and Accessibility**

EU Charging Infrastructure Law (2023): The EU has mandated the expansion of charging infrastructure for electric vehicles, requiring public charging stations every 60 km along major roads by 2026. While this primarily targets electric cars, it sets a precedent for developing similar infrastructure for e-bikes, especially in urban areas.

- **Industry Perspectives and Initiatives**

ZIV Position on Standardised Charging: The German Bicycle Industry Association (ZIV) acknowledges the potential benefits of standardised charging systems for public e-bike charging stations. However, they caution against imposing blanket regulations for private charging, emphasizing the need to balance safety, innovation, and market dynamics.

CHAdEMO's 'Charge2Bike' Initiative: The CHAdEMO Association has developed the 'Charge2Bike' charging interface, aiming to **provide** an interoperable solution for e-bike charging. This **initiative** aligns with existing standards and seeks to promote safety and compatibility across different manufacturers.

2.1.3 Solutions to Support Efficient E-Bike Mobility and Charging

In addition to regulatory support, a range of practical and technological solutions are being developed and implemented to enhance the usability and efficiency of e-bike infrastructure. These solutions address challenges such as limited charging availability, fire safety, energy sustainability, and urban congestion. This section explores emerging innovations and best practices—such as smart charging networks, battery swapping models, solar-powered stations, and integration with public transit—that can be adopted by cities, businesses, and policymakers to support the growing demand for e-bike mobility in a safe, efficient, and scalable manner.

Smart Charging Solutions

- **Dynamic Charging Systems:** These systems can adjust the charging rate based on grid demand and time-of-day pricing, ensuring more efficient use of energy.
- **Wireless Charging:** Technologies like inductive charging are being explored to eliminate the need for plugs and cables, making charging more convenient.
- **Smart Charging Networks:** A connected network of charging stations that allows users to find available stations, track charging progress, and make payments using apps. These systems also help optimize station usage and reduce wait times.

Battery Swapping Stations. An alternative to traditional charging is the use of battery swapping stations. This method allows users to swap their depleted e-bike battery for a fully charged one, significantly reducing downtime. Battery swapping networks can support the high usage of e-bikes in urban areas and help expand the overall charging infrastructure.

Solar-Powered Charging Stations. To address the environmental impact and energy sustainability of e-bike charging, solar-powered charging stations can be implemented. These stations can harness renewable energy from the sun to power the bikes, particularly in sunny areas. Solar-powered stations can be combined with storage systems (e.g., batteries) to ensure constant power availability, even when sunlight is limited.

Mobile E-Bike Charging Solutions. For areas with low infrastructure or where a fixed station is not feasible, mobile e-bike charging units can be deployed. These units can be vehicles equipped with charging stations that go to different locations based on demand. This approach supports e-bike usage in underserved or remote areas.

Integration with Public Transport. Charging stations could be integrated with public transportation hubs, allowing users to charge their e-bikes while using other forms of public transportation. This would facilitate seamless multimodal transportation, where users can combine e-bike usage with buses, trains, or trams.

2.1.4 Key Benefits of Efficient E-Bike Charging Infrastructure

Beyond the technical and regulatory aspects, the expansion of a well-planned e-bike charging network offers broad societal benefits. Efficient charging infrastructure not only supports the functionality and convenience of e-bikes but also contributes to wider goals such as environmental sustainability, economic development, and social inclusion. This section outlines the key advantages of investing in and promoting robust e-bike charging systems, emphasizing their role in decarbonizing transport, enhancing urban mobility, and supporting greener cities.

Environmental Impact. The widespread adoption of e-bikes combined with an efficient charging infrastructure significantly contributes to reducing urban air pollution and CO₂ emissions. E-bikes offer a greener alternative to cars, particularly for short-distance travel.

Economic Viability. Investing in e-bike infrastructure creates economic opportunities through job creation in the installation, maintenance, and management of charging stations. Additionally, e-bikes reduce reliance on fuel-based transport, contributing to savings for consumers.

Improved Mobility and Accessibility. E-bike charging stations contribute to improving urban mobility by providing residents with a clean, efficient, and cost-effective transport option. Properly placed charging stations ensure that users can rely on their e-bikes for daily commutes, improving access to essential services and opportunities.

2.1.5 Conclusion and Recommendations

With the foundation for e-bike mobility rapidly evolving, a combination of regulation, innovation, and investment is essential to realizing its full potential. As the European Union and its member states continue to refine their policies and technical standards, a strategic opportunity emerges to shape a safer, more integrated, and accessible e-bike ecosystem.

As the demand for e-bikes continues to grow, the establishment of comprehensive standards and regulations for charging infrastructure is essential to ensure safety, reliability, and accessibility. To fully support and optimize e-bike mobility, a range of innovative solutions—such as smart charging systems, battery swapping models, solar-powered stations, and mobile charging units—should be explored, developed, and strategically implemented. Achieving this requires strong collaboration between local governments, private sector stakeholders, and technology providers to build a sustainable, efficient, and user-friendly charging ecosystem.

In conclusion, aligning regulatory frameworks—such as the Energy Performance of Buildings Directive (EPBD)—with the growth of e-bike mobility is essential for long-term success. By embedding requirements for e-bike charging infrastructure and secure parking into building codes, the EPBD can help make sustainable transport a fundamental component of urban planning. At the same time, comprehensive battery regulation is crucial to address safety, environmental, and performance concerns. The introduction of Regulation (EU) 2023/1542, which aims to standardise batteries for light electric vehicles, underscores the importance of harmonised rules that promote interoperability and mitigate risks associated with lithium-ion storage.

Furthermore, policymakers should introduce targeted incentives to encourage the deployment of e-bike charging infrastructure and ensure it is seamlessly integrated into wider urban mobility strategies. Doing so will help facilitate widespread adoption, improve multimodal transport networks, and contribute to the long-term sustainability goals of cities and regions.

Summary Conclusions:

- The development of e-bike infrastructure requires a coordinated effort involving regulation, innovation, and investment.
- Regulation (EU) 2023/1542 plays a vital role in harmonising battery standards, enhancing safety and environmental compliance.
- Comprehensive standards for e-bike charging stations are essential for safety, reliability, and accessibility.
- Innovative charging solutions—like smart systems, solar stations, battery swapping, and mobile units— are being developed and have strong potential for the Smile City project.
- Cross-sector collaboration between governments, industry, and tech providers is key to creating a scalable and user-friendly infrastructure.
- The Energy Performance of Buildings Directive (EPBD) should support e-bike integration by mandating charging and parking facilities in building codes.
- Incentives and urban mobility planning must align to ensure the seamless integration of e-bike systems with public and multimodal transport networks.

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2.2 State of the Art of the Existing Digital Tools, Solutions, and commercially available Software related to the E-bike Charging Stations (CNR)

2.2.1 Introduction

The increasing prevalence of electric bicycles (e-bikes) has prompted the development of mobile applications designed to enhance the riding experience. These applications offer a wide range of features that extend beyond basic navigation, including advanced performance monitoring tools, safety enhancements, community engagement features, vehicle setting customization, and gamification mechanisms to encourage cycling (Fishman, 2016; Gössling, 2020).

This infrastructure must rely on dedicated software platforms that manage, monitor, and optimize e-bike charging stations. These platforms are designed to offer a range of features, including real-time monitoring, user authentication, payment processing, and integration with renewable energy sources (Kaundinya et al., 2009; Zhao et al., 2022). This section explores leading digital platforms and software solutions in this domain.

In the following section, the reference tools in this area are presented. Moreover, a comparative analysis section provides a concise overview of the different aspects of each tool.

2.2.2 Leading Software Solutions for E-Bike Charging Stations

The popularity of electric bikes is constantly growing, and the demand for efficient and user-friendly charging infrastructure is rising in parallel. Innovative software solutions designed to streamline the management, monitoring, and optimization of e-bike charging stations are at the forefront of this movement. These leading platforms have been shown to enhance the user experience and support operators in maximizing uptime, energy efficiency, and scalability. In this regard, seven reference commercial tools have been identified:

EcoSpazio SharWare. EcoSpazio SharWare (<https://ecospazio.it/en/ecospazio-software/>) is an Italian platform designed for managing bike-sharing and automated charging systems. It comprises an APP Server for comprehensive station monitoring and a Web APP for real-time operational management. Users can access charging services, monitor station status, and manage their accounts through the platform.

YoCharge. YoCharge (<https://yocharge.com/>) offers a white-label EV charging management software that supports OCPP-compliant chargers. It provides a branded admin dashboard, customized web and mobile applications, local payment and billing integration, and real-time monitoring. The platform is hardware-agnostic and supports integration with solar and wind energy sources.

TelioEV. TelioEV (<https://telioev.com/>) specializes in EV charger software that leverages the Internet of Things (IoT) for enhanced connectivity. The platform offers a comprehensive charging station network, supports interoperability, and provides features such as remote monitoring, flexible payment modes, and automated energy control. Operating on a Software as a Service (SaaS) platform, the system ensures efficient operations and timely maintenance.

Comodule. Comodule (<https://www.comodule.com/softwareprovides>) is an IoT-powered software suite designed for e-bikes, that include a Companion App and Control Center for charging stations. The platform facilitates GPS tracking, digital locking mechanisms, movement alerts, and real-time location sharing. Additionally, it facilitates remote firmware updates, facilitates bike diagnostics, and offers user engagement tools.

FiloSei. FiloSei (<https://www.filosei.it/>) is an Italian solution designed for e-bike users and service providers. It offers a web application for booking, payment, and management of charging sessions. The system is equipped with USB ports for charging external devices and supports activation via customizable smart cards.

ZeusApp. ZeusApp (<https://www.zeuschargingstation.com/app>) is a unified network for e-bike charging stations. It allows users to locate, activate, and monitor charging sessions through a single mobile

application. The platform facilitates real-time station monitoring, user statistics, and remote software updates. Moreover, it allows the collection of real-time station monitoring data, the generation of user statistics, and the implementation of remote software updates.

LiON App. The LiON App (<https://www.ongineer.de/en/products/lion/app/>) was developed by ONgeener to complement their e-bike charging stations. The app offers a user-friendly interface for managing charging sessions. The system has been designed for application in various sectors, including tourism and hospitality, and facilitates swift and straightforward wall mounting of charging units. The system has been developed for application in a large variety of sectors, including tourism and hospitality. It facilitates rapid and uncomplicated wall mounting of charging units.

2.2.3 Comparative analysis

Table 1 provides an overview of the previously described leading e-bike charging management platforms with their key features, countries of application, and pricing modes. The products in the table include both general-purpose charging management software packages and more specialized applications, such as user authentication, remote monitoring, and renewable energy integration. By highlighting these platforms, the table provides a clear picture of the technologies available and helps to identify which solutions are best suited to different operating environments. The platforms in the table are categorised according to several key characteristics:

- **Description:** A brief summary of what each platform/ tool is designed to do, highlighting its purpose and key features.
- **Main Features:** A list of the main features that define each tool, from technological features such as real-time monitoring, GPS tracking, remote updating, and support for different payment systems.
- **Country of use:** Indicates the main geographical regions where these platforms/tools are most commonly installed, reflecting their market use and suitability in different countries.
- **Paid/Open Source/Free:** Describes the pricing mechanism associated with each platform/tool. A few tools are subscription-based, a few others have individual pricing, while others are free to download or open source.

Table 1. Comparative overview of reference tools for E-Bike charging stations

Commercial Tool/Platform	Description	Main Features	Country of Use	Paid/Open Source/Free
EcoSpazio SharWare	Platform for bike-sharing and charging management	Real-time monitoring, user access control, customizable interface	Italy	Custom pricing
YoCharge	White-label EV charging management software	OCPP compliance, local payment integration, renewable energy support	India	Subscription-based
TelioEV	IoT-based EV charger software	Remote monitoring, flexible payments, energy control	India	Subscription-based
Comodule	IoT-powered e-bike software suite	GPS tracking, digital locking, firmware updates	Estonia	Custom pricing

FiloSei	E-bike charging solution with user-friendly features	Web app management, USB charging ports, smart card activation	Italy	Not specified
ZeusApp	Unified network for e-bike charging stations	Mobile app integration, real-time monitoring, remote updates	Italy	Free app download
LiON App	Companion app for LiON e-bike charging stations	User interface for charging management, designed for various sectors	Germany	Custom pricing

2.2.4 Critical Analysis and User-Centric Design Recommendations

Following the meeting held on 15 December 2025, this Section presents a critical analysis of the SMILE CITY digital tools design assumptions, identifying key challenges and proposing targeted improvements for enhanced user engagement and system inclusivity. In particular, the following paragraphs will be focused on design core assumptions, key critical points with subsequent design challenges, and implementation strategies for improvements.

Core Assumptions Driving the Design:

The SMILE CITY digital tools and mobile applications are built upon three foundational assumptions that guide their development:

- **PA as Service Provider:** Public administrations are, implicitly, presented as a service organization (service provider), the goal of which is to prevent dissatisfaction of citizens by providing well-established and user-friendly services, to maintain confidence. This assumption is based on the belief that ease of use and reliability are key to great user adoption by inhabitants and non-residents.
- **Technology-Centric Solution:** The proposed strategy is based on a digital ecosystem which includes real time monitoring, multi-payment modes, sitting on top of advanced platform such as integrated mapping system and interactive dashboard. This advanced technological architecture will satisfy technical requirements relevant to operational efficiency of public administrations as well as for the end-users in exploring urban mobility systems.
- **Balanced Stakeholder Input:** The design process emphasizes collaborative engagement between cities and user communities to align service offerings with genuine needs. This stakeholder-centered approach specifically targets two key user groups: resident populations seeking reliable daily transportation and tourists requiring accessible soft mobility solutions in urban hubs.

Key Critical Points and Design Challenges

While the assumptions provide a solid conceptual foundation, several critical challenges warrant careful attention during implementation and refinement:

- **Feature Overload Risk:** The extensive feature set incorporated into the SMILE CITY ecosystem—including NFC-based payments, reservation systems, sustainability metrics tracking, and real-time monitoring—presents a significant risk of functional complexity. Without strategic prioritization, this feature density may lead to inflated development and maintenance costs, reduced system maintainability, and potential user confusion. Clear feature prioritization and phased deployment strategies are essential to mitigate this risk.
- **Digital Divide and Accessibility Gaps:** Despite the emphasis on "user-friendly" design, the current architecture places substantial reliance on smartphone-based access and digital banking integration. This approach may inadvertently exclude critical user segments, including elderly populations,

individuals with disabilities, and citizens without access to banking infrastructure. For a public service initiative, ensuring equitable access across diverse demographic groups is not merely a design preference but an essential requirement for inclusive urban mobility.

- **Limited User Empowerment in Service Co-Production:** While the system incorporates reporting and feedback mechanisms, the current design positions users primarily as passive consumers of mobility services. The potential for users to serve as active co-producers—through gamification mechanisms, community challenge participation, and structured feedback loops—remains largely underdeveloped. This represents a missed opportunity to foster community engagement and enhance long-term service adoption.

Recommended Improvements and Implementation Strategy:

To address the identified challenges and strengthen the SMILE CITY digital infrastructure, the following improvements are proposed:

- **Prioritize and Modularize Feature Development:** Define a Minimum Viable Product (MVP) that encompasses core functionalities—such as station localization, charging management, and payment processing—with additional features implemented in subsequent phases. This modular approach should include low-technology fallback mechanisms, such as physical access cards and cash payment points, to ensure accessibility for all user segments regardless of digital literacy or banking status.
- **Enhance Accessibility and Inclusion Standards:** Implement mandatory compliance with WCAG (Web Content Accessibility Guidelines) standards to ensure digital accessibility for users with varying abilities. Expand multilingual support to serve diverse populations, and provide alternative access modalities beyond smartphone applications, such as interactive public information terminals ("totems") and designated cash payment locations. These complementary access channels are critical for ensuring equitable service delivery in the public mobility context.
- **Boost User Engagement Through Incentive Mechanisms:** Introduce structured incentive systems—such as user rewards for service reports, neighbourhood-based mobility challenges, and direct integration of citizen feedback into policy development processes. These mechanisms can transform users from passive service consumers into engaged stakeholders, fostering community ownership and supporting the long-term sustainability of the SMILE CITY initiative.

2.2.5 Conclusion

The evolution of e-bike charging infrastructure is closely tied to the advancement of software solutions that enhance user experience, operational efficiency, and integration with renewable energy sources. The platforms discussed offer a range of features catering to different market needs, from individual users to large-scale service providers. As the e-bike market continues to grow, the role of such software solutions will become increasingly relevant in promoting sustainable and efficient urban mobility.

The platforms examined in this report illustrate the diversity of approaches tailored to distinct market segments. These platforms range from applications designed for individual commuters seeking real-time information and seamless charging access to enterprise-level solutions that support fleet management, billing, and data analytics for service providers. The software landscape, therefore, reflects the multifaceted nature of the e-bike industry. These platforms frequently incorporate features such as intelligent routing, predictive maintenance, dynamic pricing, and interoperability with various types of charging stations, rendering them indispensable tools in modern urban transport systems.

Furthermore, the integration of renewable energy sources, such as solar and wind, into charging infrastructures is significantly facilitated by software. Energy management systems have the capacity to monitor availability, optimize charging times based on grid demand, and ensure the efficient use of green energy. This contributes to a reduction in environmental impact and assists cities in achieving their climate objectives while decreasing reliance on fossil fuels.

As the e-bike market continues to expand—driven by environmental concerns, urban congestion, and the rising popularity of micromobility—the importance of intelligent software solutions will grow as well.



These tools are poised to play a relevant role in scaling infrastructure, ensuring user satisfaction, and cultivating resilient, adaptable urban transport networks. In the long term, software-driven charging ecosystems have the potential to serve as a model for broader smart city initiatives, thereby underscoring the role of digital innovation in shaping the future of sustainable urban living.

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2.3 Analyse App Solutions (by Solum)

2.3.1 Introduction

In recent years, the rise of sustainable mobility has driven the growing use of electric bicycles in urban environments as an efficient, cost-effective, and eco-friendly alternative to traditional transportation. This shift in commuting habits has created an increasing demand for infrastructure and technological solutions that facilitate both secure parking and efficient charging of these vehicles.

In this context, a variety of mobile applications have emerged, designed to intelligently and conveniently manage the location, reservation, locking, and charging of electric bicycles. These apps serve as a crucial link between end users and urban infrastructure, offering experiences that range from basic parking to integrated systems powered by renewable energy and supported by operator management platforms.

This document aims to analyse and compare the main solutions available in the market for the parking and charging of electric bicycles, evaluating their functionality, scalability, sustainability, and user experience. Through this analysis, we seek to identify best practices, improvement opportunities, and trends that are shaping the future of electric micromobility.

2.3.2 Analysis Methodology

This analysis focuses on evaluating mobile applications dedicated to the parking and charging of electric bicycles through a detailed examination of **functionality**. Functionality is a key factor in the design and performance of these applications, as it significantly impacts both the user experience and the overall efficiency of the system. The following are the specific functional aspects that will be used to assess each application.

2.3.2.1 Functionality Evaluation Criteria

The selected applications will be evaluated based on several core functional parameters, with the aim of identifying their strengths and limitations in managing electric bicycle parking and charging. The following areas of functionality will be analysed:

(1) Charging Station Location

One of the most important features is the ability to locate available charging stations in real-time. Evaluation will include:

- **Geographic accuracy:** How precise is the station's location on the map?
- **Accessibility:** Are the stations strategically located in key areas, such as high-traffic zones or near public transportation?
- **Real-time updates:** Does the app accurately and promptly display station availability? Are there alert systems for station status changes?

(2) Parking Space Reservation

The ease of reserving a parking spot at a charging station is another key feature. Assessment will cover:

- **Reservation process:** Is the reservation quick and intuitive? Is user login or account creation required?
- **Reservation confirmation:** Does the app provide instant confirmation and reminders?
- **Flexibility:** Can users cancel or reschedule reservations?

(3) Bike Locking and Unlocking System

This feature is essential for user convenience and security. The analysis will include:



- **Technology used:** Does the app use smart locks, QR codes, Bluetooth, or NFC?**Reliability:** Is the locking/unlocking process seamless and consistent?
- **Security:** Does the system ensure the bike is protected while parked and charging?

(4) Charging Process Management

Charging is the core functionality. The analysis will include:

- **Ease of connection:** Is it simple to plug in the bike? Does the app guide users through the process?
- **Real-time monitoring:** Can users track the charging status live? Are they notified when charging is complete or if issues arise?
- **Connector variety:** Are multiple types of connectors available? Can users pay for charging directly via the app?

(5) Payment and Financial Management

Most apps integrate payment options for charging services. The evaluation includes:

- **Payment methods:** Does the app accept credit/debit cards, PayPal, e-wallets, etc.?
- **Pricing models:** Are the rates clear and understandable? Are there options such as time-based rates or unlimited-use subscriptions?
- **Receipts and billing:** Are digital receipts issued? Can users easily access billing history?

(6) Notifications and Alerts

Notifications keep users informed throughout the charging process. Evaluation will consider:

- **Real-time alerts:** Are there notifications about charging status, station availability, or bike issues?
- **Customization:** Can users choose which alerts to receive (e.g., end of charging, time limit)?
- **Interactivity:** Can users act on alerts directly from the app (e.g., extend session, change location)?

(7) Integration with Other Services

The value of an app increases if it integrates well with other platforms. Assessment includes:

- **Public transport links:** Can users see stations near bus, metro, or train stops?
- **Mobility app synchronization:** Can the app connect with shared mobility platforms, urban mobility maps, or EV fleet management systems?

2.3.2.2 Evaluation Tools

The analysis will be conducted using a combination of hands-on testing, user review analysis, and examination of technical documentation provided by app developers. During practical testing, the functionality will be assessed in real-use environments, noting accessibility, response speed, and any technical issues encountered.

2.3.2.3 App Selection

The selection of applications for this analysis is based on a combination of relevance, market presence, and specialization in electric bicycle infrastructure. The goal is to examine platforms that not only offer general micromobility services but that also include **specific features for the parking and charging of electric bicycles**. This targeted selection ensures the analysis remains focused on solutions that address the unique operational, technical, and user-experience challenges associated with e-bike infrastructure.

(1) Geographical Scope

Selected applications have an active presence in **Europe and/or Latin America**, two regions where the adoption of electric bicycles has been accelerating in recent years. These regions also present a diverse range of urban planning strategies and regulatory frameworks, providing a broader perspective on how these apps adapt to different mobility ecosystems.

(2) Selection Criteria

Preselection of the apps based on the criteria:

- **Focus on electric bicycles:** The app offers dedicated features or infrastructure for e-bikes, not just conventional bikes or scooters.
- **Operational maturity:** The app is in active use in one or more cities, with proven deployment and ongoing updates.
- **Functional richness:** The app provides at least three of the following: station location, smart locking, charging management, user reservations, or integrated payments.
- **Availability:** The app is accessible via mobile devices (Android/iOS) and supports local languages of the regions it operates in.

(3) Apps Considered

Some of the applications selected for analysis include:

- **miSolum:** A platform developed with a strong focus on secure parking and smart charging stations for electric bikes and scooters, with an emphasis on solar-powered infrastructure and real-time monitoring.
- **Bikeep:** An internationally deployed solution that combines hardware (physical racks and lockers) with a mobile app for secure locking and potential charging capabilities.
- **Donkey Republic:** While known for its bike-sharing system, Donkey Republic has begun integrating e-bikes and infrastructure that could support future charging functionalities.
- **Movatic:** A flexible platform that cities and campuses use to deploy bike-sharing and parking systems, including e-bike compatibility in several deployments.
- **Pin-bike:** A smart mobility incentive platform that rewards users for sustainable travel but lacks integration with charging infrastructure and eco-accounting features.

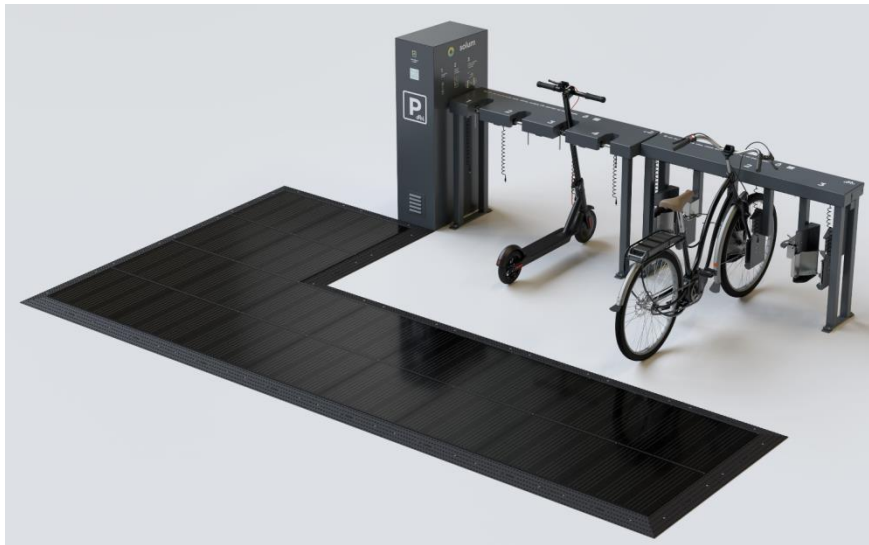
2.3.3 Application Analysis

Building upon the methodology defined in the previous section, this chapter focuses on a detailed **functional** analysis of each selected application. The goal is to assess how effectively these platforms address the specific needs associated with **parking and charging electric bicycles**, both from a technical standpoint and in terms of user experience.

Each application will be evaluated individually, following a consistent structure that allows for easy comparison across platforms. Key functional areas such as station location, reservation systems, charging processes, payment integration, and other relevant features will be explored in depth. Additionally, the analysis will highlight both the strengths and potential limitations of each solution, taking into account their performance in real-world usage scenarios.

This analysis does not seek to identify a single “best” app, but rather to provide a comprehensive overview of the different technological and operational strategies being deployed in the current market. By doing so, it aims to uncover patterns, best practices, and areas for improvement within the evolving landscape of electric micromobility infrastructure.

2.3.3.1 miSolum App



miSolum is a platform developed in Spain that focuses on providing secure parking and smart charging solutions for electric bicycles and scooters. Designed to promote sustainable urban mobility, it integrates solar-powered charging stations with a mobile app that allows users to locate, reserve, and use charging points in real time.

With a progressive expansion across European cities, miSolum positions itself as a key player in the development of intelligent micromobility ecosystems, combining energy sustainability with efficient digital services. Its infrastructure is modular, scalable, and designed for installation in strategic, high-demand urban areas.

(1) Functional Analysis

a. Charging Station Location

The app allows users to view available charging stations via an interactive map.

- **Accuracy:** The locations shown are precise and include GPS-based navigation.
- **Availability:** Real-time availability of each charging point is displayed.
- **Search Filters:** Currently, users can only filter by location.

b. Parking Space Reservation

- The app **does not allow** advance reservation of charging spaces, which may pose a limitation during high-demand periods.

c. Locking and Unlocking System

miSolum integrates a smart locking system at its stations.

- **Technology:** The lock is controlled via the app. The user manually locks the device when starting the session, and the lock automatically unlocks when the session ends.
- **Reliability:** The system is robust and resistant to tampering.
- **Security:** The locks secure both the frame and wheels of the vehicle, significantly reducing theft risk.



d. Charging Process Management

One of miSolum's standout features.

- **Ease of Connection:** The app guides the user step-by-step through the charging connection process.
- **Real-Time Status:** The app allows users to track the charging progress in real-time.
- **Alerts:** Notifications are sent in case of errors or when charging is complete.

e. Payment and Financial Management

- The app **currently does not include** integrated payment options, meaning payments are handled through other channels or institutional agreements.

f. Notifications and Alerts

- **Real-Time Updates:** Notifications are sent about operational issues and general communications.
- **Customizable Settings:** Users can choose which alerts they wish to receive.

g. Integration with Other Services

- **Public Mobility:** In some cities, miSolum is integrated with public transportation maps.
- **Urban Platforms:** Pilot projects are being developed for integration with broader urban mobility systems.
- **APIs:** The platform provides APIs to facilitate integration with municipal services.

(2) Strengths and Limitations

Strengths:

- Strong focus on **sustainability**, using solar-powered, modular stations.
- Excellent **user experience** with an intuitive app interface.
- High level of **physical security** in the locking and charging system.
- Reliable and **real-time** key functionalities.
- **Google map function:** user can search for e-bike charging stations and selected one located in service city. By zooming out it will show where the charging stations that can be used within the app are located. By clicking on each of them the following details of the charging station are:
 - Name of charging station
 - Status of charging station: Available or Occupied all the spots are taken
 - Number of docks available. Indicated by e-bike or e-scooter icon followed by available /max slots.
 - Distance to the charging station + time that takes to get there.
 - Address of charging station.
- **Dock/Lock of e-bike:** According to the guidance, users need to manually close the lock, connect the charging cable to the e-bike, and then start charging.

- **User login:** user could create account via Google Gmail. After logging in, user can edit profile and username.
- **Multi-language support:** the App supports different languages, such as English, Italian and Spanish.

Limitations:

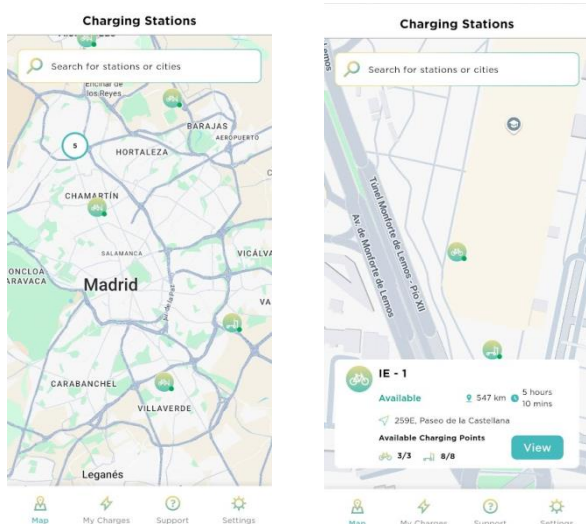
- **No advance reservation features.**
- Lack of **payment integration** within the app.
- No **offline functionality** for areas with low connectivity.
- Limited **multimodal integration**, with no direct connection to other transport solutions such as carsharing or e-scooters.
- **Display charging status (e.g. percentage charged), helping users plan their time and prevent overcharging.**
- **Not provide an estimated completion time for full charge.**
- **The above functions might require data from BMS and electronic board.**

(3) App Images

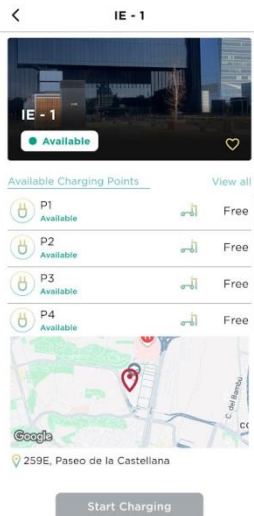
This section includes several screenshots of the **miSolum** app, which illustrate the user interface and key functionalities of the platform. These images provide a clearer view of how users interact with the app, from locating charging stations to managing the charging process and receiving notifications.

Each image is accompanied by a brief description that highlights the most important aspects of the interface and the functional features that enhance the user experience. These screenshots help to better understand how the app optimizes interaction and usability, while reinforcing the key points highlighted in the app analysis.

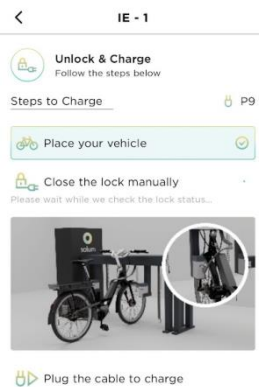
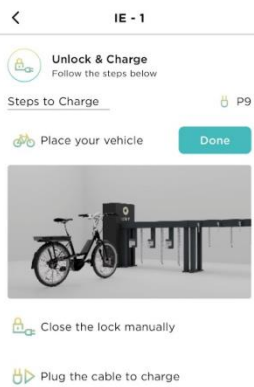
miSolum APP images



In this image, we can see the main map where users can navigate and view the available charging stations. The map displays real-time station locations, making it easy to find available spots. Additionally, there is a location filter bar at the top of the screen, allowing users to narrow down the search based on specific areas. This feature helps users quickly find charging stations that are closest to their desired location.



In this image, we can see detailed information about a specific charging station. The screen displays a photo of the station, providing a visual reference for users. Below the image, the available charging points are shown, indicating how many are currently free for use. This information helps users make informed decisions about which station to choose based on both visual cues and availability.



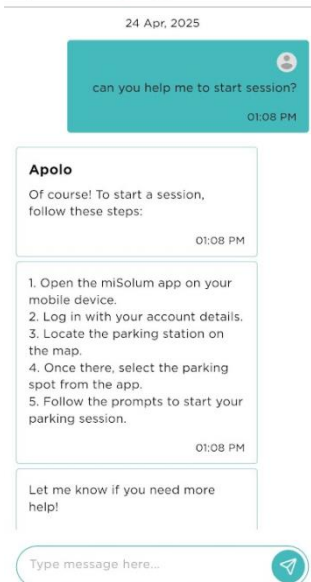
In this image, we can see an assistant feature that helps users initiate a parking and charging session. The interface provides step-by-step guidance to ensure a smooth process for connecting the electric vehicle to the charging station. This feature is designed to simplify the user's experience, making it easy to start both the parking and charging process with just a few taps.



In this image, the user can see the details of their ongoing charging session. The screen displays key information such as the current charge level and estimated time remaining. Additionally, there is a slider that allows the user to manually finish the charging session once they are satisfied. This feature provides a clear and simple way to manage the charging process, offering control and flexibility to the user.



In this image, the user can view their charging history. The screen displays a list of past charging sessions, showing details such as the date, duration, and amount of charge provided. This feature allows users to easily track their usage, review past sessions, and manage their energy consumption over time. It also helps users monitor their overall charging patterns and plan future sessions more efficiently.



In this image, a chatbot is assisting the user in starting a charging session. The chatbot provides step-by-step guidance, answering any questions the user may have and offering real-time support. This feature is designed to enhance the user experience by providing immediate assistance, ensuring a smooth and hassle-free process for initiating both parking and charging sessions.

2.3.3.2 Bikeep App



Bikeep is an application focused on providing secure parking solutions for both electric and conventional bicycles, with a strong emphasis on urban environments. Through its platform, Bikeep allows users to locate protected parking stations and, in some cases, charge their electric bikes while parked. The app is designed to offer a simple and efficient user experience, aimed at urban cyclists and anyone seeking a safe place to park their bike.

Bikeep has expanded into several European and Latin American cities, with parking stations strategically placed in high-demand locations such as train stations, commercial zones, and key transit points. Its infrastructure is scalable, allowing the deployment of additional stations as user demand increases.

(1) Functional Analysis

a. Locating Parking Stations

The Bikeep app allows users to find secure parking stations using an interactive map.

- **Accuracy:** Stations are precisely mapped and GPS navigation is available for easy access.
- **Availability:** Real-time availability of parking spots is shown, helping users choose the best location.
- **Search filters:** Users can filter by location and station type (e.g., with or without charging capabilities).

b. Parking Space Reservation

Bikeep allows users to reserve parking spots in advance, which is especially useful in high-demand areas.

- **Ease of use:** The reservation process is quick and intuitive.
- **Confirmation:** Users receive immediate confirmation, ensuring the spot will be available on arrival.

c. Locking and Unlocking System

Bikeep integrates a smart locking system to ensure the security of parked bicycles.

- **Technology:** The system uses Bluetooth for locking/unlocking via the app.
- **Reliability:** The locking mechanism is robust and designed to protect both the frame and wheels.



- **Security:** High-security standards to prevent tampering or theft.

d. Charging Process Management

Some Bikeep stations offer electric charging for e-bikes while parked.

- **Ease of connection:** Users can easily plug in their bikes at the station.
- **Real-time status:** The app provides live updates on charging progress.
- **Alerts:** Users are notified when charging is complete or if any issues occur.

e. Payments and Financial Management

Bikeep includes integrated payment options for parking and charging services.

- **Payment methods:** Accepts various methods, including credit/debit cards and digital wallets.
- **Pricing model:** Charges are based on usage time, with clear and transparent rates.
- **Payment history:** Users can view past payments and manage billing through the app.

f. Notifications and Alerts

The app sends different types of notifications to keep users informed.

- **Real-time updates:** Alerts about station availability, charging status, and other key events.
- **Customizable settings:** Users can choose which types of alerts they want to receive.

g. Integration with Other Services

Bikeep also integrates with urban mobility systems for a more comprehensive experience.

- **Public services:** The app works alongside public transit systems and mobility platforms in several cities.
- **APIs:** Bikeep provides APIs to integrate its parking and charging stations with external platforms.

(2) Strengths and Limitations

Strengths:

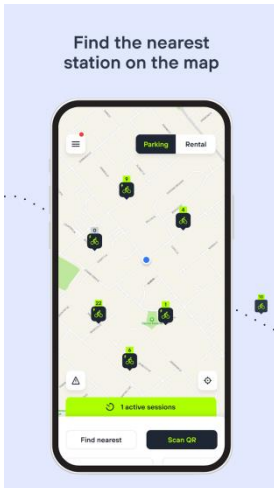
- **Easy and secure access** to bicycle parking and e-bike charging.
- **Advance booking capabilities** improve experience in busy areas.
- **Efficient locking system** for added security.
- **Integration with urban mobility services** creates a broader ecosystem.

Limitations:

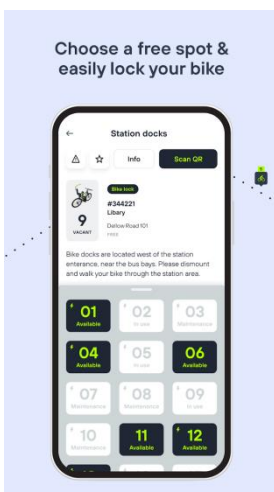
- **Geographic coverage** is limited in some cities, reducing access.
- **Not all stations** support electric bike charging.
- The **app interface** may be slightly complex for new or non-technical users.

(3) APP images

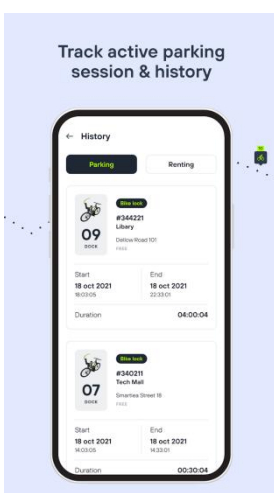
Bikeep APP



This image shows the main map screen of the Bikeep app. Users can see nearby bike parking stations marked with icons showing availability and charging options. The map is centered on the user's location, and there are buttons to find the nearest station or scan a QR code. A toggle lets users switch between "Parking" and "Rental" modes, and the app shows if there's an active session in progress.



This image shows the station details screen in the Bikeep app. Users can view information about a specific station, including its location, number of vacant docks, and instructions. Each dock is listed with its current status—available, in use, or under maintenance—making it easy to choose a free spot and lock the bike.



This image displays the user's parking history screen. It shows details of past sessions, including the dock number, station name, start and end times, and total duration, helping users keep track of their bike parking activities.

2.3.3.3 Donkey Republic App



Donkey Republic is a global bike-sharing platform originally founded in Denmark. It operates in numerous cities across Europe and beyond, offering a dockless rental system that allows users to easily locate, unlock, and ride bikes through a mobile app. The system is designed to promote sustainable urban transport by making bicycles accessible, affordable, and easy to use without the need for physical docking stations. Donkey Republic bikes are often integrated with local mobility systems and public transportation networks, fostering intermodality and reducing dependency on private cars.

(1) Functional Analysis

a. Location of bikes

- **Map navigation:** The app shows a real-time interactive map displaying all available bikes nearby.
- **GPS accuracy:** Locations are accurate, with precise positioning for easy navigation.

b. Booking and unlocking

- **Instant access:** Bikes can be unlocked via Bluetooth using the app.
- **Reservation:** Users can reserve a bike in advance for a limited time.
- **Smart lock:** The lock is integrated into the bike and controlled via smartphone.

c. Rental process

- **Guided experience:** The app provides a simple step-by-step process to rent and return the bike.
- **Ride tracking:** Duration, distance, and cost are tracked and shown in real time.
- **Multiple rentals:** Users can rent multiple bikes at once for group rides.

d. Payment and billing

- **In-app payment:** Users can pay securely via credit card or other digital methods.
- **Subscription plans:** The app offers various pricing models including pay-per-ride and monthly passes.

e. Notifications and alerts

- **Trip updates:** Users receive notifications about their ride status and alerts in case of issues.
- **Reminders:** The app reminds users to lock the bike correctly to end the session.

f. Integration with other services

- **Public transport:** In some cities, the app connects with public transit systems.
- **Mobility platforms:** Donkey Republic integrates with third-party mobility platforms via APIs.

(2) Strengths and Limitations

Strengths

- **Dockless system:** Users can park and lock bikes in flexible locations within defined zones, which increases convenience.
- **User-friendly interface:** The app is intuitive and quick to use, with clear instructions for rental and return.
- **Smart locks:** Bluetooth-controlled locks eliminate the need for internet connectivity during the ride.
- **Wide coverage:** Operates in many cities across Europe, making it great for both locals and tourists.
- **Flexible pricing:** Offers pay-as-you-go and subscription options adapted to different user needs.

Limitations

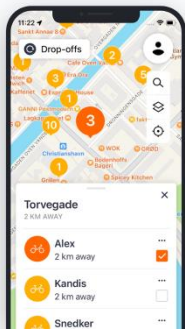
- **Requires Bluetooth:** If Bluetooth is off or malfunctioning, the bike cannot be unlocked.
- **Limited availability in some areas:** In certain zones, bike density is low and bikes are not well maintained.
- **No charging or electric bikes:** The service is limited to regular (non-electric) bicycles.
- **Zone restrictions:** Bikes must be parked within specific zones or fines may apply, which can reduce flexibility.
- **No in-app route planning:** The app doesn't offer integrated route suggestions or GPS navigation.

(3) APP images

Donkey Republic APP

Find a bike

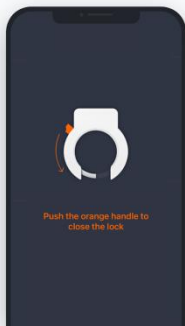
Free unlocks. Always.



This screen shows the main map interface of the Donkey Republic app. Users can view available bikes nearby, displayed as orange icons with a bike symbol. The interface includes a real-time location marker (blue dot) to help users navigate to the closest bike. The clean layout emphasizes ease of use and immediate access to nearby rental options. There's also a clear call to action ("Unlock bike") at the bottom, guiding users toward starting a ride quickly.

Enjoy the ride

Lock and unlock as many times as you want



This screen shows the bike unlocking interface. The app displays the specific bike selected, along with its ID number and location. Users are prompted with a clear "Unlock" button, suggesting the use of Bluetooth or an internet connection to remotely unlock the bike. The interface is minimal and focused, aiming for a seamless and intuitive unlocking experience.

Return

the bike to a drop-off location to end the rental



This screen displays the active ride view. It shows essential ride information such as duration, distance, and cost in real time. There's also a prominent "End Ride" button, allowing users to finish their rental. The interface ensures clarity during the ride, helping users monitor their session and stay informed about charges.

2.3.3.4 Movatic App



Movatic is a versatile micromobility platform developed in the United States that allows cities, universities, and private operators to manage fleets of bikes, e-bikes, scooters, and other shared vehicles. The app is white-label and modular, meaning that each operator can customize the interface and service experience while leveraging Movatic’s core technology. It’s designed to simplify the shared mobility experience for users and streamline operations for providers through a single, user-friendly mobile app.

Movatic operates in multiple countries and supports a variety of fleet types, offering an adaptable solution for mobility providers aiming to deploy or manage electric and pedal-based vehicles in urban and semi-urban environments.

(1) Functional Analysis

a. Location of vehicles

- **Interactive map:** Displays available bikes, scooters, and stations based on user location.
- **Real-time availability:** Shows which vehicles are ready to use and where.
- **Zone visualization:** Clearly marks allowed parking and riding zones on the map.

b. Booking and unlocking

- **Quick reservation:** Users can reserve a vehicle from the map before unlocking it.
- **Smart locks:** Unlocking is handled via Bluetooth or QR code through the app.
- **Vehicle details:** Information about the selected vehicle (ID, battery level of electric, location accuracy).

c. Rental process

- **Simple onboarding:** First-time users are guided with clear instructions.
- **Ride monitoring:** Duration, distance, and estimated cost shown in real time.
- **Pause feature:** Users can temporarily pause the ride without ending the session.

d. Charging and battery management

- **Electric vehicles only:** Displays battery status for e-bikes and scooters.
- **Low-battery warnings:** Alerts users when a vehicle is running low on charge.

e. Payments and billing



- **Integrated payments:** Secure checkout via credit card or digital wallet.
- **Promos and passes:** Offers custom pricing, promo codes, and membership passes depending on the operator.

f. Notifications and support

- **Ride updates:** Push notifications about session status, issues, or important messages.
- **In-app support:** Access to help and support channels directly from the app.

g. Integration with other systems

- **White-label flexibility:** Can be fully customized for different cities or organizations.
- **API integrations:** Connects with third-party systems for fleet management and urban mobility platforms.

(2) Strengths and Limitations

Strengths

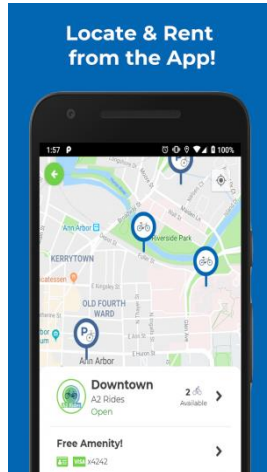
- **Modular and customizable platform:** Movatic can be adapted for cities, universities, or private operators with branded experiences.
- **Multi-vehicle support:** Handles bikes, e-bikes, scooters, and more, all within a single app.
- **Smart lock and QR code unlocking:** Offers flexible and secure methods to access vehicles.
- **Integrated payment and promo system:** Allows for flexible pricing structures, subscriptions, and discount codes.
- **Real-time ride monitoring:** Users receive up-to-date info on ride time, battery levels, and cost.
- **White-label model:** Operators have full control over branding and features.

Limitations

- **Inconsistent user experience:** Because the app is white-labeled, user interfaces may vary significantly between operators.
- **Limited presence in some regions:** Compared to larger global apps, Movatic's deployment is more localized.
- **Not always tailored for individual users:** Some custom implementations are designed primarily for institutional use, which may not focus on general public needs.
- **Battery info limited to electric vehicles only:** Non-electric fleet items lack deeper status insights.
- **No direct integration with public transport apps:** Unlike some competitors, Movatic does not natively offer multimodal journey planning.

(3) APP images

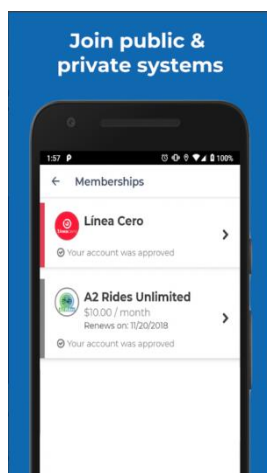
Movatic APP Images



The first image shows an interactive city map of Ann Arbor, highlighting several bike rental locations. Bike icons mark the available stations. A bottom panel displays information about a specific station ("Downtown - A2 Rides"), which is open and has 2 bikes available. Allows users to locate nearby stations and view real-time availability for renting bikes directly through the app.

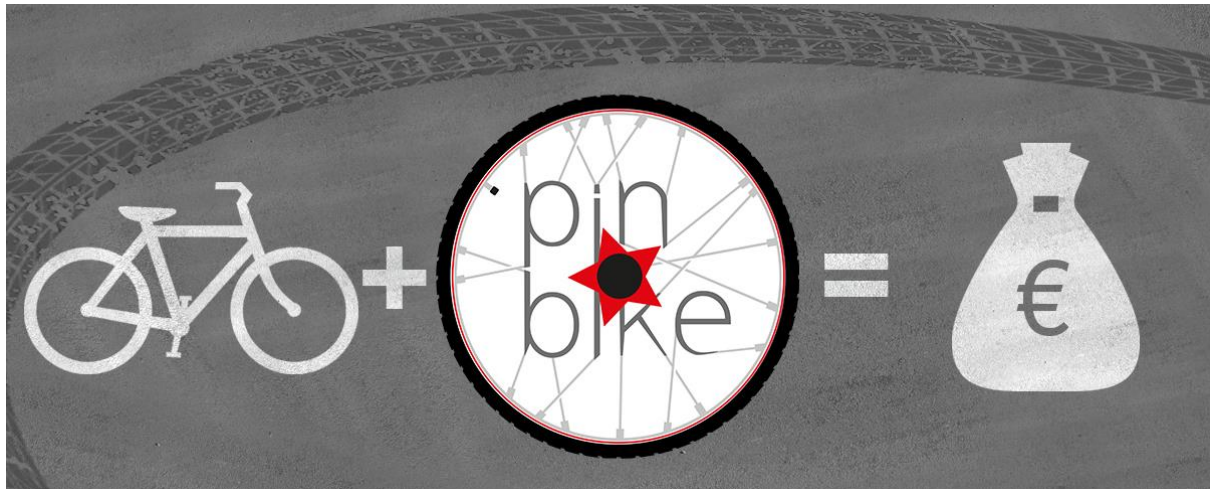


The second image shows the QR code scanning functionality. The screen is focused on a QR reader, where users aim their camera to scan the bike's code. Enables users to quickly and easily unlock bikes by scanning a QR code through the app.



The third image displays a "Memberships" screen, showing two systems: "Línea Cero" and "A2 Rides Unlimited" (the latter costing \$10.00 per month). Both memberships are marked as approved. Users can subscribe to public or private systems to access benefits such as discounted rates or unlimited bike usage.

2.3.3.5 Pin Bike App



Pin Bike is an innovative platform developed in Italy, focused on promoting sustainable urban mobility by rewarding citizens for cycling. Unlike traditional micromobility apps, Pin Bike is not a vehicle-sharing system but a tracking and incentive platform that encourages the use of private bicycles through gamification, smart tracking, and public-private collaborations.

The platform is designed for municipalities, companies, and schools that want to reduce traffic congestion and pollution. Through a dedicated mobile app and a certified hardware kit, users track their cycling activity and receive economic incentives or rewards based on verified kilometers and trips.

Pin Bike has been implemented in multiple European cities as part of pilot programs and broader sustainability initiatives.

(1) Functional Analysis

a. Trip Tracking and Validation

- **GPS tracking:** The app monitors cycling trips using GPS.
- **Certified tracking:** To ensure validity, trips are verified using a dedicated hardware sensor installed on the user's bicycle.
- **Anti-fraud system:** Combines app data with the physical sensor to prevent false reporting or cheating.

b. Incentive System

- **Reward calculation:** Users earn points or financial incentives based on distance, frequency, or other parameters defined by the local authority or organization.
- **Leaderboard and challenges:** The app gamifies mobility by offering rankings, badges, and local challenges.
- **Personal statistics:** Users can view history, kilometers cycled, CO₂ saved, and rewards earned.

c. Integration with Institutions

- **Municipal programs:** The app is typically linked to city-led sustainability or mobility initiatives.



- **Corporate use:** Companies can use it to promote green commuting among employees.
- **School programs:** Adapted versions exist for educational contexts to promote active mobility in youth.

d. Notifications and Alerts

- **Activity summaries:** Regular updates about cycling activity and progress toward goals.
- **Event reminders:** Notifications about local challenges, updates from the municipality, or app news.

e. User Interface and Accessibility

- **Simple dashboard:** The main screen provides trip summaries and active incentives.
- **Multi-language support:** Depending on deployment, the app supports several European languages.
- **QR codes and vouchers:** In some implementations, users receive QR codes for redeeming rewards or benefits.

f. Data and Privacy Management

- **User consent:** Data collection complies with GDPR and is managed with transparency.
- **Usage data:** Municipalities can access aggregated, anonymized data for planning and policy decisions.

(2) Strengths and Limitations

Strengths

- **Verified and anti-fraud tracking:** The use of a physical sensor ensures that trips are authentic, boosting the credibility of reward programs.
- **Direct incentives for behavior change:** Users are rewarded for cycling, making it an effective tool for encouraging sustainable mobility.
- **Adaptable for various institutions:** Suitable for cities, companies, and schools, with configurable rules and incentives.
- **Gamification and community building:** Leaderboards and challenges motivate users and create a sense of shared purpose.
- **Data-driven insights:** Aggregated trip data can help cities make informed mobility decisions.
- **Promotes private bicycle use:** Complements shared mobility by incentivizing ownership and daily use of personal bikes.

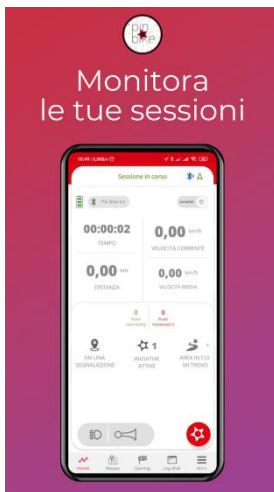
Limitations

- **Requires hardware installation:** Users must install a sensor on their bikes, which may be a barrier to adoption.
- **Limited scalability without public programs:** The app's effectiveness relies on institutional backing and funding.
- **Not a vehicle-sharing platform:** It does not provide access to bikes or e-bikes, which may limit interest among users without their own vehicle.

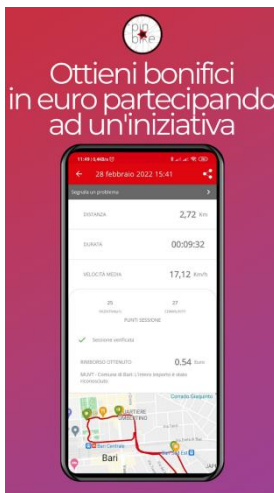
- **Dependence on external incentives:** Without ongoing financial rewards, long-term user engagement may decrease.
- **Initial setup complexity:** Some users may find the onboarding process (registration, hardware setup) slightly complex compared to standard apps.

(3) APP images

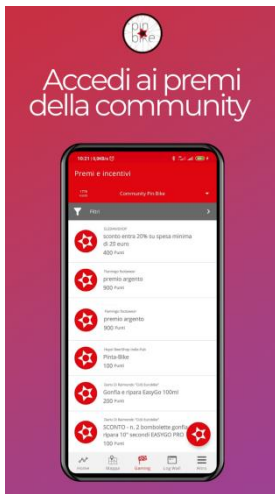
Pin.Bike APP Images



This screen displays the real-time session monitoring interface of the Pin Bike app, allowing users to track their cycling activity during an ongoing trip. The interface is clean and metric-focused, reflecting the app's emphasis on verified tracking and gamified reward systems.



This screen displays a completed session summary, emphasizing transparency in ride data and the reward system. It highlights Pin Bike's core feature: earning monetary incentives through verified cycling activity within municipal or community programs.



This screen shows the “Rewards and Incentives” section, a key feature designed to encourage frequent cycling through gamification and tangible benefits.

2.3.4 Comparative Analysis of Apps

2.3.4.1 Comparison Criteria

To ensure a consistent evaluation, all apps (miSolum, Bikeep, Donkey Republic, Movatic and Pin Bike) have been compared using the following key functionality criteria:

- Station/vehicle localization
- Reservation capabilities
- Locking and unlocking system
- Charging management
- Payment integration
- Notification system
- Integration with other services
- User experience and reliability

2.3.4.2 Comparative Table

Feature / App	miSolum	Bikeep	Donkey Republic	Movatic	Pin Bike
Station Localization	Yes (high precision)	Yes (accurate)	Yes (dynamic map)	Yes (city-wide view)	Yes (GPS trip tracking, verified with hardware sensor)
Real-time Availability	Yes	Yes	Yes	Yes	No

Space Reservation	No	Yes (via app)	Yes	Yes	No
Smart Lock System	Yes (semi-automatic)	Yes (directly integrated)	Yes (bike locks)	Yes (QR + Bluetooth)	No (not a parking/charging system; relies on certified hardware sensor)
Charging Management	Yes (real-time monitoring)	Limited (not app-based)	No (rental focus)	Limited (battery status only)	No (not designed for charging management)
Payment Integration	No	Yes	Yes	Yes	Yes
Notification and Alerts	Yes (customizable)	Yes	Yes	Yes	Yes
Integration with Other Services	Yes (APIs and pilots)	Moderate (some integrations)	Limited	Yes (white-label options)	Yes (municipal, corporate, school programs; supports sustainability policies)
UX/UI Design	Very intuitive	Good	Very intuitive	Good but operator-dependent	Simple dashboard, gamified interface, user-friendly

2.3.4.3 Key Observations

- **miSolum** excels in charging management and sustainability but lacks in payment integration.
- **Bikeep** is strong in security and reservation features, targeting both bikes and e-bikes.
- **Donkey Republic** offers a very user-friendly experience with a strong focus on bike sharing but does not focus on charging functionalities.
- **Movatic** provides the most flexibility through its white-label model, but the user experience can vary depending on the operator's customization.
- **Pin bike** shows a smart mobility incentive platform that rewards users for sustainable travel but lacks integration with charging infrastructure and eco-accounting features.

2.4 Concept of eco-cost management application (by IETU)

2.4.1 General description and functionality

The primary function of the app is to provide information on eco-credits and eco-costs. The second function is to provide information on operating bicycle charging points. An additional function is to inform users about eco-labels etc. The application is one of many components of the system and brings together the visualization layer of the mentioned functionalities.

The application is one of the many components of the system and its task is to visualize the functionality performed by the various subsystems like eco-costs service, city services – eco-offers.

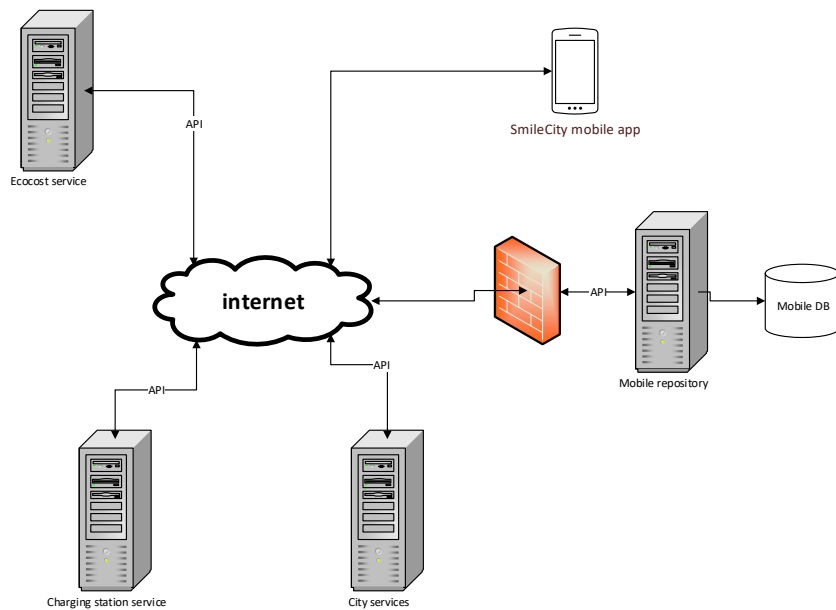


Figure 1 Component diagram

The application will provide the ability to create a user (eco-account) and provide the typical functionality to recover/reset a password (Figure 2). User information will be stored in Mobile DB shown in Figure 1. Personal data will be encrypted with AES algorithm in order to ensure broadly understood security. User passwords will be stored in the database as hashed character strings using MD5 or SHA the algorithm.

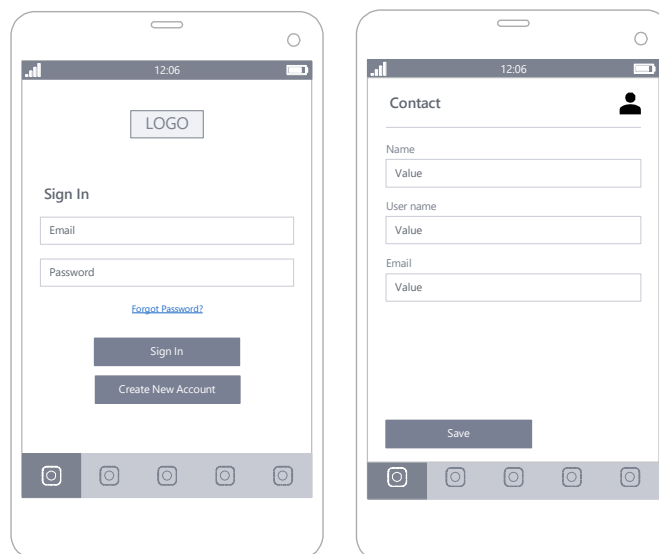


Figure 2 Login and user data page

The system will be distributed in nature. Different partners will be responsible for different components, in particular, the IETU will be responsible for the mobile application for handling eco-credits. In terms of eco costs, the application will provide access to the history of eco-credits received (Figure 3) and their transformations into eco-vouchers.

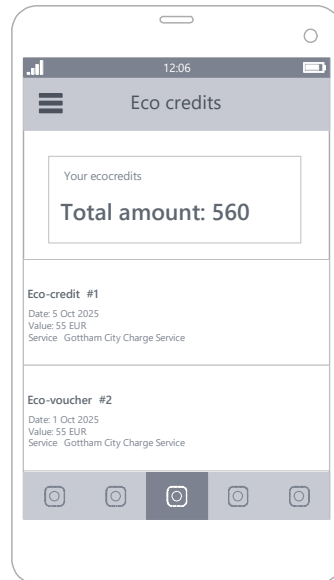


Figure 3 Eco credits

It is envisaged that vouchers will be made available to the user in the form of text code or QR code in a format compatible with the potential eco-service provider's (Figure 4). The voucher can be used in the third-party system by entering the code (text string) on the payment page or by scanning the QR code. The exact method of use will depend on the capabilities and features of the third-party service system. The format of the codes, particularly their uniqueness, must be determined in cooperation with the service provider. Consideration is being given to implementing a code-generating algorithm in the system or downloading the code via an API. The code should be generated by some kind of function based, for example, on the user's name (or email) and the current date. The details can be worked out only at the stage of designing or building the system.

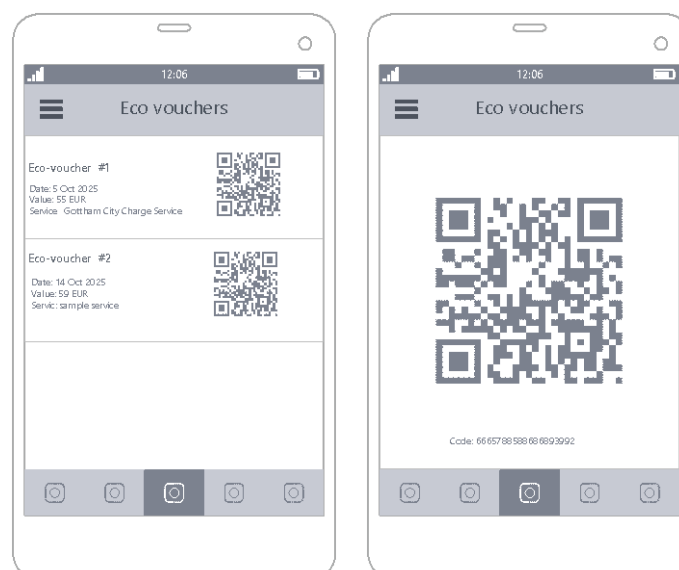


Figure 4 Eco vouchers

The application will provide information about current eco-promotions/offers, information about the duration of the offer (Figure 5). It is expected that eco-offers will be presented in the form of a link or an

image with a link to a page specified by the supplier. It is possible to present not only currently available offers but also new offers available soon. It is envisaged that eco-offers can be downloaded directly from the service provider via an API, and of course it will also be possible to enter them manually into the system. This method will naturally be used in the initial phase of the project and will be automated as capabilities arise.

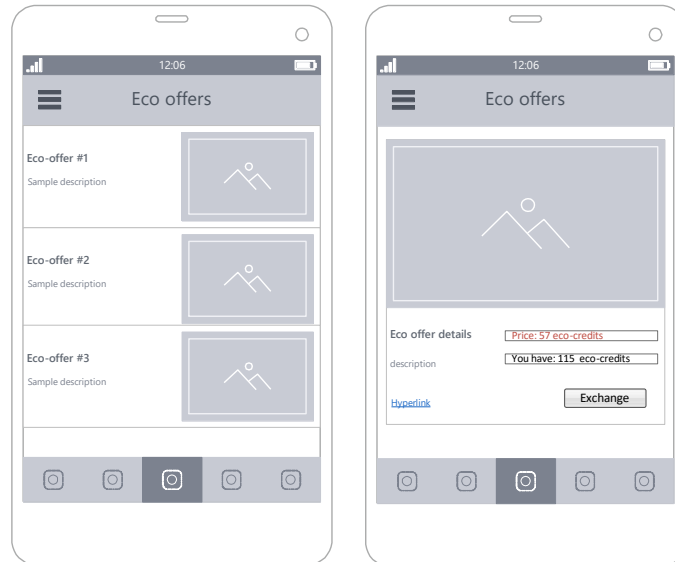


Figure 5 Eco offers

Since the project is a demonstration, it is not expected to build tools for the system administrator. For the same reason, downloading data via API will be possible only for one selected eco-provider to show the functionality.

The application will not send voucher data to the systems of service providers. The correct use of the code will be incumbent on the user. Integration of the systems will take place at the level of the user's email address (same email in both systems). Dedicated offers for a specific user will be considered.

Information about the acquisition of new eco-credits will be updated periodically with a frequency of a few minutes through the API provided by NTU or NTU will call a dedicated function of the API provided by IETU. Similarly, information on the conversion of credit into a voucher will be provided. Detailed specific solution will be agreed later. Due to the potential transmission of sensitive personal data, it is envisaged to set up an IPsec tunnel between the IETU and NTU subsystems. Integration of subsystems will take place at the level of username or email address.

The application will display information about charging stations - included in the system's network (Figure 6). On the one hand, there will be information describing the charging station, such as its location, charging current, availability, battery charge level, number of outlets, cost of charging and other parameters related to the terms of use of the eco-offer service. On the other hand, information from other sensors will be shown, such as meteorological and air quality parameters - the exact set of parameters will be determined during the project. The data will be downloaded by the system (or uploaded) via API and stored in the IETU database. This approach will make it possible to present not only current values, but also history. The frequency of downloading and the storage period will be determined later. Other project partners will be responsible for the API.

An additional feature will be the presentation of the location of charging points on a map. Also considered is the memorization of bicycle routes - perhaps such a functionality will be needed in the algorithm for calculating eco-credits - especially when the user uses eco-routes.

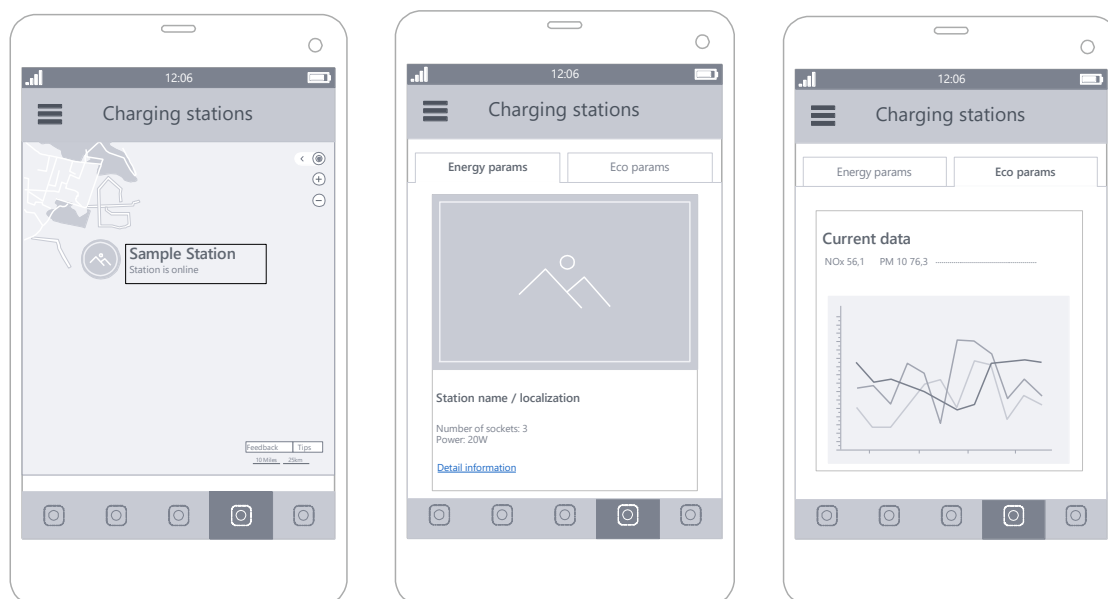


Figure 6 Charging stations

The application will also support the provision of information about the so-called eco-labels - the information will be provided in the form of links to websites with an appropriate description.

2.4.2 Tools and database

The following tools are expected to be used to build the application:

- mobile application:

Android Studio - is the official integrated development environment (IDE) for Google's Android operating system using languages (C++, Kotlin), Android Studio is licensed under the Apache license but may contain some non-free components.

or

Visual Studio (.NET MAUI, C#) is a cross-platform framework for creating native mobile and desktop apps with C# and Extensible Application Markup Language (XAML), which also supports Android and iOS.

- relational database e.g.:

SQL Server - (e.g. SQL Server Express) - free edition of SQL Server, which includes the core database engine, has some limitations (database file size, number of cores, operating memory, lack of advanced management mechanisms - the version is sufficient for the needs of the project - these limitations do not matter, in the case of production implementation, it is possible to scale the system up to the Standard version or higher without interfering with the database (compatibility of database files) and rebuilding the database;

or

MySQL - a freely available, open-source relational database management system. MySQL is developed by Oracle. MySQL is available under the GPL license; however commercially licensed versions can also be purchased.

or

PostgreSQL - a powerful, open-source object-relational database system that uses and extends the SQL language combined with many features that safely store and scale the most complicated data workloads.

The choice of the final solution may be influenced on the one hand by the possible policy of the project, i.e. promotion of open-source tools and products, on the other hand by the possible need to create a multi-platform application.

The database will be based on a relational model. The main entities will be user, eco-offers

and charging station. The preliminary concept of the database is shown in the Figure 7.

Communication between subsystems will be done through APIs. It is proposed to use the most popular form that is RESTful API and data sent as JSON. The concept of action was presented at the Figure 8. Subsystem end points can simultaneously act as server and client. The details of the interface (functions and parameters) will be agreed later in the project.

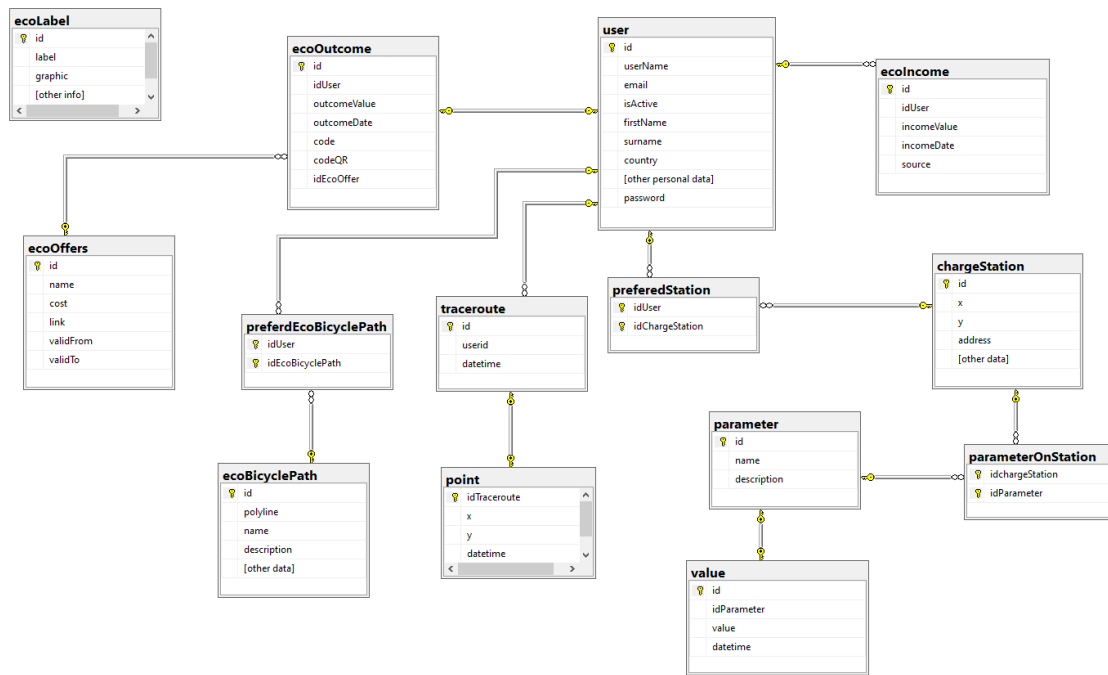


Figure 7 Preliminary concept of the database

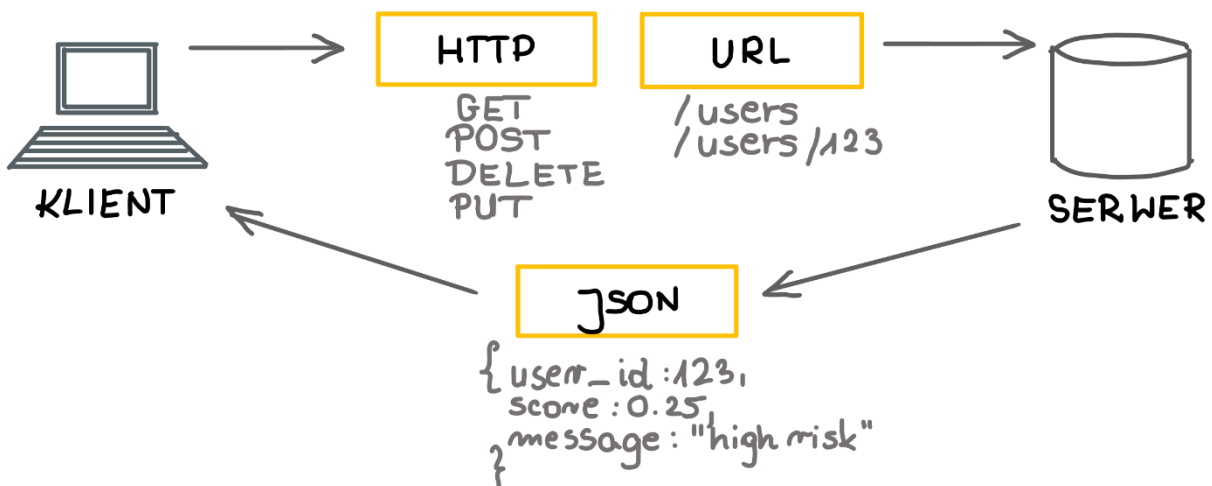


Figure 8 REST JSON API concept

Proposed tables in database:

TABLE [user] - a table storing common user information including login data (username and password), the data can be encrypted, e.g. using the AES algorithm.

- [id] - unique identifier of the user
- [userName] - unique username
- [password] - password



[email] - unique email used during registration
[isActive] - flag confirming verification of registration
[firstName] - first name of the user
[surname] - surname of the user
[country] - country where the user lives
[other personal data] - other user data - not yet specified

TABLE [ecoIncome] - table storing information about the acquired eco-credits by user in particular the value and the source of its origin.

[id] - unique identity identifier
[userId] - user identifier
[incomeValue] - eco-credit value
[incomeDate] - date of obtaining eco-credit
[source] - source of eco-credit origin [incomeDate] - date of obtaining eco-credit

TABLE [ecoOutcome] - table storing information about eco-credits converted by user into eco-vouchers

[id] - unique identity identifier
[userId] - user identifier
[outcomeValue] - value of exchanging eco-credit into eco-voucher
[outcomeDate] - date of exchanging eco-credit into eco-voucher
[code] - eco-voucher code compatible with an external promotional system
[idEcoOffer] - identifier of eco-offer

TABLE [ecoOffers] - table storing voucher offers related to eco-credits

[id] - unique identity identifier
[name] - the offer name
[cost] - exchange amount
[link] - link to the page describing the offer
[validFrom] - date from which the offer is valid
[validTo] - date until which the offer is valid

TABLE [chargeStation] - table storing information about charging stations - the list of fields will be agreed later

[id] - unique identity identifier
[x] - longitude
[y] - latitude
[address] - address of station localization
[other data]

TABLE [parameterOnStation] - table storing the relationship between parameter and station

[idChargeStation] - identifier of chargeStation
[idParameter] - identifier of parameter

TABLE [parameter] - a dictionary table of parameters that can be monitored at the station

[id] - unique identity identifier
[name] - parameter name
[description] - parameter description

TABLE [value] - table storing values measured on station

[id] - unique identity identifier
[idParameter] - identifier of parameter
[value] - measured value
[datetime] - date and time when parameter was measured

TABLE [preferredStation] - table storing the list of preferred stations by user

[idUser] - user identifier



[idChargeStation] - station identifier

TABLE [route] - optional table storing routes taken by user

[id] - unique identity identifier

[userid] - user identifier

[datetime] - date and time when the route was taken by user

TABLE [point] - optional table storing the shape of the route

[idTraceroute] - identifier of route

[x] - longitude

[y] - latitude

[nr] - sequence number of the point on the route

[datetime] date and time when user location was measured

TABLE [ecoLabel] - table storing information about eco-labels

[id] - unique identity identifier

[label] - name of eco-label

[graphic] - graphic of eco-label

[other info] - other info

2.5 Track developments on EU data and mobility regulations and instruments which will integrate with the e-bike charging station (by CIE, ECF)

Integrating E-Bike Charging Station Data into EU Mobility Frameworks. The European Union is actively advancing its digital and sustainable mobility agenda by developing comprehensive frameworks to integrate e-bike charging station data into broader mobility systems. Key initiatives include the European Mobility Data Space (EMDS), the National Access Point Coordination Organisation for Europe (NAPCORE), and projects like MegaBITS, all aiming to enhance data interoperability and accessibility across member states.

European Mobility Data Space (EMDS). The EMDS initiative seeks to create a unified data environment that facilitates the sharing and utilization of mobility-related data across the EU. This includes up-to-date information on cycling infrastructure, such as parking garages, charging stations, and bike-sharing services, to promote cycling and inform cyclists. By supporting local authorities in implementing urban vehicle access regulations and informing travellers through navigation apps, the EMDS aims to reduce emissions and traffic congestion.

NAPCORE and National Access Points (NAPs). NAPCORE coordinates the harmonization of National Access Points, which serve as centralized hubs for mobility data in each EU member state. While there is progress in data availability for services like bike sharing and public charging/refuelling, the overall coverage for dynamic information on mobility services and infrastructure remains low. Efforts are ongoing to improve data standards and coverage, particularly for cycling infrastructure and services.

MegaBITS and the Bicycle Data Space. The MegaBITS project, funded by the Interreg North Sea Programme, focuses on developing a Bicycle Data Space (BDS) to address challenges in accessing and interpreting cycling data in the EU. By fostering collaboration among governments, bike-sharing companies, and cyclists, the BDS aims to enhance data sharing and improve cycling infrastructure and services.

Conclusion:

Integrating e-bike charging station data into EU mobility frameworks is crucial for promoting sustainable transportation and achieving the EU's Green Deal objectives. Continued efforts in standardizing data, enhancing interoperability, and fostering collaboration among stakeholders will be essential in realizing a seamless and efficient e-bike mobility ecosystem across Europe.

2.6 Methods for connecting SMILE CITY digital tools and App with databases (by NTU)

In this sub-task, several methods have been investigated for this project to connect digital tools and Apps with the databases, with particular attention to ensure the efficient data management, and data security and privacy, which are detailed as follows:

2.6.1 Methods for connecting digital tools & Apps with databases

- (1) Direct database connection to digital tools and App
 - **ODBC/JDBC**, which are standardized methods for database access. ODBC (Open Database Connectivity) and JDBC (Java Database Connectivity) are two of the most widely used standardized APIs for database access across different platforms and programming languages. Key characteristics of ODBC/JDBC include Standardized interfaces that provide consistent access to various database systems; Database-agnostic approach that allows applications to connect to multiple database types; Driver-based architecture where specific drivers handle the actual communication with each database.
 - **Native Drivers**, which are database-specific connectors, such as MySQL Connector and PostgreSQL adapter. Native drivers are database-specific connectivity solutions that provide optimized communication between applications and particular database management systems. Unlike standardized interfaces like ODBC/JDBC, these drivers are tailored to specific databases for maximum performance and functionality. Native Drivers are usually vendor-specific, which are developed by database vendors or community contributors and designed to leverage database-specific features. Native drivers are typically provided for popular programming languages by implementing the native network protocol of the target database.
 - **ORM (Object-Relational Mapping)**: Object-Relational Mapping (ORM) is a programming technique that converts data between incompatible type systems in object-oriented programming languages and relational databases. ORM tools can create a "virtual object database" that developers can interact with using their preferred programming language. As core concepts of ORM, Model Classes represents database tables as programming language classes, Relationships handle associations (one-to-one, one-to-many, many-to-many), and Query Abstraction is used to convert object-oriented queries to SQL via transaction management to simplify database transactions. Major ORM tools include Hibernate (Java), Sequelize, Django ORM, etc.
- (2) Utilisation of API-based interfaces to connect the database
 - **RESTful APIs**: is an architectural style for designing networked applications that use HTTP for communication between clients and servers. RESTful (Representational State Transfer) APIs expose database functionality through standardized HTTP endpoints that follow these principles: (1) resource-based: everything is a resource identified by URIs; (2) stateless: each request contains all necessary information; (3) cacheable: responses define their cache ability; (4) uniform interface: consistent use of HTTP methods; (5) layered system: intermediary servers can be inserted without client knowledge. RESTful APIs map database CRUD (Create, Read, Update, Delete) operations to HTTP methods:

HTTP Method	CRUD Operation	Typical Response Codes
POST	Create	201 (Created), 400 (Bad Request)
GET	Read	200 (OK), 404 (Not Found)
PUT/PATCH	Update	200 (OK), 204 (No Content)
DELETE	Delete	200 (OK), 204 (No Content)

- **gRPC APIs**, with high-performance RPC framework for inter-service communication. gRPC (gRPC Remote Procedure Calls) is a modern, open-source RPC framework initially developed by Google. It enables efficient communication between distributed systems by allowing clients to call methods on a server application as if they were local objects.

(3) MQTT (Message Queuing Telemetry Transport)

MQTT is a lightweight, publish-subscribe protocol designed for machine-to-machine communication and IoT applications. To connect MQTT to mobile apps and database, a system must be set up where (1) MQTT Broker handles messaging, (2) Mobile App subscribes to or publishes topics, (3) Database stores messages or device data. The MQTT Broker is the central server in the MQTT system, which handles all message routing between clients, such as mobile apps, sensors, or backend services. The broker manages Topic filtering, Session persistence, Quality of Service (QoS), and Security and authentication.

Application of Middleware solutions, including database proxies (known as connection poolers like PgBouncer), data integration platforms (such as Informatica, Talend, MuleSoft), and ETL tools for data transformation during data transmission.

2.6.2 Efficient data management with security

- GraphQL can be applied for efficient data management. GraphQL is a query language for APIs and a runtime for fulfilling those queries with your existing data. Developed by Facebook in 2012 and open-sourced in 2015, it provides a more efficient, powerful, and flexible alternative to traditional REST APIs. GraphQL provides the feature of client-specified queries, where clients request exactly what they need. Unlike common multiple endpoints, GraphQL is based on single endpoint with hierarchical structure that queries mirror response shape, allowing clients to discover API schema.
- Encryption of TLS/SSL for data in transit. Transport Layer Security (TLS) and its predecessor, Secure Sockets Layer (SSL), are cryptographic protocols designed to secure data transmitted over networks. While SSL is now deprecated, the term "SSL" is still commonly used to refer to TLS. TLS ensures that data in transit remains confidential and unaltered, protecting it from eavesdropping and tampering.

TLS operates by establishing an encrypted connection between two communicating parties, typically a client (like a web browser) and a server. This process involves a handshake mechanism that authenticates the server (and optionally the client), negotiates encryption algorithms, and establishes session keys for secure communication. The encryption ensures that any data exchanged is unreadable to unauthorized parties, while integrity checks verify that the data has not been altered during transmission.

- In addition, Blockchain technique is often used to resolve the problems of the traditional centralized data management, such as poor data security and privacy protection ability, insufficient scalability of the system and poor interaction ability,

Currently, most traditional data sharing platforms build data centres and manage shared data in a centralized manner, which results in weak data interaction between data owners and risk of data abuse

and privacy leakage in data sharing. Furthermore, it affects the enthusiasm of data owners to share and hinders the sharing of data resources and value mining

Blockchain technology integrates distributed storage, point-to-point communication, distributed consensus mechanism, encryption algorithm and other technologies to establish a set of trust mechanism through the joint maintenance of ledger by multiple nodes, to make ledger data public, transparent, traceable, and not tampered which highly meeting the demand of data sharing

Based on the distributed trust mechanism of blockchain, many corresponding data storage, management and sharing systems and platforms have been proposed for different applications. One example is the distributed data management architecture based on the Internet of Things and blockchain technology. In this system, the distributed consensus mechanism of blockchain and the distributed storage technology are employed to manage the access and storage of Internet of Things data in a secure manner.

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2.7 Feasibility study for the implementation of digital tools (by NTU)

2.7.1 Overview of the condition monitoring system for e-bike charging stations

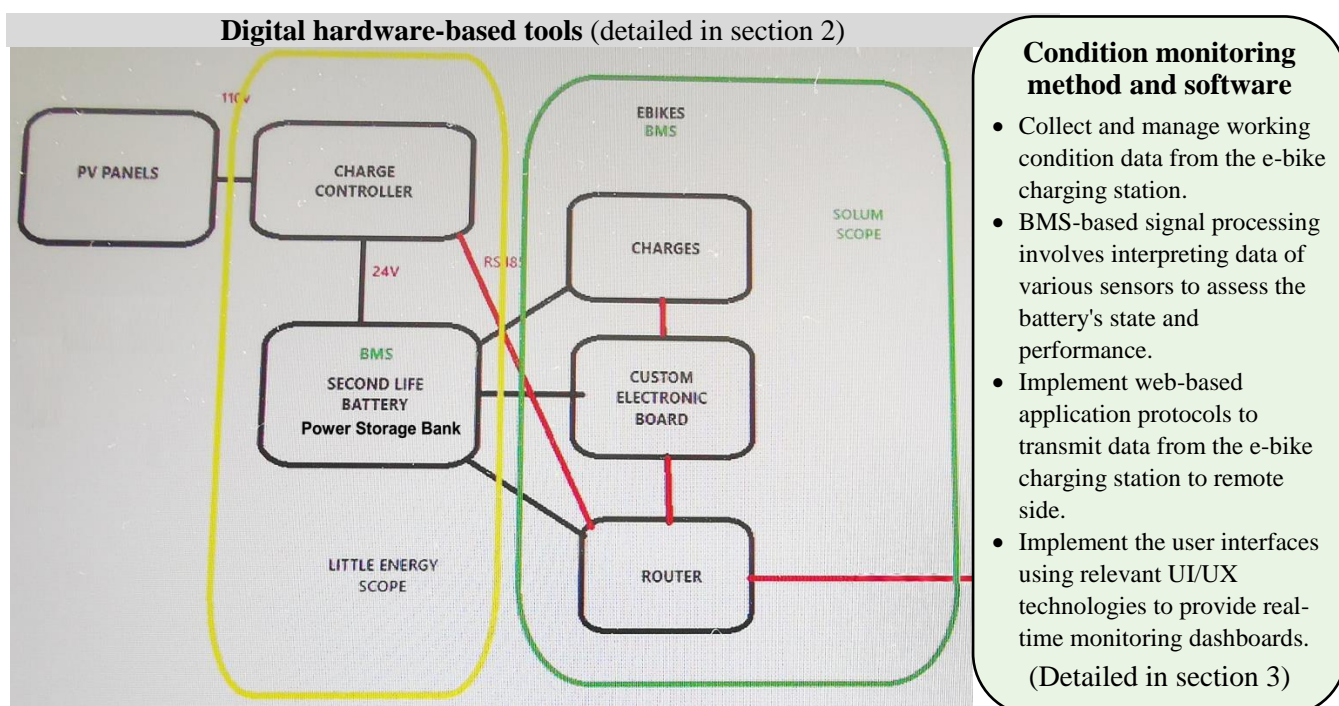


Figure 1: Condition monitoring of the e-bike charging station (The diagram in the grey area was copied from David Barroso).

Figure 1 shows the condition monitoring system for the e-bike charging station, which is required for this project to monitor the working condition of the e-bike charging station. It consists of two parts: (1) Digital hardware-based tools, and (2) condition monitoring method and software, which are detailed below.

2.7.2 Digital hardware-based tools (T4.1)

The e-bike charging station developed in this project is to use solar panels to charge the second life batteries and then provide power for e-bikes.

The condition monitoring system consists of solar PV panels, charge controller, battery power storage bank, e-bike charger, BMS card, electronic board, router, and related monitoring software, which are detailed as follows:

- 1) PV panels are applied to convert solar energy into electricity through photovoltaic cells.
- 2) The battery power storage bank is built with an array of second life batteries, which is the essential component in the e-bike charging station. It is used to store solar energy generated during the daytime, allowing for continuous power supply to e-bikes. Batteries within the power bank must be tested with battery technical standards, complying with EU's safety assessment and quality assurance.
- 3) The charge controller, also known as charge regulator, is used to manage the flow of electrical energy from the solar PV panel to the battery power storage bank. Its primary role is to prevent overcharging, over-discharging, and other conditions that could damage batteries or reduce their lifespan. Solar charge controllers include two types: MPPT (Maximum Power Point Tracking) and MPPT (Maximum Power Point Tracking).
- 4) The Battery Management System (BMS) is used to monitor various battery parameters, such as voltage, current, and temperature at the battery cell and pack levels, ensuring safe and efficient

operation of batteries. The BMS consists of a set of voltage and current sensors (measure electrical parameters), temperature sensors (monitor thermal conditions), micro-controller/ processor (processes data and executes control algorithms), balancing circuits (manage equal charge distribution among cells) and communication interfaces (enable data exchange with external devices).

- 5) The custom electronic board provides routing function (e.g. wires, WiFi, 4G) by connecting with a router, to transmit the working condition data over mobile networks.

To collect data remotely from the charging station, one scenario is for the e-bike charging station to host the process of data transmission over the networks, while the remote computer connects to the station to pull or retrieve data. It is suitable to establish the smart station with built-in computing, transmission and networking capabilities, ensuring the station's independent data collection and management. Another possible scenario is, the remote computer hosts the data transmission process, being a central location for control, logging, and data processing. However, the major concern is the need for continuous and stable network communication from the station to the host computer.

2.7.3 Condition monitoring method and software (T4.5)

(1) Condition monitoring with remote capability

Condition monitoring is conducted to collect working condition data from the e-bike charging station, such as the power energy produced and stored in the battery power bank and used for charging e-bikes, etc.

Combining with the online communication functionality, the condition monitoring system will allow operators to monitor and/or control charging stations from a remote place. This capability may include detecting the working state of the charging station, diagnosing issues, performing firmware updates and starting or stopping specific sessions, which can be achieved by integrating various programming methods and techniques:

- Implement application protocols (e.g., HTTP, MQTT, socket) to transmit data from a charging station to a remote side. For instance, a Web-based monitoring system can display live data like voltage, current, and battery percentage on a website, enhancing user accessibility.
- Create user interfaces using relevant technologies (HTML, CSS, JavaScript) to provide monitoring dashboards. These applications can display charging status, historical data, and alerts, facilitating user interaction and system management.

(2) Signal processing tool

A critical aspect of BMS functionality is signal processing, which involves interpreting data from various sensors to assess the battery's state and manage its performance.

- Sensor Data Acquisition: BMS relies on sensors to measure parameters such as voltage, current, and temperature. For instance, Hall Effect sensors are commonly used for current measurement, while voltage-to-frequency converters can be employed for voltage sensing. These sensors provide real-time data crucial for battery monitoring.
- Signal conditioning: Raw signals from BMS fusion sensors often require conditioning to be suitable for processing. This includes amplification to enhance signal strength, filtering to remove noise, and isolation to protect the system from high voltages. Signal conditioning ensures that the data fed into the processing units is accurate and reliable.
- Analog-to-Digital Conversion (ADC): Conditioned analogue signals are converted into digital form using ADCs. This digital data can then be processed by microcontrollers or digital signal processors (DSPs) within the BMS for further analysis and decision-making.

- Digital Signal Processing (DSP): DSP techniques are employed to analyse and interpret the digital signals. Advanced algorithms, such as Kalman filtering, adaptive filtering, and machine learning models, can be used to estimate the battery's state of charge (SOC), state of health (SOH), and predict future performance. These techniques enhance the accuracy and responsiveness of the BMS.

(3) Condition monitoring software

The necessary software is applied to collect working condition data of the e-bike charging station from the custom electronic board via the router. Multiple condition monitoring techniques can be combined, for example, the Real Tech techniques is suitable to track charging progress, such as charge percentage and remaining time. Powerbox developed a method for real-time status updates and efficient energy management, allowing the management systems accessible via the custom application.

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2.8 Technical Requirements for Client Endpoints Including Monitored Parameters (by IETU)

2.8.1 Technical requirements for client endpoints

Standards and norms describing technical requirements for the construction of charging points are described in detail in the Standards and Regulations for E-Bike Charging Stations, and Solutions for Efficient E-Bike Mobility report in particular CHAdeMO's standard describing universal charging link is cited. This report focuses on IT requirements.

The bicycle charging point must be connected to the IT network for communication with the central system and the mobile application. If the system will be implemented on an existing charging network, then the most favourable solution would be to make an agreement with the network manager to provide the existing Internet connection at the charging point. The charging station will certainly be equipped with such an Internet connection, although one can imagine a situation when it uses a dedicated network (e.g. for security reasons), but such a situation is unlikely.

With the right willingness to cooperate, it would then suffice to install a simple network switch and configure the network settings accordingly. The problem may be the issue of responsibility for the correct operation of the switch, which may prevent the use of such a solution, and you would have to realize your own connection.

In physical terms, both a wired network (LAN based on fibre or copper) and a wireless network (WLAN based on Wi-Fi or 4G, 5G cellular network) can be used. The number of transmitted data will tend to be relatively small, so a cellular network may prove to be the cheapest and most efficient. The target choice of solution will depend on the existing and available local IT infrastructure. However, it may turn out that the system embedded in the charging station will have some special requirements - then it may be necessary to implement additional investments such as pulling fibre optic cable, purchasing directional antennas and Wi-Fi/4G signal boosters.

Whatever solution you choose, you will need a router. In addition to the software requirements (discussed later), when choosing a router, you should consider the temperatures prevailing at the point in winter. The cheaper solutions guarantee correct operation only in temperatures above zero degrees. If there is a high risk of sub-zero temperatures, you should choose a more expensive solution, such as Omada devices. For the pilot solution, however, this is of little importance, and if there is a technical possibility, we suggest using a cheap and flexible devices from the Mikrotic product range.



The use of the Internet should be done using the appropriate safety rules. As the popularity and number of electric bicycles grows, the number of charging points is increasing. They are usually fully self-service, and payments are made using a terminal: with payment cards, or smartphone NFC, blik, or through dedicated mobile apps. Management of such charging points is done remotely so they are becoming a target for hackers and a breeding ground for cybercriminals. Charging points are at an early stage of development and necessarily lack robust security features and refined technologies and standards for effective protection and charging point operators are vulnerable to far-reaching cyberattacks.



Charging points are critical infrastructure usually directly connected to the power grid and are vulnerable to power theft. Stations can be mechanically damaged causing a short circuit which in turn can shut down power over a large area. The second aspect is the exposure to theft of sensitive data. In the process of charging and purchasing electricity, it is required to log into the system and make a payment - then personal data, login, email, payment account information are (can be) transferred.

An inadequately secured system can be breached, and hackers can gain access to the charging system user database - a data leak. As a result of a cyber-attack, for example, payments may be redirected to another account, login data may be intercepted and used for payments in the recharge system, or personal data may be used in other systems, e.g. to take out a cash loan.

The weakest link in the system is the endpoint (with terminal) at the charging station. Due to the lack of direct supervision, it is vulnerable to physical attack - swapping the card reader, replacing the terminal, placing false information.

Among the most common forms of cyber-attack are:

- Phishing;
- Spoofing;
- Quishing;
- SQL injection;
- Pharming;
- Cross-site scripting.

To minimize the risk of a successful cyber-attack, all endpoints and the central system should be connected via a VPN (e.g., IPsec, WireGuard), and the service's web pages should be secured with an appropriate SSL certificate.

Among the most important security standards and regulations should be highlighted:

- NIS2 - is legislation governing cybersecurity in the EU. The NIS2 directive places EV charging networks under stricter cybersecurity requirements, recognizing their growing importance in both the energy and transport sectors.
- OCPP - Open Charge Point Protocol set up complex price plans and tariff models, automated billing and receipt generation and allow the creation of a secure communication channel between the CPMS and the charging station (using Basic Authentication, TLS or TLS2).
- ISO 15118 - an international standard that defines the communications protocol between the charging station and the electric vehicle.
- Eichrecht - a German calibration law that applies to all measuring devices, including electricity meters on EV charging stations.

The charging point should be equipped with a computer capable of connecting the appropriate sensors and providing network communication. The choice of a suitable computer can be made only after determining the target functionality of the charging point. There are still open questions about the integration of our solution with the charging network and the scope of operation of the charging station, whether it should support the terminal, etc.

At the moment it seems (especially for the pilot solution) that a single-board computer e.g. Raspberry Pi micro controller e.g. ST or minicomputer e.g. Intel Compute Stick based on ARM or Intel Atom processor will be sufficient.



A computer with an ARM processor provides the flexibility of the operating system used (Linux, Window), which allows flexible adaptation to requirements and capabilities. The key functionality seems to be the ability to plug in external sensors (e.g., temperature or particulate matter).

Of course, it is possible to use a more expensive specialized industrial computer equipped with a number of USB and/or RS-232 ports providing the ability to connect multiple sensors.



At the moment we do not have information on the requirements for interfaces (both physical and software) of the bicycle charging stations - it is also unknown whether the software being developed will communicate directly with the hardware (sensors and switches) or with the software installed at the station, or with the central system. As a result, the requirements to be met by the infrastructure and software built on the project side to ensure compliance cannot be specified at this time. These parameters can be defined in a later phase of the project.

2.8.2 Monitoring solutions for air quality and meteorological conditions

In terms of monitoring air quality and meteorological conditions, it is possible to use simple systems that measure basic parameters, such as WINSON ZPHS01C. Such a chip can be successfully mounted inside a charging point and connected to an endpoint computer via RS-232C or USB ports. In this case, it is necessary to take care of cyclic reading of data from the COM port decoding the values and writing them to the database.



Using these sensors, meteorological parameters such as temperature and humidity can be measured, and in the case of air quality, PM2.5. The accuracy of such sensors is poor. In addition, it is impossible to place them in such a way that they meet the appropriate standards and norms. But it seems that such sensors are sufficient to meet the goals set for the project.

Measuring other parameters (e.g., precipitation, wind direction and speed, concentrations of NO_x, SO₂, etc.) requires use of more specialized and significantly more expensive devices, which additionally require protection and physical safeguards (including fencing). Examples of such devices include weather stations providing online data access manufactured, for example, by Davis or TFA and substance concentration meters by Recordum. Such devices require constant service, supervision and periodic calibration.



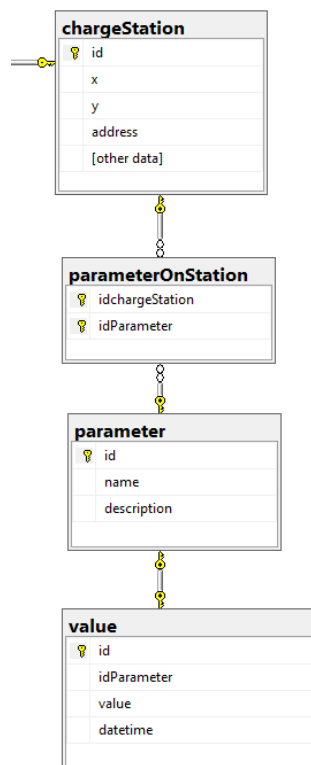
2.8.3 Selection, integration and processing of monitored and collected parameters

The final list of parameters will be identifiable once the final functionality is determined. At the moment, it can be seen that it is necessary to monitor such parameters as:

- meteorology:
 - o air temperature;
 - o humidity;
- air quality:
 - o PM 10;
 - o PM 2.5;
 - o CO₂;
- battery:
 - o battery level at the station;
 - o number of available outlets;
 - o e-bike battery status;
 - o charging speed;

It is proposed to read the sensors cyclically in a period of about 1 minute. the data should be sent to a central database. data in the database for the presentation of archival data should be aggregated, for example, to a period of 10 minutes.

Monitoring data measured at charging stations is proposed to be stored in the tables described in the report *Concept of eco-cost management application*. Due to the potentially large amount of data, retention should be provided for and data should be archived and back-up regularly.



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3 Concluding Remarks

The SMILE CITY Deliverable report has provided a comprehensive review and assessment of the current landscape of digital tools, mobile application solutions and technical standards that underpin the transition toward sustainable e-bike mobility in European cities. Through coordinated contributions from NTU, CIE, ECF, CNR, Solum, IETU, ETRA, and UNITO, this deliverable establishes a consolidated knowledge base to guide future implementation, system integration, and policy alignment within the project.

Firstly, the regulatory analyses conducted by CIE and ECF offer clear insights into the evolving EU framework governing both e-bike batteries and charging infrastructure. Regulation (EU) 2023/1542, alongside harmonized standards such as EN 15194:2017+A1:2023, provides a robust foundation for achieving battery safety, interoperability, traceability, and environmental compliance across Member States. Additionally, EU-level initiatives—including the European Mobility Data Space (EMDS), NAPCORE, and MegaBITS—highlight the growing importance of data interoperability and cross-platform coordination. These developments underscore the need for strengthened regulatory harmonization, improved mobility data integration, and continuous stakeholder collaboration to fully support a future-ready, efficient, and user-focused e-bike charging ecosystem. Secondly, the analyses conducted by CNR and Solum demonstrate the breadth of existing digital platforms and mobile applications that can support the management, monitoring, and optimisation of e-bike charging systems. Commercial tools such as EcoSpazio SharWare, Comodule, YoCharge, and solar-integrated platforms like miSolum reveal substantial potential for integration with SMILE CITY's digital infrastructure, particularly in areas such as real-time monitoring, user authentication, renewable energy use, and payment systems. Comparative evaluations illustrate that while many tools offer advanced functionalities, future deployments should prioritise interoperability, scalability, and alignment with SMILE CITY's operational and eco-accounting aims. These findings reinforce the importance of integrating user-centric interfaces with robust backend systems to deliver a seamless experience for riders, operators, and city authorities.

Thirdly, the technical contributions from IETU and NTU highlight the essential requirements for backend data management, database connectivity, condition monitoring, and system interoperability. The feasibility studies confirm that the proposed digital infrastructure—supported by secure database interfaces (e.g., RESTful APIs, MQTT, ORM frameworks), structured data flows, and remote monitoring tools—is both viable and adaptable to pilot city conditions. The emphasis on cybersecurity, efficient data handling, and clear UI/UX design principles ensures that the SMILE CITY digital ecosystem can evolve alongside regulatory, technical, and operational needs.

Collectively, the outcomes of this deliverable provide the technical feasibility, economic practicality, and regulatory compliance necessary for successfully deploying digital mobility solutions. Comprehensive assessments highlight critical factors, including cross-sectoral collaboration, harmonized policy frameworks, innovative technological solutions, and consistent stakeholder engagement, essential for achieving sustainable urban mobility objectives aligned with the EU Green Deal and the Circular Economy Action Plan.

In conclusion, the deliverable shows that SMILE CITY is well positioned to implement a cohesive set of digital tools that support sustainable mobility, optimise infrastructure performance, and promote behavioural change. The next steps will involve refining the technical architecture, aligning platform development with pilot city needs, and continuing to integrate regulations, digital tools, and real-world infrastructure. By fostering cross-sector collaboration and leveraging technological innovation, SMILE CITY can significantly enhance urban mobility systems and support the EU's broader transition toward low-emission, inclusive, and data-driven transport ecosystems.