ELABORATOR

Deliverable 4.1

Mobility intervention data framework

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Project Executive Summary

ELABORATOR stands for 'The European Living Lab on designing sustainable urban mobility towards climate neutral cities'. The EU-funded project uses a holistic approach for planning, designing, implementing and deploying specific innovations and interventions towards safe, inclusive and sustainable urban mobility. These interventions consist of smart behaviour and policy adaptation tools, space redesign and dynamic allocation, shared services, and integration of active and green modes of transportation.

They will be specifically co-designed and co-created with a broad array of local stakeholders including relevant authorities who will be identified as "vulnerable to exclusion" (V2E) Interventions will be demonstrated in a number of cities across Europe, starting with six Lighthouse cities and six Follower cities with three principal aims:

I. to collect, assess and analyse user needs and requirements towards a safe and inclusive mobility and climate neutral cities;
II. to collect and share rich information sets made of real data, traces from dedicated toolkits, users' and stakeholders' opinions among the cities, so as to increase the take up of the innovations via a twinning approach;
III. to generate detailed guidelines, policies, future roadmap and built capacity for service providers, planning authorities and urban designers for the optimum integration of such inclusive and safe mobility interventions into Sustainable Urban Mobility Plans (SUMPs).

ELABORATOR Lighthouse cities

- Milan (Italy)
- Copenhagen (Denmark)
- Helsinki (Finland)
- Issy-les-Moulineaux (France)
- Zaragoza (Spain)
- Trikala (Greece)

ELABORATOR Follower cities

- Lund (Sweden)
- Liberec (Czech Republic)
- Velenje (Slovenia)
- Split (Croatia)
- Krusevac (Serbia)
- Ioannina (Greece)

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MUNICIPALITY OF IOANNINA	EL	**IOANN**
PLATOMO GMBH	DE	**PLAT**

List of abbreviations and acronyms

Acronym	Meaning
API	Application Programming Interface
CA	Consortium Agreement
CCAM	Cooperative, Connected and Automated Mobility
DC	Data Consumers
DMP	Data Management Plan
DMPO	Data Management and Protection Officer
DoA	Description of Action
DP	Data Providers
EC	European Commission
EEAB	External Expert Advisory Board
FAIR	Findable, accessible, Interoperable, and Reusable
FMEA	Failure Mode and Effects Analysis
GA	General Assembly
GE	Generic Enablers
GDPR	General Data Protection Regulation
GRA	Grant Agreement
NDA	Non-disclosure Agreement
PC	Project Coordinator
PPDS	Privacy-preserving data sharing (PPDS) mechanisms
PU	Public

SUMP	Sustainable Urban Mobility Plans
TM	Technical Manager
TMT	Technical Management Team
VRU	Vulnerable Road User
WP	Work Package
WPL	Work Package Leader

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Deliverable executive summary

Deliverable 4.1 Mobility Intervention Data Framework …

- Describes a logical data model as a core component of ELABRATOR's Data Marketplace
- Defines and align relevant types of data (quantitative as well as qualitative) collected in relation to ELABORATORs interventions
- Constitutes a Taxonomy of relevant stakeholders to enable consideration of potential data providers and communication/dissimilation strategies
- Propose a framework of procedures for unification of mobility intervention data
- Enacts a data model based on the domain protocol for transport research enacted by D1.5.
- Eventually serve as point of departure for ELABORATORs Task 4.2: Secure, trusted and privacy-preserving intervention data platform which will deliver data and indicators of project activities, including
    - Co-creation and citizens involvement activities
    - Effects of Interventions

The data entities of the model will follow D1.5 (Data domain protocol for transport research) to include – not only data per se - but also stakeholders, co-creative processes, interventions, and evaluation methods (see section 6).

Data as such constitutes maps, geodata (point/line/polygon/raster), and tables at different levels of spatial/temporal/semantic aggregation and scales, to potentially accommodate both raw data as well as results of analysis.

1 Introduction

1.1 Overview

ELABORATOR partner cities are – by co-design with stakeholders - implementing sustainable urban mobility interventions. As part of this process, transport planners and other stakeholders rely heavily on data. Data can be used at multiple stages of urban intervention lifecycles, from realization, definition, design, and implementation toward co-evaluation of effects and experiences. In this context, stakeholders may rely on data for example to i) define needs and challenges ii) decide which intervention to implement; iii) to design the details of the intervention; iv) to monitor and evaluate its effectiveness.

ELABORATOR WP4 is coordinating and facilitating the sharing of mobility intervention data - linked to co-creative processes - among partner cities, living labs (LLs), and other (internal and potentially external) stakeholders for the purposes of enabling cross-benchmarking of co-creative processes and interventions, and to foster mutual inspiration.

To achieve sharing of data collected at different locations, using different methods and stored using different media and technologies, D4.1 will identify and enable semantic interoperability by devising and designing a framework for the unification of mobility intervention data with direct reference to the data domain model documented by D1.5. Subsequently, development of a technology platform that will implement semantic integration of data from across multiple heterogenous sources owned by different cities will be established by T4.2, by application of open data standards (section 3). With that in place, the platform can then enable different stakeholders to search, combine, share, analyze and visualize data. The platform (T4.2) will serve as a core component of ELABORATORs Data Marketplace (section **Error! Reference source not found.**) enabled by WP4.

Depending on their needs, different stakeholders will require access to different types of data, using different formats. For example, one may need access to a full data set – 'raw' from its data source or directly from a censoring device via IoT - or to aggregated and filtered summaries. Or they may need visualizations of data in relation to a given situation without necessarily needing access to the underlying raw dataset. At the same time, to comply with data-related legislation and good FAIR practices, data sharing and exchange needs to differentiate stakeholders in terms of who can access what part of a dataset, in what format, when, how and for what purpose.

To this end, deliverable 4.1 will:

- Use the outputs of Task 1.3 (Research data management and ethical consideration); Task 2.2 (Evaluation methodology and plan); and Task 3.1 (Discovery of stakeholders, needs, practices and data) as input, documents a taxonomy of different types of data to be collected during the project.
- Analyze (internal and external) project stakeholders is undertaken and documented to subsequently enable development of data access control policies.
- Introduce a concept architecture of ELABORATORs Data Marketplace to enable semantic integration of data allowing for searching, sharing, analyzing, and visualizing mobility intervention data among stakeholders in a secure and privacy-preserving fashion.

- Introduce semantic Taxonomies for central ELABORATORs data entities (D1.5) – stakeholders, co-design processes, interventions, devices, and data sets – search across all cities and living labs will be enabled

1.2 Purpose of the deliverable

D4.1 serves as point of departure of the implementation of ELABORATORs Secure, trusted and privacy-preserving intervention data platform by T4.2 which will devise, design, prototype, and make available a shared Data Marketplace with searchable mobility intervention assessment data for use to partner cities, citizens, researchers, and other stakeholders.

1.3 Intended Audience

Since D4.1 serves as description of the general understanding of data and data handling in ELABORATOR, PIs, WP and Task Leaders are the general intended audience of the deliverable.

Task/WP leaders related to activities concerning data/information handling and dissemination will be addressed. Including, in particular, leaders of

1. T4.2: Secure, trusted and privacy-preserving intervention data platform)
2. Tasks relating to ELABORATORs 'Knowledge hub' addressing the project's 'Community of practice'. Including T3.3: Interventions definitions and solutions' twinning towards uptake) as well as tasks embedded in WP5 and WP6.
3. WP7: Evaluation and impact assessment
4. WP8: Outreach, dissemination, and exploitation

1.4 The overall structure of the deliverable

Section 1 provides an introduction the deliverable.

Section 2 describes ELABORATOR Data Marketplace of which the mobility data framework is a core component (see section **Error! Reference source not found.**):

Section 3: Motivates the application of open data sharing standards and the selection of FIWARE as the core data model of the platform.

Section 4 introduced stakeholders considered crucial for data management for several reasons:

- As a data entity on its own, relations between, for instance, planning activities and interventions can be linked to the stakeholders and stakeholder types that have been involved.
- To adjust dissemination of information revealed from the platform according to the needs of different stakeholders' modes of communication
- To delineate access right to different groups – internal as well as external to ELABORATOR

Section 5 motivates and introduces a set of semantic Taxonomies in relation to relevant data entities of the data platform for the sake of

- Unification

- Alignment of terms
- Seamless data sharing and analysis across Living Labs
- Searching and relational data management

Section 6 describes the data entities of the platform, derived from D1.5. Entity types constitute any piece of data that can be relevant for the data domain of the project – such as stakeholders, interventions, evaluation data, devices etc.

Section 7 concludes by the deliverable's main contributions.

In Annex 1 provides lists, for each data entity, details as point of departure for the database implementation (T4.2), including

- A brief description
- Required fields: Abstract descriptions, reflecting the domain model (D1.5)
- Links from: Abstract descriptions, reflecting the domain model (D1.5)
- Suggested FIWARE model(s): Abstract descriptions, reflecting the domain model (D1.5) Taxonomy (if considered applicable) list of abstract code numbers and types of elements. For instance, types of co-creative processes, stakeholders, or evaluation data etc.

2 The Mobility Intervention Framework

2.1 Introduction

The proposed mobility intervention framework aims to facilitate seamless data sharing and analysis across Living Labs while maintaining privacy and security hosted by a common Data Marketplace. As mandated by D1.4 (Data Management Plan), this framework adheres to FAIR data principles while ensuring compliance with GDPR requirements for data handling and sharing. Figure 1 illustrates the conceptual architecture of this framework, which consists of five main components:

- Data Providers (DP)
- A centralised Mobility Intervention Data Framework
- Privacy-preserving data sharing (PPDS) mechanisms
- Analytic processors
- Data Consumers (DC).

Figure 1 illustrates the high-level architecture of Work Package 4 in the ELABORATOR project, which facilitates secure and efficient data sharing between cities and data consumers. At its core, the architecture implements a PPDS framework that manages how urban mobility data flows from DP to DC. Cities, acting as Data Providers, transmit their data through an API to a mobility intervention data framework, which standardizes and validates the information while ensuring proper access control. The data then follows one of two paths: it either moves directly to visualization tools through the PPDS platform, or it undergoes analytical processing through ML/AI applications before visualization. This dual-path approach ensures that data consumers receive appropriately processed and visualized information while maintaining data privacy and security throughout the pipeline. The framework serves as a guiding principle for all aspects of data management, including recording, storing, indexing, querying, and distribution of relevant mobility intervention data.

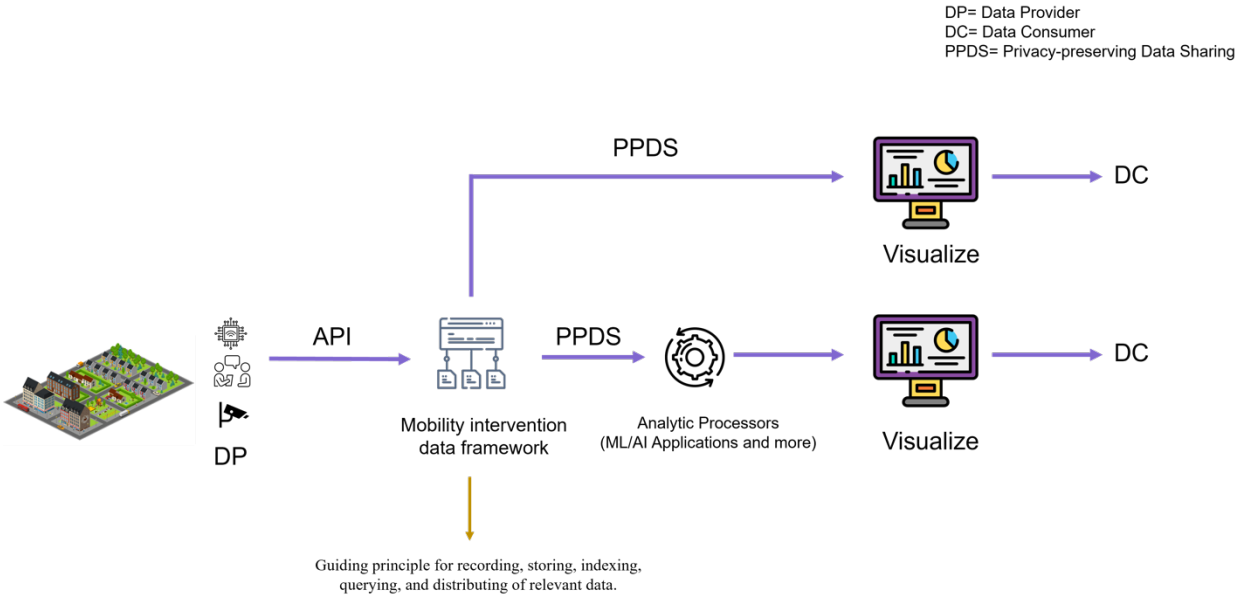

Figure 1: High-level ELABORATOR Mobility intervention data framework

The underlying assumption is that multiple different Data Providers (DPs) will collect raw intervention data and will store them safely in their own infrastructure, using the technology. As a result, two different pilots' DPs may end up collecting data about the same topic - for example, CO^2 concentrations or the number of traffic incidents. Even though those data will be collected and initially stored using different technologies and as different data types, they will conceptually convey the same information. The Mobility intervention data framework will be able to combine the raw data from heterogenous DP platforms and present them to a querying user in a unified, homogenous format.

The framework begins with DPs, which employ the various data collection methodologies identified in D2.2, including both qualitatively (surveys, interviews, workshops) and quantitively (sensors, traffic counts, monitoring systems) data which is ingested into the central framework through standardised APIs, ensuring consistent data formatting and metadata annotation aligned with the domain model presented in D1.5.

2.2 The Data Marketplace

ELABORATORs Data Marketplace facilitates data sharing, processing, provision, and visualisation across cities. Cities can be a member of this marketplace through two distinct approaches. The first approach enables cities to utilise local instance of the Data Marketplace, where back-end systems directly access data using native marketplace APIs, providing seamless integration with the visualisation tools developed in T4.4.

In the second approach, cities may choose to store intervention data in their preferred database systems, whether SQL-based solutions like PostgreSQL and MySQL, or NoSQL-based systems such as MongoDB. These external data stores operate independently of the mobility data platform but require a standardised communication framework with the marketplace. This communication is facilitated through FIWARE data models (see section 3 and 6) and WP4-defined APIs, ensuring consistent data exchange across different platforms. The integration process requires intervention owners to implement WP4 APIs for data access that will connect generated data to the Data Marketplace. To bridge the technological gap between city databases and the Data Marketplace, the Data Integration Framework entities in T4.2 i.e., connectors/adapters, play a crucial role. These adapters handle the complex task of translating between different data formats and structures, ensuring smooth data flow between disparate systems.

This flexible architecture ensures standardised data access while respecting cities' autonomy and technical requirements in choosing their preferred data supplier/vendor solutions. The system's design allows for scalability and adaptability, accommodating various technical requirements across different Living Labs while maintaining data consistency and accessibility through the data marketplace.

Figure 2 illustrates the data sharing architecture of the ELABORATOR project. The architecture is designed to accommodate different data collection and storage approaches across participating cities while ensuring efficient data integration into the ELABORATOR Data Marketplace.

The architecture comprises three main components:

- the ELABORATOR Data Marketplace as a platform
- the ELABORATOR Data Integration Framework layer serving as an intermediary processing layer that controls and grants access on
- the data transmission and visualizations for stakeholders, cities, and other DCs

Cities maintain autonomy over their data collection infrastructure and storage solutions adhering to ELABORATOR data management plan as depicted by City A and City B in figure 2. To facilitate data integration, different API pathways are provided. The Internal ELABORATOR Marketplace API serves cities using the Yggio framework (see section 3.2), enabling direct data collection through internal APIs. The Data Marketplace API for Non-ELABORATOR Data Repositorysupports cities using alternative platforms, requiring external APIs to transfer data.

deleted.

The architecture ensures flexible data sharing whilst respecting cities' existing infrastructure investments and technical capabilities. This approach aligns with the project's commitment to interoperability and practical implementation across diverse urban environments.

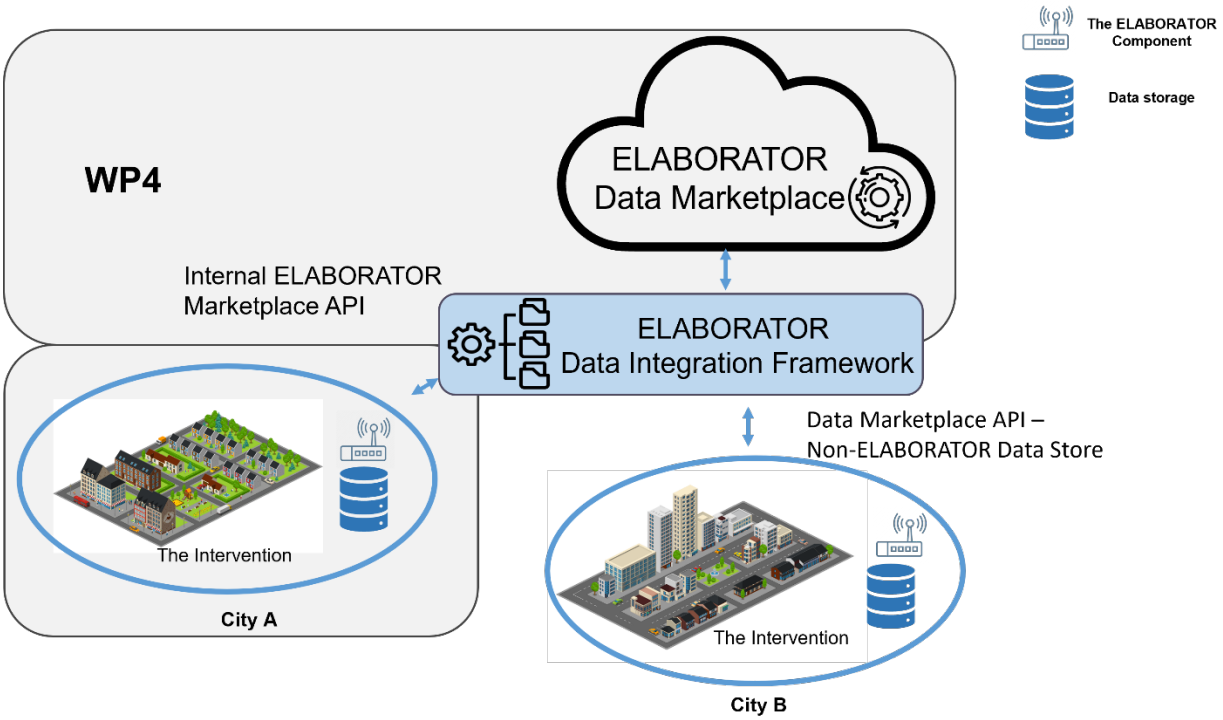

Figure 2: Cross-technology data sharing architecture and WP4 boundaries, while adhering to the data management plan (D1.4 and 5).

2.3 The data Integration Framework

The data integration framework directs queries to correct data sources, if the access requirements fulfilled. Figure 3 presents the core components of the ELABORATOR Data Marketplace and its relationship with the data Integration Framework. The ELABORATOR Data Integration Framework serves as the foundational layer, managing access control and query permissions for all users interacting with the marketplace.

Once access is granted through the Data Integration Framework, users can utilise various components within the Data Marketplace. The T4.2 Privacy-preservation component ensures that all data processing and sharing activities comply with data protection requirements, GDPR regulations and FAIR data requirements. The T4.3 Data analysis/prediction component provides analytical capabilities and predictive modelling tools, enabling users to derive insights from the collected urban mobility data. The T4.4 Visualisation component offers interactive dashboards and visual analytics tools, allowing users to explore and present the data in meaningful ways.

This layered architecture ensures secure and controlled access to data whilst providing comprehensive tools for analysis, privacy protection, and visualisation. The integration between the Data Integration Framework platform and the marketplace components creates a cohesive environment for handling urban mobility data, supporting the project's objectives for data-driven decision-making in city interventions.

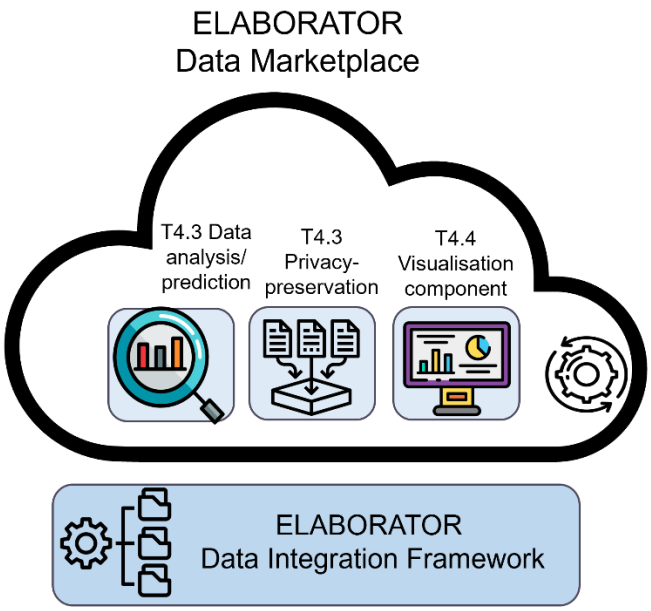

Figure 3: The ELABORATOR Data Marketplace components

Through the Data Integration Framework and Data Marketplace components DCs are able to request data from single or multiple cities according to the type of the requested data. In Figure 4, The ELABORATOR Data Marketplace enables data consumers and cities to access urban mobility data

through the platform. Data consumers can initiate queries to retrieve information filtered/grouped by for instance

- City
- Living Lab
- Stakeholder type
- Co-design/Co-evaluation method type
- Intervention type
- Device type

All requests will be processed through the ELABORATOR Data Integration Framework layer. The platform ensures privacy preservation throughout the data sharing process, from the initial query to the final visualization, enabling secure knowledge exchange between cities whilst maintaining data protection standards.

At the core of the design of the data marketplace lies the Mobility Intervention Data Framework, which serves as a centralised or decentralised repository that follows the data landscape principles outlined in D1.5. This component implements the guiding principles for:

1. Recording: Standardised data ingestion protocols aligned with ELABORATOR KPIs (D2.2)
2. Storing: Secure and scalable data storage solutions following Open and FAIR data principles (D1.5)
3. Indexing: Efficient data categorisation based on the evaluation indicators framework (D2.2)
4. Querying: Flexible data access patterns for different stakeholder needs as identified in D1.5
5. Distribution: Controlled data sharing protocols respecting stakeholder roles and requirements

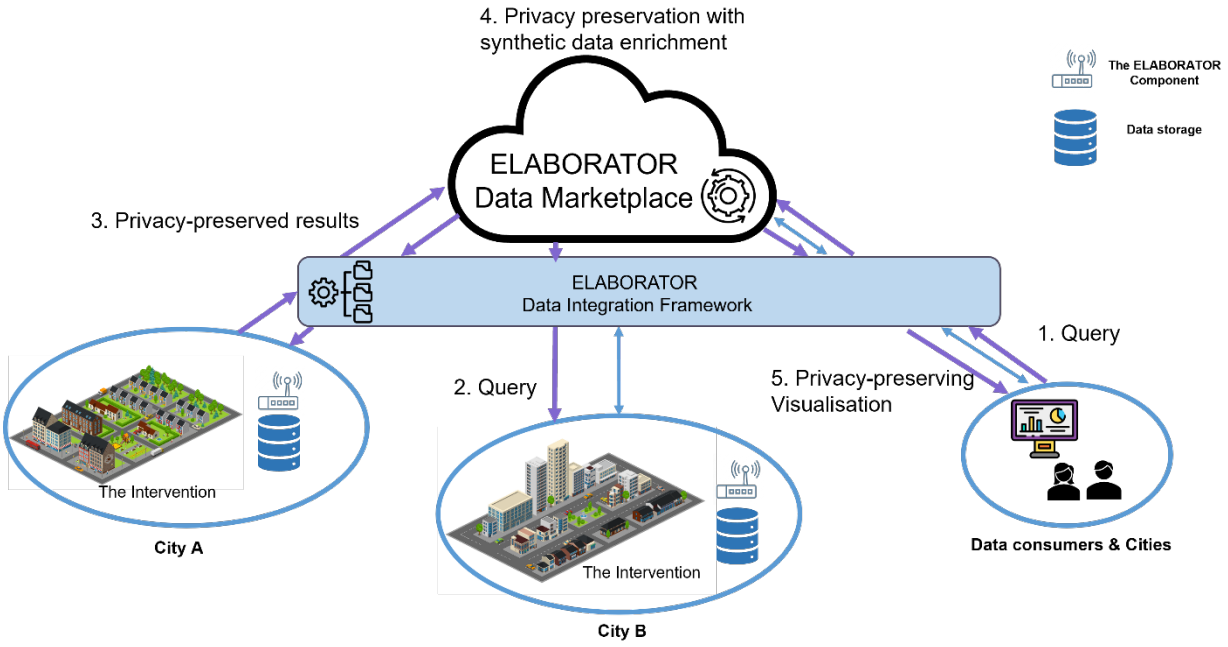

Figure 4: Data requesting and providing workflow.

2.4 The communication workflow

The workflow given in Figure 4 begins with DCs requesting data from the marketplace to obtaining desired data in a visualisation interface that has five high-level stages. These are,

1. Query: Data consumers and cities initiate requests for specific intervention data through the ELABORATOR Data Marketplace. After the query is approved by the Data Integration Framework. These queries are standardized according to WP4-defined APIs and specify the type of mobility data required.
2. Query: The marketplace forwards these queries to relevant city interventions (in this case, City A and/or City B) that maintain their own data storage systems, whether using local Yggio instances or external databases (SQL/NoSQL).
3. Privacy-preserved results: Data marketplace process the queries and return results through its data processors, which ensure privacy preservation of sensitive data during transmission. This step involves the Privacy-Preserving Data Processors that implement anonymization, aggregation, or other techniques.
4. Privacy preservation with synthetic data enrichment: The marketplace has capability to enhance the privacy-preserved data with synthetic data where appropriate, using Data Integration & Fusion Processors to maintain data utility while ensuring GDPR compliance.
5. Privacy-preserving Visualization: Finally, the processed and enriched data is presented to the data consumers through privacy-aware visualization tools (T4.4), ensuring that the displayed information maintains both utility and confidentiality.

3 Open data

3.1 Introduction

To comply with the FAIR principles (more details will be provided by T8.1) ELABORATOR adopts open data standards and protocols. For this purpose, the European FIWARE standard[1] was selected.

Open Data normally refers to datasets that are freely available to the public for use, reuse, and redistribution, typically under licensing [2]of minimal restrictions such as copyright or licensing. Building and managing Open Data solutions involves several technical aspects to ensure data accessibility, usability, and integrity. Relevant aspects are briefly described in annex 2.

3.2 FIWARE and open data

The data platform selected for ELABORATOR, Yggio[3] (made available by SENS), as described in the present deliverable, builds on the European FIWARE standard. FIWARE is a comprehensive open-source framework for building smart applications including strong support for Open Data initiatives. It is particularly focused on smart cities and IoT-driven solutions. FIWARE facilitates Open Data through its ecosystem of Generic Enablers (GEs) and its emphasis on interoperability, open standards, and scalability. See annex 3, for a list of facilities supported by FIWARE.

3.3 Data spaces

The European initiative on Data Spaces[4] complements and enhances Open Data solutions by creating frameworks. marketplaces, and ecosystems for sharing data securely and in interoperable ways across sectors and borders. While Open Data typically involves publicly available datasets with minimal restrictions, data spaces extend this concept to include both open and shared (private) data, enabling a broader scope of data-driven innovation.

Data Spaces are frameworks for secure and interoperable data sharing among trusted parties, including public and private entities. Data spaces prioritize control, governance, and sovereignty over shared data.

The European data spaces initiative focuses on sector-specific and cross-sectoral data ecosystems, such as Health, Agriculture, Mobility, Energy, Green Deal and Public Administration. These domains often incorporate Open Data but also facilitate sharing non-open (private or sensitive) data under defined rules.

Data spaces promote the use of open standards, which are also foundational to Open Data solutions. This ensures that both Open Data and shared data can integrate seamlessly.

[1] https://www.FIWARE.org/
[2] https://theodi.org/insights/guides/publishers-guide-to-open-data-licensing/,
[3] https://sensative.com/yggio/
[4] https://digital-strategy.ec.europa.eu/en/policies/data-spaces

Data spaces often utilize shared platforms for secure and efficient data exchange, which can include Open Data repositories.

Data spaces provide mechanisms to enrich Open Data by integrating it with private or shared data under agreements. Data Spaces also focus on standardizing access to data, ensuring that Open Data remains discoverable and usable within broader ecosystems. Also, by fostering collaboration, data spaces expand the use cases for Open Data, such as combining real-time IoT data with open datasets for smart cities.

Finally, as an additional motivation for Data Spaces in the context of D4.1, the European Union's initiatives for Common Data Spaces align with its policies for Open Data, particularly:

- European Data Strategy: Aims to create a single market for data while emphasizing interoperability and open access.
- Open Data Directive: Ensures public sector information is available as Open Data, contributing to data spaces as foundational elements.
- Data Governance Act (DGA): Establishes the legal framework for trusted data sharing, including Open Data as a key pillar.

4 Typology of stakeholders

4.1 Introduction

The implementation and evaluation of urban mobility interventions within the ELABORATOR project necessitates a comprehensive understanding of stakeholder dynamics and their interrelationships. This stakeholder analysis provides a structured framework for identifying and engaging with key actors who influence or are affected by mobility interventions. Given the project's focus on creating safe, inclusive and sustainable urban mobility solutions, particular attention is paid to vulnerable road users and their specific needs. The analysis considers both direct stakeholders who actively participate in the evaluation process and indirect stakeholders who may be affected by the interventions. Understanding these stakeholder relationships is crucial for ensuring effective data collection, meaningful evaluation outcomes, and sustainable implementation of mobility solutions.

To evaluate the types of stakeholders and their roles in the ELABORATOR project, the unique stakeholders introduced in D2.2 and D3.1 are presented in Table 1. A systematic identification and categorization of unique stakeholder classes provides the foundation for developing a comprehensive stakeholder analysis and typology in Deliverable 4.1.

Table 1: Examples of unique stakeholders in the project ELABORATOR. Applied from D2.2..

Unique stakeholders		
Stakeholders 1	**Stakeholders 2**	**Stakeholders 3**
Car users	Visitors	Passengers
Motorbike users	Wheelchair users	Public transport operators
Cyclists	Pedestrians	App developers
Traffic planners	Students	Transport planners
Urban planners	Technology providers	Local businesses
E-scooter operators	Children	Commuters
E-scooter users	Local citizens	Rural citizens
VRUs	Road users	Municipal police

. This analysis provides a structured approach to identifying key stakeholders and their contributions to data collection, evaluation, and implementation processes. By mapping these stakeholder profiles and their interactions, the framework can provide better performing data management protocols that serve the project's evaluation needs while ensuring meaningful participation from all relevant actors.

4.2 Primary stakeholder types

Within the ELABORATOR framework, five primary stakeholder types have been identified based on their roles, influence, and involvement in mobility interventions. These groups represent the key

actors whose participation is essential for comprehensive evaluation and sustainable implementation of mobility solutions. The following stakeholder groups form the foundation of the evaluation framework:

- Local Public Authorities Local authorities comprise municipal transport and planning departments, traffic management authorities, policy makers and enforcement bodies. These stakeholders provide institutional framework and regulatory oversight necessary for implementing and evaluating mobility interventions.
- Transport Service Providers This group includes public transport operators, shared mobility service providers, infrastructure maintenance teams and monitoring system providers. They are crucial for operational implementation and provide essential data for evaluation of mobility services.
- Vulnerable Road Users (VRUs) VRUs encompass pedestrians, cyclists, people with mobility impairments, elderly citizens, children, and those with visual or hearing impairments. As primary beneficiaries of safety improvements, their experiences and feedback are central to evaluation outcomes.
- Local Community The community stakeholder group consists of residents in intervention areas, local businesses, schools, healthcare facilities, and community organisations. They provide crucial context and feedback on the broader impacts of mobility interventions. Technical Partners Technical stakeholders include data analysts, technology providers, and research institutions who ensure rigorous methodology in data collection and analysis for evaluation purposes.

4.3 Stakeholder roles in evaluation

The evaluation of urban mobility interventions requires clear definition of stakeholder responsibilities to ensure comprehensive assessment. Each stakeholder group contributes unique perspectives and capabilities to the evaluation process, from data collection to implementation support. Understanding these roles is crucial for coordinating evaluation activities and ensuring that both quantitative metrics and qualitative insights are captured effectively. The following roles have been identified as essential to the ELABORATOR evaluation framework:

- Data Provision and Collection: Transport operators provide operational data, while technical partners contribute sensor data and analysis. VRUs offer experiential data through surveys and interviews, and local authorities provide historical data and contextual information essential for comprehensive evaluation.
- Feedback and Validation: The local community provides input on intervention acceptance and impact, while VRUs contribute insights on safety perception and accessibility. Businesses offer perspective on economic impacts, and technical partners ensure methodology validation throughout the evaluation process.
- Implementation Support: Local authorities coordinate implementation activities, while transport operators make necessary operational adjustments. Technical partners maintain monitoring and evaluation systems, and community organisations facilitate engagement and communication with local stakeholders.

4.4 Stakeholder communication across expertise levels

In the ELABORATOR project, stakeholders represent a diverse spectrum of expertise levels, from technical specialists to everyday citizens. This diversity necessitates a carefully crafted communication strategy that effectively reaches both expert and non-expert audiences while maintaining the integrity of technical information.

Expert stakeholders, including municipal transport planners, traffic engineers, and academic researchers, require detailed technical documentation and data-driven insights to inform their decision-making processes. These stakeholders are familiar with specialised terminology, complex mobility concepts, and quantitative analysis methods. For this group, communications should maintain their technical depth and academic rigour, providing comprehensive methodological explanations and detailed analytical results.

However, non-expert stakeholders, such as local community representatives, vulnerable road users, and citizen groups, need information presented in a more accessible format. These stakeholders bring valuable experiential knowledge and user perspectives that are crucial for the project's success. Communication with this group should focus on clear, jargon-free language and visual representations that effectively convey complex concepts. This includes the use of infographics, simplified maps, and real-world examples that relate directly to their daily experiences with urban mobility.

ELABORATOR's communication strategy (D8.3) is structured around these different Taxonomies, adopting a Taxonomy-based approach that improves accessibility while maintaining technical accuracy. Technical deliverables are developed by adapted versions that align with different stakeholder types' of communication needs and knowledge bases. This Taxonomy-based approach ensures that information reaches all stakeholders effectively, promoting inclusive participation while preserving the project's scientific integrity. Understanding and responding to these stakeholder types is fundamental to achieving the project's objectives of inclusive, effective urban mobility solutions.

5 Taxonomies of data entities

A set of Taxonomies – discreet types/classes and codes – are introduced as part of the data framework. These serve three key purposes in ELABORATORs data handling:

- Unification of common terms across Living Labs and cities
- Ease of internal and external communication
- Enable search across the ELABORATOR marketplace by simple 'dropdown boxes'

As far as applicable the Taxonomies are adapted from previous ELABORATOR deliverables.

Individual Taxonomy code tables are provided in annex 1 found in section 0.

Table 2: Data entities Taxonomies applied data framework.

Data entity	Reference deliveries
Stakeholders	D2.2/D3.1
Co-creation methods	D2.3
Interventions	D3.4, D3.2
KPIs	D3.4
Devices	D2.3/D2.4
Data processors	D4.3
Data sets	D2.3/D2.4
Publications	WP8

The Taxonomies are most likely to be adjusted, extended and detailed as data collection continues through the implementation phase of the project

6 Data entities

6.1 Introduction and outline

The data model presented in D4.1 will, for each of the data entities enacted by D1.5 (Data domain protocol for transport research) provide a unified schema for data storage and handling.

Furthermore, in accordance with D1.4 (data management Plan – version 1) definitions of "Data" are summarised by three classes:

- Class 1: "Co-creation data" that comes in multiple different formats, including physical – potentially scanned - documents from co-creation activities, such as post-it notes, flipcharts, and hand-written documents. Most of those are captured in photographs, and will be accessible via links to the location where the original digital version of data can be located using metadata descriptors, for example location and date of co-creation activity, type of activity (e.g. workshop), number of attendees. Class 1 data will not be applicable to further analysis/aggregation by the data integreation platform.
- Class 2: "Intervention Definition data". Will be included in the marketplace. As far as applicable - the platform will supply metadata. As for class 1 data, links to sites, home pages, services, and repositories from where the data can be accessed directly – but not to be issued to further analysis/aggregation, will be part of the metadata included.
- Class 3: "Evaluation data". Raw evaluation data will also be accessed the marketplace, by link reference, as far as possible, as for class 2 data. They will subsequently form the basis for calculation of pre-intervention baseline measurements and post-intervention impact assessment metrics. In some cases, for instance when data are static and not stored by DPs, data can be stored at the marketplace.

All data types will be part of ELABORATOR's Data Marketplace as metadata and summary data. Some actual data (Class 2 and 3) – will be present directly (with respect to analysed/revealed evaluation data, compiled by the system). Remaindering data will be accessibility by reference.

6.2 Data entities

The data entities listed in D1.5 – ELABORATORs Data Domain Model (see the illustration in annex 4).

The D1.5 domain model constitutes the following data entities:

1. Stakeholders
2. Project partners
3. Living Lab actors
4. Externals
5. Co-design event*
6. Co-design methods.
7. Planning tasks
8. Intervention plans
9. Areas/Living Lab.
10. Intervention

11. Co-evaluation event*
12. Co-evaluation methods
13. KPI's.
14. Devices.
15. Data processors.
16. Data sets - Raw and aggregated/analysed results
17. Publications

* Event entities have been added to the domain model

6.3 Detailed data model descriptions

Beyond descriptors of the content of the data set, metadata will include reference to a FIWARE model used for the data. Potentially also information about translators – given a range of external data sources - can be specified.

Specifications of the data models for each data entity will be provided in annex 1

7 Conclusions

Deliverable 4.1 provides a logical intervention data framework aimed at its implementation by Task 4.2. The data framework – as a core part of ELABORATORs Data Marketplace - serves as an integrating middle layer between the raw data collected and hosted by cities to enable searching, aggregation, analysis, and visualisation of pre- and post-intervention data and to inform different types of stakeholders during co-design and co-evaluation.

Annex 1. Details of data entities

7.1 Introduction

Each data entities are described by

- A brief description
- Required fields: Abstract descriptions, reflecting the domain model (D1.5). Concretely stated for the instantiated interventions
- Links: Abstract descriptions, of links to other data items. Reflecting the domain model (D1.5)
- Suggested FIWARE model(s): Abstract descriptions, reflecting the domain model (D1.5)
- Taxonomy (if considered applicable) list of abstract code numbers and types of elements. For instance, types of co-creative processes, stakeholders, or evaluation data

Some clusters of data entities – in particular in relation to Monitoring (sensors, data etc.) (5.5) - will require further subdivision.

The ELABORATOR project will as far as possible utilize existing standards for the sake of both short- and long-term interoperability and efficiency. FIWARE data models are the natural choice as they are widespread and are under continuous development. For the following data entities suitable FIWARE data models have been selected for application and testing I T4.2. In cases where no matching FIWARE data model have been found the project will implement them; these are in the following named "Elaborator data model".

7.2 Stakeholders

Brief description: Superclass of stakeholders for all main stakeholder types involved in the project: Project partners, living lab actors, and externals

Required fields: Name; ActorID; ELABORATOR role; StakeholderType;

Links: Other stakeholders; devices; data processers; data sets; Interventions

Suggested model(s): Elaborator data model

Table 3: Taxonomy of stakeholders

Code	StakeholderType
1	Public Authorities
2	Transport Service Providers
3	Citizens
4	Citizens Groups
5	Technical Partners
99	Other Stakeholder

7.3 Project partners

Brief description: ELABORATOR project partner

Required fields: PartnerID; Role in ELABORATOR; StakeholderType

Links: LL actors; External partners

Suggested model(s): Elaborator data model

Taxonomy: see super class

7.4 Living lab actors

Brief description: Stakeholdes beyond the ELABORATOR consortium, involved in LL actions; StakeholderType

Required fields: LLActorID

Links: Project partners; External partners; co-evaluation and – design methods

Suggested model(s): Elaborator data model

Taxonomy: see super class

7.5 External

Brief description: Relevant external stakeholders. For instance: interested city planners, academia, citizens etc.

Required fields: ExternalD; StakeholderType

Links: LLActors; Stakeholder super class; project partners

Suggested model(s): Elaborator data model

Taxonomy: See super class

7.6 Co-design events

Brief description: Co-design event hosted by ELABORATOR

Required fields: Title; Date; Number of participants; co-creation type; URL to (scanned) documents

Links: co-creation method; Stakeholder; LL/Area

Suggested model(s): Elaborator data model

Taxonomy: n/a

Table 4: Taxonomy co-design methods. Applies to co-evaluation methods too.

Code	CoCreationType

1	Mobility surveys/questionnaires with a gender perspective
2	Interviews and discussion groups
3	Exploratory walks (on foot, by bike, by public transport) with vulnerable to exclusion groups'
4	Workshops
5	Citizen Science & Participatory action research (with groups of citizens)
6	Participatory mobility apps
7	Serious games
8	Tactical urbanism
99	Other process

7.7 Planning tasks

Brief description:

Required fields: Name; TaskD

Links: co-evaluationMethod; InterventionPlan

Suggested model(s): Elaborator data model

Taxonomy: n/a

7.8 Intervention plans

Brief description:

Required fields: PlanID

Links: Co-design method; Intervention; plan task

Suggested model(s): Elaborator data model

Taxonomy: n/a

7.9 Area/LL

Brief description: Location (area, line, or point) of the Living Lab (LL)

Required fields: Title; InterventionID, DataID (for location)

Links: Intervention; stakeholder

Suggested model(s): Elaborator data model

Taxonomy: n/a

7.10 Interventions

Brief description: Instances of ELABORATOR interventions

Required fields: InterventionName; InterventionID; InterventionType;

Links: LLID/AreaID, StakeholderID; deviceID; PlanID

Suggested model(s): Elaborator data model

Table 5: Taxonomy of interventions

Code	InterventionType
Policy and Governance Interventions	
11	Regulation and Legislation • Emission standards and vehicle regulations • Policies for pedestrianization and car-free zones
12	Financial and Economic Tools • Congestion pricing and tolls • Subsidies for public transport • Incentives for electric vehicles (EVs) and active mobilities • Rewards for bike commutes or public transport use
Infrastructure Development	
21	Active Transportation Infrastructure • Bike lanes • Bike-sharing stations • Pedestrian pathways and sidewalks • Accessible routes for people with disabilities • Improvement of facilities for bicycle and micro mobility parking
22	Public Transit Infrastructure • Transit hubs and intermodal stations
23	Road and Traffic Management • Roundabouts and smart intersections • Temporal or directional restrictions to car traffic • Reduction of parking space for cars
	Technological Interventions
31	Traffic and Transport Monitoring • Sensors and IoT for real-time traffic management • Big data analytics for mobility planning • Open data platforms for public use
	Behavioral and Cultural Interventions

41	Public Awareness and Education • Campaigns promoting active transport • Educational programs on sustainable commuting • Real-time updates on environmental impacts of travel choices
Social Equity and Accessibility	
51	Universal Design • Step-free access to buses and trains • Audible and tactile signage for visually or hearing-impaired road users
52	Inclusive Policy • Transport planning that addresses gender and safety concerns • Connecting underserved neighborhoods with urban cores
Integration and Multimodal Connectivity	
61	Seamless Intermodal Connections • Park-and-ride facilities • Last-mile connectivity solutions (e.g., scooters, shuttles)
62	Coordination Across Modes • Sharing infrastructure between modes (e.g., bus-bike lanes)

7.11 Co-evaluation events

Brief description: Co-evaluation event hosted by ELABORATOR

Required fields: Title; DateOfOcurrence; Number of participants; co-creation type; URL to (scanned) documents

Links: co-creation method; Stakeholder; LL/Area

Suggested model(s): Elaborator data model

Taxonomy: See co-design events

Table 6: Co-design Taxonomy. Applies to co-design methods too.

Code	CoCreationType
1	Mobility surveys/questionnaires with a gender perspective
2	Interviews and discussion groups
3	Exploratory walks (on foot, by bike, by public transport) with vulnerable to exclusion groups'
4	Workshops
5	Citizen Science & Participatory action research (with groups of citizens)
6	Participatory mobility apps
7	Serious games

8	Tactical urbanism
99	Other process

7.12 KPI's

Brief description: The revised intervention KPI's

Required fields: KPIID, KPIType

Links: Dat sets; Co-evaluation methods

Suggested FIWARE model(s): **dataModel.KeyPerformanceIndicator**

Table 7: Taxonomy of KPIs

Code	KPIType
1	General mobility
2	Safety
3	Environmental
4	Social

7.13 Devices

Brief description: Devises applied

Required fields: DeviseID

Links: Stakeholder; co-design method; intervention; data processor

Suggested FIWARE model(s):

- Devices, generic: **Smart-Sensoring**
- Traffic Monitoring: **TrafficFlowObserved**
- Environmental Monitoring: **dataModel.Environment**
- Infrastructure Monitoring : **dataModel.Parking** & **TrafficFlowObserved**
- Social Monitoring: Elaborator data model

Table 8: Taxonomy of devises

Code	DeviceType	Comments
Traffic Monitoring		Devices that capture mobility patterns and behaviour in urban spaces. These include video cameras for vehicle/pedestrian detection, radar and lidar sensors for

		speed and movement analysis, and automated counting systems for modal split assessment. These devices are crucial for gathering quantitative data about intervention impacts on traffic flow, safety, and mobility patterns.
11	Surveillance cameras	
12	Vehicle counters	
13	Pedestrian counters	
14	Radars	
15	Lidars	
16	Speed sensors	
17	GPS sensors for public transport	
18	GPS sensors for e-mobility	
Environmental Monitoring		Sensors and measurement devices that collect data about environmental conditions affected by mobility interventions. This category includes air quality meters for pollutant measurement, noise level sensors for acoustic impact assessment, and weather stations for contextual data. These devices provide various metrics for evaluating the environmental impact of mobility interventions, particularly for climate neutrality objectives.
21	CO_2 level sensors	Ppm CO_2 PPB counts/cubic feet
22	Air quality sensors	
23	Noise sensors	
24	Weather stations	
25	Temperature sensors	
26	Humidity sensors	
Infrastructure Monitoring		Specialised devices that track the usage and performance of mobility infrastructure. This includes parking occupancy sensors, bicycle counting stations, e-mobility charging point monitors, and smart crossing systems. These devices help assess infrastructure utilization, identify usage patterns, and evaluate the effectiveness of intervention-related infrastructure changes.
31	Car parking space counters	
32	Bicycle space counters	
33	Micro mobility counters	
34	Smart crossing systems	
35	Electrical charging stations	
Social Monitoring		Digital and physical tools that facilitate stakeholder engagement and capture social impact data from mobility interventions. This category includes digital collaboration platforms for workshops, survey tools for user feedback, interview recording systems, and interactive mapping tools for community input. These devices are essential for gathering qualitative data about user experiences, accessibility needs, and social acceptance of

		interventions, particularly focusing on vulnerable road users and underrepresented groups.
41	Workshops	
42	Survey tools	
43	Interview recordings	
44	Mobile apps for community feedback	
45	Qualitative data digitizers	

7.14 Data processors

Brief description: Processors are entities that transforms, converts, filter and aggregates data – raw as well as analysed to provide information for other processes – for instance KPI's for intervention evaluation, data for visualisation, etc.

Required fields: ProcessorID

Links: Datasets, co-creative methods, KPIs

Suggested model(s): Elaborator data model

Table 9: Taxonomy of data processors

Code		**Comments**
Privacy-Preserving		Essential components that transform sensitive intervention data using anonymisation, pseudonymisation, and secure computation techniques to enable GDPR-compliant data sharing while maintaining analytical value. These ensure confidential information remains protected throughout data collection, storage, and analysis phases across Living Labs.
11	Anonymisation/ Pseudonymisation	
12	Synthetic data generators	
13	Secure computation	
14	GDPR compilance checker	
Data Integration & Fusion		Specialised processors that combine and harmonise diverse data streams from multiple sources (sensors, surveys, workshops) into unified, consistent formats. They handle data cleaning, quality assurance, and standardisation while maintaining temporal and spatial alignment across different data sources.
21	Data cleaners	
22	Data unifiers	
23	Data quality assurance	

24	Data standardization controller	
Analytical		Analytical engines that implement either unsupervised (pattern discovery, clustering) or supervised (prediction, forecasting) algorithms to extract insights from mobility intervention data. These processors enable cross-city analysis, intervention impact assessment, and automated pattern recognition from multi-modal data sources.
31	Synthetic data trainers	
32	Data analysers	
33	Data predictors	

7.15 Data sets

Brief description: All kind as qualitative and quantitative relevant to the ELABORATOR project

Required fields: DataID

Links: KPIs; Stakeholders; dataProcessors; KPIs; URL for raw data

Suggested FIWARE model(s): **dataModel.DCAT-AP** or Elaborator data model

Table 10: Taxonomy of data sets

Code	DataType	Comments
Unstructured data		
10	General text data	
11	Publication, report, white paper	See the Taxonomy for publications
12	Image, or collection of …	
13	Footage, or collection of …	
14	Sound recording, or collection of …	
…		
19	Other	
Structured data		
20	Tabular data	
21	Time series	
…		
29	Other	
Geodata		
30	Maps	Images files with entire maps including title, as well as symbology (legend) and other standard map element enabling full appreciation of the relevant content and message
31	Points	

32	Lines	
33	Polygons	
34	Raster	
35	Point Clouds	

7.16 Publications

Brief description: Container for all possible public domain material published from the project

Required fields: PublicationID

Links: Stakeholder; intervention

Suggested model(s): Elaborator data model

Table 11: Taxonomy of publications

Code	PublicationType
Publication as text	
11	Non-scientific and non-peer-reviewed publication (popularised publication)
12	Article in journal
13	Publication in conference/proceedings/workshop
14	Book/monograph
15	Chapter in a book
16	Thesis/dissertation
Other communication and Dissemination activities	
21	Interview
22	TV / Radio campaign
23	Media article
24	Newsletter
25	Press release
26	Print materials (brochures, leaflets, posters, stickers, banners, etc.)
27	Video

Annex 2: Aspects of open data solutions

Open Data solutions involve several technical aspects to ensure data accessibility, usability, and integrity. Including:

- Data Standards: Open Data initiatives often rely on international standards (e.g., W3C, ISO) for interoperability. Metadata standards like DCAT (Data Catalogue Vocabulary) ensure that datasets are well-documented and searchable, while semantic web standards, including RDF and SPARQL, enhance machine interpretability and integration.
- APIs for Data Access: Commonly used RESTful APIs provide programmatic access to datasets, enabling developers to query and retrieve data efficiently. GraphQL APIs allow for flexible queries tailored to specific user needs and SPARQL Endpoints offer access to RDF data for semantic queries.
- Cataloguing and Discovery: Open Data Portals through platforms like CKAN, Socrata, and DKAN enable publishing, searching, and accessing datasets. Searchability is facilitated through indexing and tagging datasets with metadata.
- Interoperability and Integration: Common ontologies and taxonomies are used to enhance data compatibility. Cross-Domain Linking may be facilitated through identifiers, e.g., URIs in Linked Data.
- Data Security and Privacy: When required, methods for anonymization are used to ensure that sensitive information is not exposed. There are various techniques that can be used to anonymize different sorts of data. For partially open datasets, access may be restricted using authentication mechanisms like OAuth.
- Licensing: Datasets should clearly specify usage rights, e.g., using licenses like Creative Commons (CC0, CC BY) or Open Data Commons (ODC)

Annex 3: FIWARE facilities

Facilities offered by FIWARE

- Open Data: The FIWARE standard and solutions simplify the publication, access, and use of Open Data while ensuring compliance with modern interoperability standards.
- Context Data Integration Framework and APIs: Central to FIWARE, Orion-LD Context Broker manages real-time context information and enables access to data through NGSI-LD (a standard API for context information). Data collected through IoT sensors, applications, or systems can be published as Open Data via APIs or Open Data portals. NGSI-LD API allows for seamless access and management of context data, supporting Open Data initiatives by enabling interaction with both real-time and historical data. FIWARE's APIs are open and standardized, ensuring interoperability with other platforms and Open Data systems.
- Open Data Portals: FIWARE provides plugins and connectors for CKAN, which is an open-source data portal platform commonly used for Open Data. This enables users to easily catalogue, publish, and share datasets. Data from the Orion Context Broker can be synchronized with CKAN to automate the publication of dynamic, real-time data streams.
- Data Interoperability: FIWARE promotes the use of Linked Data and semantic standards to enhance the usability of datasets. Semantic data models are aligned with FIWARE's Smart Data Models initiative, enabling the integration of diverse datasets across domains.
- Integration with IoT and Smart Solutions: FIWARE enables the collection of IoT and sensor data, transforming it into usable formats for Open Data publication. The platform facilitates real-time and historical data sharing for smart cities and IoT ecosystems.
- Open Standards and Licensing: FIWARE supports open-source development and aligns with standards such as ETSI NGSI-LD and OASC MIMs (Minimal Interoperability Mechanisms), ensuring that Open Data solutions are widely interoperable. The use of open licenses (e.g., Creative Commons) for datasets is promoted.
- Community and Ecosystem Support: FIWARE partnerships with Open Data initiatives and city administrations (e.g., through the Smart Cities Marketplace) drive the adoption of Open Data standards.

Annex 4: ELABORATORs data domain model cited from D1.5.