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LIFE2M – Long Life to Micromobility

Grant Agreement - 101074307

Deliverable D2.1
Data Collection Plan

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Dissemination Level

PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Change History

Document status		
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Disclaimer/ Acknowledgment

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Executive Summary

The LIFE2M technological innovative equipment and microvehicles designed, developed, and produced during the project will be tested in 3 cities. Firstly, the report presents the data that must be collected to monitor the impacts of demonstrators and micromobility: the data will cover technical, and environmental aspects. Secondly high-level KPIs concerning the global project impact necessary to evaluate the project's achievement are presented

Table of contents

Abbreviations and acronyms

Abbreviation / Acronym	Description
WP	Work Package
EC	European Commission
DCP	Data Collection Plan
OBU	On Board Unit
BMS	Battery Management System

Partner short name used in this document	Partner FULL name
UNIFI	UNIVERSITA' DEGLI STUDI DI FIRENZE
EUABOUT	EUROPEAN RESEARCHES AND PROJECTS FOR INNOVATION
USGM	UNIVERSITA' DEGLI STUDI GUGLIELMO MARCONI – TELEMATICA
UNEED	UNEED.IT SRL.
SILIDEA S.R.L	SILIDEA S.R.L.
ESCO S.R.L.	ESCO MOBILITY
F&N COMPOSITI	F&N COMPOSITI SRLS
L'AQUILA	COMUNE DELL'AQUILA

Deviations

No deviation from the actions foreseen in the LIFE2M Grant Agreement.

1. Introduction

This document pertains to Deliverable 2.1 of the LIFE2M project, funded by the European Union's LIFE Programme under Grant Agreement #101074307. This deliverable falls under WP2, Monitoring and Evaluation, precisely Task 2.1. The primary objective of this report is to define the Data Collection Plan (DCP), which aims to identify the data to be gathered, along with the methods and tools for collection. The data summarized in the plan, as well as the data acquired throughout the project, will play a crucial role in the subsequent evolution of WP2 when the "Analysis of the impact of micromobility" on the environment (including a Life Cycle Assessment - LCA) and urban mobility will need to be prepared. Ultimately, the collected data will be used to calculate impacts and Key Performance Indicators (KPIs), which will then be compared with the estimations made in the project proposal.

In particular, the data will be acquired, and the monitoring strategy will be based on a two-level approach:

- Full equal monitoring of every single site.
- Cross-evaluation process to compare the data of different sites to evaluate the performances of innovative accumulators and microvehicles in different route conditions.

The DCP encompasses the parameters collected from: i) the microvehicles' onboard system (OBU) and uploaded in the platform's users (e.g., distance travelled, vehicle speed, time in service, etc.), ii) the charging stations (e.g., operational period, number and type of failures, etc.), and iii) indirectly obtained and used to calculate the key performance indicators (KPIs) of the project, necessary to evaluate how successful is the project at reaching a target (e.g., specific energy consumption, primary energy used, emissions, etc.).

2. Data collection

In order to calculate the KPIs, data have to be collected either manually or obtained from the OBUs installed on the microvehicles. The OBU includes a smart battery management system (BMS) and Bluetooth modules on each vehicle. The OBU connects via Bluetooth with the App installed on the cellphone of the user. The data originated will be internally acquired and timestamped at specific regular intervals depending on the dynamics of the corresponding signal. Some local aggregation and edge processing are also envisaged to optimize both the latency and the bandwidth needed to connect to the remote platform. The system that will be implemented is an innovative advanced IoT System with the aim of digitalizing supply chain management. The link between the Digital Platform and the OBUs is performed by adopting a server that exports all the services for web access. A specific software will elaborate all the data and visualize the indicators on a single dashboard in real time. It will also be possible to extrapolate the data on Excel files.

For what concerns the charging stations, two communication hypotheses have been developed for interaction with the server:

- Charging station via cable, Wi-Fi, or can-bas.
- Charging stations equipped with a GPRS module directly communicate with the server.

In either case, the charging station initiates communication with the server and subsequently with the App. The App then suggests the nearest available charging station to the user.

This section lists the sampling rate and the unit of measure of each parameter retrieved from the On-board-Unit.

2.1 Microvehicles data

The table below showcases the data collected directly and automatically from the microvehicles' onboard system or entered by users through the platform. Daily collection of this data will take place, and it will be aggregated to facilitate viewing and consultation. Subsequently, it is provided a description of the parameters introduced in the table.

Parameter	Unit
Microvehicles operation characteristics	
Odometer, dist	km
Vehicle speed, v	Km/h
Time in service, t_{servon}	h/day
State of charge, SOC	%
Energy consumed, EE_c	kWh
Energy recharged, EE_{rec}	kWh

Recharging time	min
GPS data	Lat, Long

Table 1 - Microvehicles operation data to be collected.

- **Odometer, dist (km):** this represents the distance covered by the microvehicle. The value will be recorded each time the microvehicle is unlocked and will be displayed on a daily basis.

- **Vehicle speed, v (km/h)**: refers to the rate at which a vehicle travels and indicates how fast the vehicle moves along its path or route. This data will be showcased on a daily basis and aggregated to reflect the total usage.

- **Time in service, t_{servon} (h/day):** it is the time in which each microvehicle is operating. This data will be collected daily and displayed also on aggregated averages.

- **State of charge, SOC (%):** this parameter indicates the battery's current level at the communication time. It serves as a valuable indicator for users to understand the remaining charge in the battery and verify the feasibility of reaching the charging station recommended by the App.

- **Energy consumed, EEc (kWh)**: it represents the total amount of electrical energy drawn from its battery during operation. This parameter will be gathered on a daily basis and aggregated to reflect the total consumption during the utilization.

- **Energy recharged, EErec (kWh)**: is the energy withdrawn from the grid during the vehicle's charging.

- **Recharging time, t_{rec} (min)**: refers to the duration required to fully replenish the energy in the battery of an electric scooter after it has been depleted during use. It is the time taken from connecting the scooter to a power source until the battery reaches its maximum capacity. The value will be recorded each time the microvehicle is connected to the station and displayed daily and on the total average aggregate.

- **GPS data**:

2.2 Station data

The following table presents the data collected directly and automatically from the photovoltaic (PV) charging stations or collected by the operator during the project's lifetime. Daily collection of this data will take place, and it will be aggregated to facilitate viewing and consultation. Subsequently, is provided a description of the parameters introduced in the table.

Parameter	Unit
PV Charging stations	
Energy produced by PV, EE_{prod}	kWh
Energy provided to microvehicles, $EE_{prov, FV}$	kWh
Operational period, t_{servon}	h/day
State of charge, SOC	%

Data to be obtained by operators (repair microvehicles personnel)	
N. batteries substituted	#
N. failures	#

Table 2 – Charging station operation data to be collected.

- **Energy produced by PV, EEprod (kWh):** refers to the energy produced by the solar panels installed in the charging facilities. This data will be collected on a daily basis and aggregated total average.

- **Energy provided to microvehicles, EEprov (kWh)**: This parameter represents the total energy supplied to the microvehicle once it is connected to the charging station. This data will be collected on a daily basis and aggregated total average for each single scooter.

- **Operational period; t_{servon} (h/day):** it is the time in which each the station is operating and providing anergy either from the grid or the panels to the microvehicles. This data will be collected daily and displayed also on aggregated average.

- **State of charge, SOC (%)**: refers to the current level of stored energy in the station's battery or energy storage system at the time of the connection with the microvehicles.

- **N. batteries substituted:** number of batteries of the microvehicles that are replaced during the project lifetime.

- **N. failures:** refer to any malfunctions, breakdowns, or issues that prevent the vehicle from operating correctly or safely that are not linked to problems of the charging stations.

2.3 Equations for the calculation of the KPIs

By utilizing the data derived from the aforementioned vehicles and station parameters, the database will offer an opportunity to compute additional essential parameters. These calculated values will prove valuable in the project's KPIs analysis. This will be achieved by configuring and implementing the specific formulas outlined in the provided table. Such an approach allows for a comprehensive examination of the project's progress and performance, providing valuable insights for decision-making and optimizing overall efficiency.

Parameter	Unit
Formulas	
Specific energy consumption, SEC	SEC = EEc/dist (kWh/km)
Primary energy used by SC microvehicle, $P_{EM,SC}$	$P_{EM,sc}$ = EEc/56.2% (kWh/year)
Primary energy used by Li microvehicle, $P_{EM,Li}$	$P_{EM,Li}$ = PEsc/15% (kWh/year)
Emissions avoided, Pi_{NOX}	Pi_{NOX} = $P_{EM,sc}$ * 0.210*10^-3 (kg)
Emissions avoided, Pi_{COVNM}	Pi_{COVNM} = $P_{EM,sc}$ * 0.09*10^-3 (kg)
Emissions avoided, Pi_{CO}	Pi_{CO} = $P_{EM,sc}$ * 0.094*10^-3 (kg)

Emissions avoided, Pi_{PM10}	$Pi_{PM10} = P_{EM,sc}$ * 0.002*10^-3 (kg)
Emissions avoided, Pi_{CO2}	$Pi_{CO2} = P_{EM,sc}$ * 415.5*10^-3 (kg)
Primary energy saved using microvehicles vs cars, PES	PES = (0.66-SEC) * dist (kWh)
Emission saved Nox using microvehicles vs cars, ES_{Nox}	$ES_{Nox,}$ = 0.66 * dist * 0.084 *10^-3 (kg)
Emission saved COVNM using microvehicles vs cars, ES_{COVNM}	ES_{COVNM}= 0.66 * dist * 0.152 *10^-3 (kg)
Emission saved CO using microvehicles vs cars, ES_{CO}	ES_{CO} = 0.66 * dist * 1.18 *10^-3 (kg)
Emission saved PM10 using microvehicles vs cars, ES_{PM10}	ES_{PM10} = 0.66 * dist * 0.001*10^-3 (kg)
Emission saved CO2 using microvehicles vs cars, ES_{CO2}	ES_{CO2} = 0.66 * dist * 123*10^-3 (kg)
Primary energy saved due to PV, PV_PES	PV_PES= $EE_{prov,FV}$/56.2% (kWh)
Total energy recharged, EEtot,rec	EEtot,rec= EEc + EEprov, FV (kWh)

Table 3 – Equations for the calculation of the KPIs.

- **Specific energy consumption, SEC (kWh/km):** is defined as the ratio between the electric energy consumption and the distance travelled by each microvehicle. This metric is used to quantify the amount of energy required to travel from one point to another. A lower SEC generally indicates better efficiency, as it implies that less energy is needed to achieve the desired output. The value will be recorded each time the microvehicle is unlocked and displayed daily and on the total aggregated average.

- **Primary energy used by SC microvehicle, $P_{EM,SC}$ (KWh/year):** refers to the energy required to power and charge the vehicle's battery. For microvehicle equipped with supercapacitors (SCs), it is calculated by the ratio of electric energy consumption to the value of power generation efficiency in Italy in 2019 (equal to 56.2%). The value will be recorded each time the microvehicle is unlocked and displayed daily and on the total aggregated average.

- **Primary energy used by Li microvehicle, $P_{EM,Li}$ (KWh/year):** refers to the energy required to power and charge the microvehicles equipped with Li-ion batteries (their number depends on the project's status). It takes into account that the Li microvehicles have a recharge efficiency equal to 85%, so a 15% loss must be added to the primary energy used by the supercapacitors. The value will be recorded each time the microvehicle is unlocked and displayed daily and on the total aggregated average.

- **Emissions avoided, Pi_i (kg):** this KPI indicates the amount of NOx, COVNM, CO, PM10 and CO2 emissions (i refers to the pollutant) avoided by retrofitting lithium batteries with SCs. The quantity is calculated once known the $P_{EM,SC}$ of each microvehicle per day and the average values of power generation emission factor (mg/kWh).

Pollutants (g/kWh)	Year: 2019
Nox	0.21
COVNM	0.09
CO	0.094
PM10	0.0026
CO2	415.5

Table 4- Average values of emission factor (g/kWh) of power generation in Italy in 2019 (ISPRA)

- **Primary energy saved using microvehicles vs cars, PES (kWh):** similarly to the previous description, the primary energy saved by implementing SC microvehicles that will replace the cars after the end of the project is calculated. 0.66 is the energy consumption of the car in kWh/km.

- **Emission saved using microvehicles vs cars, ES_i (kg):** The emission savings achieved by using microvehicles instead of cars, denoted as ESi (kg), is evaluated considering a scenario where, five years after the project's conclusion, 2% of private car journeys are replaced by electric microvehicles. This assessment aims to gauge the impact of this shift on emissions. The calculation for each pollutant, denoted as "i," relies on several factors: the energy consumption of the car (0.66 kWh/kg), the daily distance travelled by each vehicle, and the average emission factor for a medium petrol car (measured in grams per passenger-kilometre, g/pkm).

Pollutants (g/pkm)	Medium petrol car
Nox	0.084
COVNM	0.152
CO	1.18
PM10	0.001
CO2	123

Table 5 - EU average values per passenger and km of emission factor of medium petrol car (TRACCS database).

- **Primary energy saved due to PV, PV_PES (kWh):** refers to the amount of primary energy that is conserved or not consumed as a result of using solar photovoltaic systems to generate electricity. It is calculated as the ratio between the energy provided to each microvehicles once connected to the station and the value of power generation efficiency in Italy in 2019 (equal to 56.2%).

- **Total energy recharged, EEtot,rec (kWh):** is the comprehensive amount of energy required to recharge the microvehicles. This total is computed by summing two distinct components: the total amount of electrical energy consumed by the microvehicle's battery during its operation and the energy sourced directly from the PV system connected to the charging station.

2.4 BMS

The OBU includes a smart Battery Management System (BMS) that is an electronic board located as close to the accumulator as possible. Its task is to prevent the battery from operating outside of safe conditions, such as overcharging, over-discharging, drawing too much current, or experiencing a strong imbalance between internal cells. More advanced Battery Management Systems, known as smart or software BMSs, are equipped with a microcontroller that enables active monitoring of various parameters in real time. For this project, smart BMSs were selected to provide the state of charge, identify problems within the pack, track the number of charge and discharge cycles, and other important data to accurately monitor the battery's consumption and degradation. This data is conveyed via a Bluetooth modulator or wired connections that support various communication protocols.

BMS technical specifications will be analyzed in Tasks T3.1 and T3.2.

2.5 Collecting platform

The planned functionalities for the development of the collection platform include a back-office (front-end and back-end) and a Progressive Web App (PWA) functionality.

2.5.1 Back office

- Beneficiary Edit: This functionality is essential to ensure that beneficiary information is always up-to-date and accurate. Administrators can use a user-friendly interface to update details such as name, surname, contacts, and other relevant beneficiary information.
- User Edit: A similar feature is also available for user management. This allows administrators to maintain control over user information, including details such as role, access level, and contact data.
- Roles and Permissions Management: Effective management of roles and permissions is crucial for the security and efficiency of any IT system. This feature allows administrators to define specific roles for users and assign appropriate permissions to each role, ensuring that each user has access only to relevant areas and functionalities based on their role.
- User Administration (Description: Register new users, assign roles, modify users, reset passwords, delete users): This feature provides a centralized hub for user management, allowing administrators to perform critical operations, including registering new users, assigning and modifying roles, resetting passwords, and removing users.
- User Registration: This feature provides a clear and secure onboarding process for new users, ensuring that all necessary information is collected consistently and securely.
- User Registration - FE: The front-end of the user registration process is designed to be intuitive and user-friendly, guiding new users through the registration process and ensuring that information is entered correctly.
- Beneficiary Registration (Description: An Administrator user, with permissions to manage Beneficiaries, can register a Beneficiary...): This feature provides a structured process for registering new beneficiaries in the system, ensuring that all relevant information is collected.
- Beneficiary Registration - Upload Document: This feature extends the beneficiary registration process, allowing the upload of documents, such as identity documents, directly into the system.
- User Detail: This feature provides a detailed view of user data, allowing administrators to quickly view and verify user information.
- Beneficiary Detail: This feature provides a detailed view of beneficiary data.

- Beneficiary List: This feature provides a comprehensive list of all beneficiaries registered in the system, allowing administrators to have an overview and quick access to beneficiary information.
- User List: Similarly, the User List provides a comprehensive list of all system users, facilitating user management.
- Login (Description: Ability to log in with set credentials): This feature provides a secure authentication process, allowing users to access the system using their personal credentials.
- Login - BE: The back-end of the login process handles authentication requests, verifies credentials, and maintains system security.
- Login - FE: The front-end of the login process provides a user-friendly interface for users, guiding them through the login process.
- User Registration - BE: The back-end of the user registration process handles data collection and validation, ensuring that all information is correct and secure.
- Beneficiary Registration - BE: Similarly, the back-end of the beneficiary registration process handles data collection and validation.
- Beneficiary Registration - FE: The front-end of the beneficiary registration process provides an intuitive and guided interface for beneficiary registration.

2.5.2 Progressive Web App (PWA)

Progressive Web App (PWA) it’s necessary to communicate both with hardware mounted on a vehicle and the back-end of the back-office, the following different functionalities have been considered

- Integration with Vehicle Hardware: This task includes developing functionalities to communicate with the bicycle's hardware. This may involve the use of technologies such as Bluetooth Low Energy (BLE) for direct communication with the hardware.
- Integration with Back-office: This task includes developing functionalities to communicate with the back-end of the back-office. This may involve creating RESTful APIs or using a protocol like GraphQL.
- Authentication and Security Management: This task includes implementing functionalities to authenticate users and protect data. This may involve the use of JWT tokens or OAuth.
- Development of Application-Specific Features: This macro-task involves developing application-specific features, such as tracking the bicycle's route, displaying real-time hardware data, etc.
- Application Testing: Once the features are developed, thorough testing will be necessary to ensure that the application functions correctly and reliably.
- Application Deployment: This task involves preparing the application for launch and its actual release.

Task T3.4 will involve the analysis of the distinct technical features and functioning of the collecting platform."

3. Conclusion

In this report, a list of key performance indicators to evaluate the project achievements is presented. In particular, high-level impacts, which have been divided into groups according to their affinity, are defined.

The collection and analysis of data will occur through both direct methods (from the microvehicles and charging stations) and indirect methods (by solving specific equations using the directly collected data). The direct method involves the use of the Battery Management System (BMS), while the indirect method will leverage the computational capabilities of the online platform. The results will enable the drafting of project KPIs and provide technical feedback to the partnership regarding the proper functioning of the new microvehicles.

If any instance in this document is ambiguous or further assistance/advise is required, please refer to the Project Management Team:

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