

D5.1 Data models and KPIs definition

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Executive summary

Project summary

Shift2Zero, Shifting to zero-emission logistics through right-sized, mission-focused, N1 eLCVs

Current market dynamics in EU reveal a gap between supply - existing N1 vehicles, and demand - evolving needs of urban logistics and climate targets. In 2023, 1.2M new LCV registrations were diesel-powered, and only 108,200 battery electric. Last-mile logistics, the least efficient and most complex part of the supply chain, presents significant opportunities for improvements at vehicle and operations levels. Dynamic requirements and increasing environmental impact require innovative solutions from the automotive industry, both from high volume OEMs and new entrants. S2Z aims to capitalize on the benefits of both vehicle platforms in the N1 segment - represented by IVECO's eDaily multipurpose platform, and Alke's ATX design-for-purpose platform - ultimately contributing to "Shifting to zero-emission logistics through right-sized, mission-focused, N1 eLCVs".

To achieve this vision, S2Z proposes a 4-step user- and mission-centric design approach placing end-users and their needs at the core of all project activities. To this end, S2Z involves 5 LSPs & mobility operators as partners: LSPsber, DHL, Diakinisis, Clem, DPD. As a result, S2Z will co-develop and shape at least 6 novel N1 concepts with enhanced and safe functionalities leading to tighter market fit, particularly in the segments of e-commerce, returns and cold deliveries.

Innovative concepts, from modular cargo bodies to vehicle control strategies with optimized tyres & brakes, as well as dual transport of people & freight, will be physically prototyped and tested in real-life operations in 6 pilot sites (Belgium, Greece, Italy, 2 in Norway, Poland).

S2Z brings a multidisciplinary consortium of 30 partners from 10 countries to cover the complete automotive and logistics value chains, complemented by policymakers to effectively ensure route to market: overcoming barriers for the adoption of S2Z eLCVs, reducing operational costs and environmental impact in scalable urban & sub-urban operations.

This deliverable presents the **outcomes of Task 5.1 – Data requirements, governance models and KPIs alignment towards pilots' evaluation**, carried out within the Shift2Zero (S2Z) project. The objective of the task is to **establish the data foundations required to support pilot demonstrations, enable interoperability across digital solutions, and ensure the consistent measurement of impacts** across all pilot sites.

The work conducted in T5.1 focuses on three main aspects: (i) the **identification and structuring of data requirements** emerging from pilot operations, (ii) the **definition of preliminary data models** capable of integrating heterogeneous operational, technical, and economic datasets, and (iii) the **alignment of Key Performance Indicators (KPIs)** with the project's impact assessment framework developed in WP7.

To achieve these objectives, a structured methodological approach was adopted combining **stakeholder engagement, process analysis, and iterative technical validation**. Pilot operators, cities, and technology partners were actively involved in a series of **workshops and technical meetings** aimed at mapping logistics operations and identifying the information flows required to support digital optimisation tools and simulation engines developed in WP5. Business Process Modelling (BPM) techniques were used to describe operational processes within each pilot and to identify the data inputs necessary for modelling fleet operations, charging strategies, logistics consolidation processes, and urban access constraints.

Based on these interactions, a **consolidated data requirement framework** was developed. Data needs were categorised into three main domains:

- **operational data** (e.g., routing information, delivery volumes, service times),
- **technical data** (e.g., vehicle characteristics, battery performance, charging behaviour),
- **economic data** (e.g., total cost of ownership components, operational costs, productivity indicators).

Despite differences in operational configurations across pilots, a strong convergence in data structures was identified, allowing the definition of a **harmonised core data architecture applicable across demonstration sites** while maintaining flexibility to accommodate pilot-specific features.

Building on this analysis, the deliverable proposes an **initial data model architecture** capable of organising and integrating the required datasets into a coherent structure. The model identifies key entities representing logistics operations, such as vehicles, routes, orders, infrastructure and operational events, and describes their relationships within the broader S2Z digital ecosystem. These models are intended to support the integration of pilot data into the S2Z platform (Task 5.4) and provide the necessary inputs for simulation and large-scale scenario analysis (Task 5.5).

In parallel, the deliverable defines a **preliminary KPI framework aligned with the impact evaluation methodology developed in Task 7.1**. The KPIs are structured across **operational, technical, economic, and environmental dimensions**, enabling the consistent assessment of pilot performance and supporting the evaluation of electric light commercial vehicle (eLCV) deployment and associated logistics innovations. The proposed KPI structure ensures alignment with the broader impact assessment framework of the project and contributes to the monitoring of performance indicators relevant to the 2ZERO partnership objectives.

Last, this deliverable builds on and is strongly aligned with Task 1.2 on quality, data management and ethics, which provides the overarching **principles, protocols and governance framework forming the foundation for all data handling activities** in Task 5.1.

Overall, the work confirms the feasibility of **establishing a common and interoperable data and KPI framework** across heterogeneous pilot contexts, providing a structured basis for linking operational data, analytical tools and impact evaluation. While some uncertainties remain related to data availability, pilot full

description and the progressive definition of analytical engines, these are expected at this stage and will be addressed in subsequent tasks. The outcomes of Task 5.1 therefore lay the groundwork for the **effective deployment of WP5 tools, the implementation and monitoring of WP6 pilots, and the robust assessment of impacts** at project level.

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Terminology and Acronyms

API	*Application Programming Interface*
APM	*Automated Parcel Machine*
BPM	*Business Process Modelling*
EC	*European Commission*
EV	*Electric Vehicle*
(e)HDV	*(electric) Heavy Duty Vehicle*
(e)LCV	*(electric) Light Commercial Vehicle*
EU	*European Union*
FP	*Framework Programme*
KPI	*Key Performance Indicator*
LCA	*Life Cycle Assessment*
LEZ	*Low Emission Zone*
LSP	*Logistics Service Provider*
OEM	*Original Equipment Manufacturer*
PI	*Physical Internet*
S2Z	*Shift2Zero*
TCO	*Total Cost of Ownership*
UVAR	*Urban Vehicle Access Regulation*
VRP	*Vehicle Routing Problem engine*
WP	*Work Package*
ZEZ	*Zero Emission Zone*

1. Introduction

This deliverable presents the work carried out in Task 5.1 of WP5. The purpose is to provide a common basis for how data and performance indicators are defined and used across the Shift2Zero pilots. This work supports the project in moving from pilot-specific operational needs to a shared framework that can feed the WP5 tools and, at the same time, allows a consistent evaluation of results across sites. The deliverable therefore sits at the intersection of pilot reality, data modelling and impact assessment, helping ensure that the different technical components developed in the project are grounded in comparable and usable information.

1.1 Objectives of the deliverable

The objective of this deliverable is to define the data and KPI foundations required to support pilot development in Shift2Zero. More specifically, it identifies the information needed to describe and analyse pilot operations, translates these requirements into an initial data model structure and aligns this work with the KPI framework used for impact assessment in WP7. The deliverable therefore helps build a common analytical basis without forcing artificial uniformity across sites. It also prepares the ground for the next steps in WP5, especially those related to platform integration, simulation activities and KPI calculation.

1.2 Structure of the deliverable

The deliverable is organised into six chapters:

- Chapter 1 introduces the deliverable and explains its objectives and overall structure.
- Chapter 2 describes the methodology used to collect requirements, structure the data mapping exercise, harmonise concepts and connect data needs with KPIs.
- Chapter 3 analyses the requirements emerging from the pilot use cases, highlighting both common patterns and pilot-specific needs.
- Chapter 4 presents the proposed data model architecture, including its core logic, main entities, relationships and its connection with the S2Z engines.
- Chapter 5 focuses on KPIs and their alignment with the broader project impact assessment framework.
- Chapter 6 concludes the deliverable by summarising the main findings, identifying the main gaps still to be addressed and outlining how this work will support the next project tasks.

2. Methodology

This section describes the general methodological framework adopted for Task 5.1, explaining the rationale behind the integration of data-driven, stakeholder-centric, and cross-functional approaches. It introduces the steps followed from requirement gathering to KPI validation, highlighting the iterative and collaborative nature of the process.

2.1 Stakeholder Engagement and Requirements Collection

The task 5.1 adopted a structured and progressive stakeholder engagement process aimed at capturing operational realities in the pilots, identifying data needs for the S2Z digital tools, and aligning expectations across cities, end-users, OEMs, and technical partners. The approach combined collective workshops, bilateral technical meetings, and site-specific follow-up sessions, enabling the gradual refinement of process representations, data requirements, and tool selection.

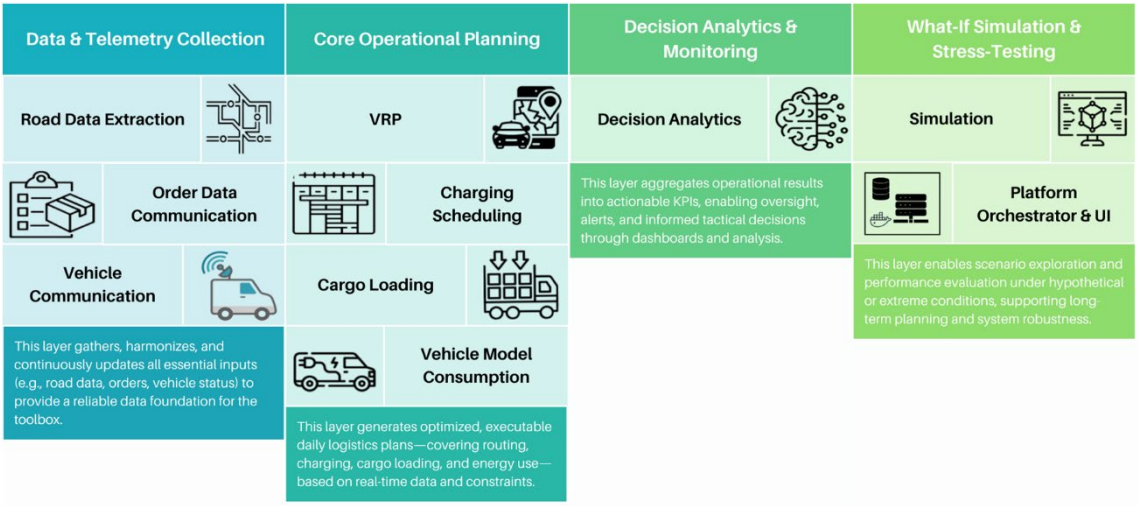
The engagement strategy was designed to be iterative rather than linear: initial hypotheses regarding operational processes and digital solutions were continuously challenged and refined through feedback loops with pilot stakeholders, ensuring that the resulting data models and KPIs would remain grounded in real-world logistics operations and feasible within the constraints of existing information systems.

A first collective workshop was organised during the project meeting on 19 September 2025. This session had two complementary objectives, achieved through the following actions.

First, the consortium partners presented the portfolio of analytical and optimisation tools foreseen within WP5, classified in four layers:

1. Data & Telemetry Collection
    a. Road Data Extraction
    b. Order data communication
    c. Vehicle communication
2. Core Operational Planning
    a. VRP
    b. Charging scheduling
    c. Cargo Loading
    d. Vehicle model Consumption
3. Decision Analytics and Monitoring
    a. Decision Analytics
4. What-if Simulation and Stress Testing
    a. Simulation

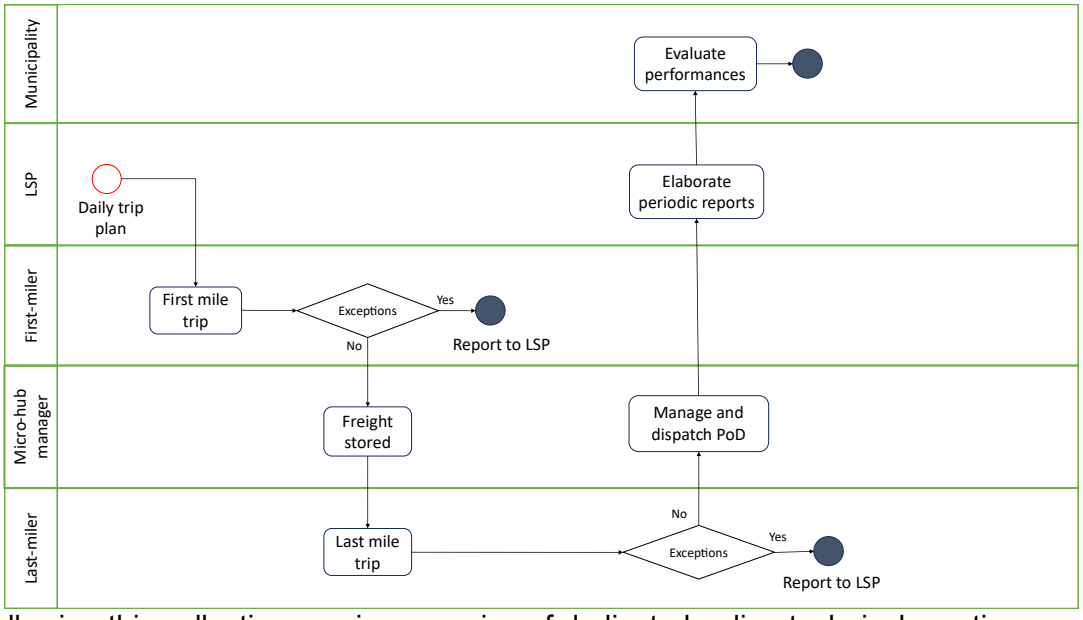
Figure 1. Four-Layer Architecture of the Shift2Zero Toolbox



During the workshop the intended role was explained of each tool in supporting operational planning and large-scale scenario analysis.

Second, a process-oriented methodological framework based on Business Process Modelling techniques was introduced. Through this framework, the pilots were guided in describing their logistics operations in a structured way, covering first-mile and last-mile activities, transhipment operations, depot processes, charging operations, and performance monitoring. During the workshop, preliminary discussions were held with each pilot site to outline their main operational configurations and the types of activities foreseen during the demonstrations planned in WP6.

Figure 2. Business Process Modelling template



Following this collective session, a series of dedicated online technical meetings were organised with each demonstration site. These bilateral meetings focused on reviewing

and refining the preliminary BPM representations developed by the technical partners and on validating them against the actual operational practices of the logistics service providers and municipalities involved. During these discussions, stakeholders were asked to clarify operational constraints, decision-making processes, and data flows currently available in their organisations. In parallel, an initial identification of data processing needs was conducted for each pilot, and a preliminary selection of the most relevant optimisation and simulation engines was performed, distinguishing between tools required by logistics operators, municipalities, or both. This phase allowed the consortium to move from generic platform concepts to pilot-specific configurations.

A second round of data retrieval was then carried out with the objective of moving from conceptual alignment to technical specification. In these sessions, the data formats required by each tool were presented and discussed in detail, together with possible data exchange modalities, including manual uploads, semi-automated file transfers, and fully automated interfaces based on APIs. Particular attention was devoted to assessing the compatibility of existing ERP, TMS, telematics platforms, and municipal data systems with the S2Z toolbox requirements, as well as to identifying constraints related to data access, frequency, and reliability. These meetings also marked the start of the detailed design phase of the WP5 tools, ensuring that their development would be fully aligned with the operational planning of the demonstrations foreseen in WP6.

Across all engagement phases, structured documentation was produced in the form of meeting minutes, updated BPM diagrams, engine-selection matrices, and preliminary data requirement tables. These materials constituted the analytical backbone for the subsequent chapters of this deliverable, where pilot-specific data models and KPI definitions are presented.

Importantly, the stakeholder engagement process established a continuous coordination mechanism between Task 5.1 and the activities carried out in WP2, WP6, and WP7, enabling a coherent translation of user needs into technical data requirements and measurable performance indicators.

2.2 Data Collection Strategy and Classification

The data collection strategy adopted in Task 5.1 is driven by the need to ensure that optimisation engines, simulation tools, and impact assessment activities will be supported by consistent, pilot-specific and interoperable datasets. Rather than starting from available datasets alone, a requirement-driven approach has been followed: data needs were first derived from operational processes and decision-making functions identified through BPM analyses and stakeholder consultations, and only subsequently matched against existing data sources.

To operationalise this approach, a structured data-mapping exercise was carried out through a shared spreadsheet model. For each identified data item, a set of common attributes was associated, including:

- engine(s) making use of the data
- expected data provider
- collection frequency

- availability level
- preferred exchange format and connection modality
- priority level
- impact area addressed
- linked KPIs

This allowed a direct traceability between operational processes, analytical tools, and performance assessment objectives.

Within this framework, data types were preliminarily grouped into thematic categories, reflecting both their functional role and their origin within logistics systems and urban infrastructures. The following categories were identified:

Operational data types, supporting day-to-day logistics planning and execution:

- Vehicle Specifications
- Fleet Telematics
- Order & Delivery Data (Historical)
- Charging Infrastructure
- Road & Traffic Network
- Depot & Hub Data
- Modular Concepts (DHL)
- Thermal Operations (Diakinisis, LSPsber)
- Sharing Operations (DPD)
- V2L & Returns (InPost)

Economic data types, supporting cost assessment and business case evaluation:

- Cost Data

Technical and system-enabling data types, supporting modelling, simulation and integration layers:

- Vehicle Specifications (technical parameters)
- Fleet Telematics (sensor-level information)
- Charging Infrastructure (power levels, interfaces, control logic)
- Road & Traffic Network (network topology and regulatory attributes)

While several categories contribute simultaneously to more than one dimension, the classification was used to guide both prioritisation and development sequencing, distinguishing data strictly necessary for operational optimisation from those primarily required for economic evaluation or advanced simulation.

The spreadsheet-based data model thus acted as a living instrument to consolidate stakeholder inputs, compare pilot heterogeneity, and highlight gaps between required and currently available information. This structured inventory constitutes the basis for the pilot-specific analyses presented in the following chapter.

2.3 Semantic Alignment and Harmonisation Approach

Given the heterogeneity of pilots, logistics service providers, vehicle manufacturers and municipal data platforms involved in S2Z, strong emphasis was placed on semantic alignment and data harmonisation from the earliest stages of the modelling exercise. The objective was not to impose a single rigid data schema, but to define a common conceptual layer capable of feeding the S2Z optimisation and simulation engines while accommodating site-specific implementations.

The methodology adopted followed three main principles.

1. data requirements were defined from the perspective of analytical functions rather than IT systems. Each data type in the spreadsheet was explicitly linked to one or more engines, such as routing optimisation, charging scheduling, energy consumption modelling, cargo loading, or simulation and decision analytics, ensuring that semantic definitions were anchored to computational needs. This engine-driven logic is intended to guide developers in specifying interfaces and pre-processing pipelines for their tools;
2. common descriptors and minimum datasets were introduced for recurrent concepts across pilots, such as vehicles, trips, charging events, depots, and orders. These conceptual entities form the backbone of the S2Z data layer and will be progressively translated into harmonised data structures and APIs during tool development. Where existing standards or commonly adopted formats are available (e.g. telematics data models, routing network representations, charging infrastructure descriptors), these will be used as reference points to maximise interoperability;
3. the harmonisation strategy explicitly distinguishes between core mandatory variables, required for all pilots in order to enable cross-site comparison and impact assessment, and optional or pilot-specific variables supporting advanced use cases. This layered approach is expected to allow a gradual implementation of automation levels, ranging from manual uploads to semi-automated batch transfers and fully automated API-based exchanges, depending on the maturity of local ICT systems.

At this stage, the harmonisation effort remains conceptual and methodological, providing design guidance for the WP5 engines rather than detailed interface specifications. The outputs of this work will progressively inform the technical architecture of the S2Z platform and the detailed tool design activities carried out in the subsequent tasks.

2.4 KPI Definition Process and Validation

The definition of Key Performance Indicators within Task 5.1 follows a structured, impact-oriented methodology aimed at ensuring consistency with the project objectives, the evaluation requirements of WP7, and the impact pathways described in DoA. KPIs are treated not merely as monitoring metrics, but as decision-support instruments enabling the assessment of operational improvements, environmental benefits, economic viability, and system-level effects generated by the S2Z solutions.

The process adopted is articulated into four main steps.

1. Project-level objectives and expected impacts, in particular those related to emissions reduction, energy efficiency, operational performance, cost effectiveness, and service quality, have been translated into evaluation dimensions. These dimensions provide the reference framework for structuring KPI families and for linking performance assessment to the broader sustainability ambitions of the project.
2. Pilot-specific objectives and use cases have been mapped against these impact dimensions. Through stakeholder engagement activities, logistics operators and municipalities identified the operational questions they intended to address during the demonstrations (e.g. routing efficiency, charging strategies, fleet utilisation, cargo consolidation). This ensures that KPIs are both scientifically relevant and practically meaningful for end-users.
3. Each candidate KPI will be tested against technical feasibility criteria using the data-requirement model developed in Task 5.1, by verifying whether the necessary data types are available or could realistically be collected during the pilots, identifying proxy variables where direct measurements would not be feasible, and associating each KPI with specific engines and data providers. This step establishes a strong traceability between raw data, analytical tools, and final performance indicators.
4. A validation process with stakeholders is embedded into the methodology. Draft KPI sets have been discussed with pilot partners to assess interpretability, relevance for decision-making, and alignment with operational practices. In parallel, consistency checks with WP7 will ensure that the selected indicators will feed the overall impact assessment framework and support cross-pilot comparability at project level.

Through this iterative and participatory approach, Task 5.1 aims to converge towards a harmonised yet flexible KPI framework capable of capturing both local pilot benefits and aggregated project-wide impacts, while remaining grounded in the actual data ecosystems of the participating sites.

2.5 Cross-task Coordination

Building on the stakeholder engagement, data modelling, semantic harmonisation, and KPI definition processes described in Sections 2.1–2.4, Task 5.1 operates as a coordination layer across work packages, ensuring that user-centric requirements, analytical tools, pilot demonstrations, and impact evaluations evolve in a consistent and mutually reinforcing manner. Rather than acting as a standalone technical activity, Task 5.1 is explicitly designed to interface continuously with WP1, WP2, WP5, WP6 and WP7, supporting the iterative refinement of assumptions, data structures, and evaluation frameworks throughout the project lifecycle.

Collaboration with WP1, and in particular Task 1.2 on quality, data management and ethics, ensures that the data requirements, models and KPI framework developed in Task 5.1 are grounded in the project-wide principles, protocols and governance structures established for data handling.

Collaboration with WP2 is central to aligning Task 5.1 with real operational and user needs. Task 5.1 builds directly on the structured outputs of WP2, translating stakeholder contexts (T2.1), user-centred design inputs (T2.2), quantified preferences (T2.3), and emerging logistics concepts (T2.4) into measurable data requirements, KPI definitions, and modelling parameters. This translation is supported through targeted coordination meetings and validation loops with WP2 task leaders, ensuring that requirements identified at vehicle, fleet and system level are consistently mapped to operational processes, analytical engines and impact dimensions. Where WP2 identifies future-oriented or PI-related requirements (e.g. modularity, interoperability, synchromodality), Task 5.1 integrates these into scenario definitions and data attributes to be tested within simulation and impact assessment activities.

The interaction with WP5 is operational and continuous, reflecting the role of Task 5.1 as the methodological backbone of the S2Z toolbox. The harmonised data models, semantic definitions and KPI registries developed in Task 5.1 are used to configure optimisation, simulation and decision-analytics engines developed in WP5. Coordination is maintained through shared technical documents (data-mapping tables, BPM diagrams, engine-selection matrices) and regular technical integration meetings, allowing WP5 developers to align their implementations with agreed data semantics and performance indicators. Feedback from WP5 regarding data availability, computational constraints, or proxy variables is systematically fed back into Task 5.1, triggering refinements of data definitions or KPI formulations if needed. This bidirectional interaction avoids duplication of modelling efforts and ensures that analytical tools remain both technically feasible and methodologically consistent across pilots.

Strong coordination is also established with WP6, which acts as the empirical validation layer of the methodology. Task 5.1 supports pilot preparation by aligning data collection templates, KPI monitoring protocols, and reporting formats with the requirements of the optimisation and simulation tools. During pilot execution, operational data and qualitative feedback from demonstration sites are used to validate assumptions embedded in the data models and KPIs. Differences between simulated and observed behaviour, such as charging patterns, routing constraints, or vehicle energy consumption, are recorded as structured feedback to support iterative calibration of WP5 models and refinement of KPI definitions in Task 5.1. This feedback loop ensures that analytical results remain grounded in real-world operational conditions.

Collaboration with WP7 ensures that the outputs of Task 5.1 directly support the project's impact assessment objectives. Early alignment with WP7 guides the definition of KPI families, as well as the required data granularity and temporal resolution for economic, environmental, societal, and safety impact analyses. Data structures developed in Task 5.1 are used by WP5 to generate simulation outputs, providing ex-ante estimates of project impacts, while operational data collected under WP6 during pilots supports ex-post evaluation. Findings from WP7 analyses can then be fed back into Task 5.1 to highlight sensitivities, identify data gaps, or indicate where KPIs require refinement, reinforcing an iterative methodology and supporting consistent impact assessment and comparability across all pilots.

To implement this cross-task collaboration, Task 5.1 relies on a set of coordination mechanisms embedded throughout the project: regular cross-WP technical meetings,

joint validation workshops at key milestones, and the use of shared and version-controlled methodological documents. These include the living data-requirement spreadsheet, the canonical KPI registry, BPM representations and interface assumptions. Clear ownership of each artefact and structured documentation of changes ensure transparency, consistency and traceability of decisions over time.

Overall, Task 5.1 enables a continuous cycle of requirement translation, modelling, validation and impact assessment, supported by structured feedback loops and iterative refinements across WP2, WP5, WP6 and WP7. This coordinated approach ensures that the S2Z analytical framework remains coherent, avoids duplication of effort, and supports the smooth integration of outputs from user engagement to simulation results and impact evaluation.

Building on the methodological approach described in Chapter 2, the following chapter presents the outcomes of the data requirement analysis conducted across pilots.

3. Analysis of Data Requirements

The identification and analysis of data requirements represent a key step in defining a robust foundation for data modelling and simulation activities. Based on inputs gathered from pilots and stakeholders, this section presents the types of data needed to support the different use cases, as well as the main challenges related to data availability and integration.

The following subsections provide an overview of the pilot scenarios, detail the specific data needs across operational, technical, and economic dimensions, and highlight the cross-pilot convergence encountered during this phase.

3.1 Summary of Pilot Use Cases

This section summarises the main characteristics of each pilot site, focusing on the operational context, types of eLCV services deployed, and specific goals of the demonstrations. The aim is to provide the necessary background to understand the diversity of data requirements across pilots.

3.1.1 Norwegian macro-pilot (Bergen and Oslo): Modularity, standardisation & access regulations

The Norwegian macro-pilot, implemented by DHL in collaboration with the Cities of Bergen and Oslo, the Norwegian Public Roads Authority and research partners, investigates two strongly complementary innovation streams: modular swappable cargo units enabling flexible multi-tier logistics chains, and geofenced regulation of electric delivery vehicles to support safe, efficient and policy-driven access to dense urban areas. Together, the two sites aim to demonstrate how N1 vehicles can be fully integrated into urban logistics ecosystems through standardised transshipment operations, real-time digital governance of street space, and advanced data sharing between operators and public authorities.

Across both locations, DHL is testing a modular swap-box concept allowing goods to be transferred either vehicle-to-vehicle or at designated hubs and micro-depots. This approach is intended to reduce refill times, enable dynamic exchanges with vehicles already en route, and create synergies between larger N1 vehicles performing trunking operations and smaller L7-type vehicles serving restricted zones. Foldable swap bodies are also explored in order to simplify reverse logistics and storage operations. The pilot is explicitly designed to assess the scalability of this concept across DHL's Norwegian and European operations and its compatibility with Physical Internet principles.

In Bergen, the focus is placed on the interaction between logistics operations and dynamic urban regulation through geofencing technologies. The BPM analysis highlights a process in which first-mile vehicles transport consignments to transfer points, where goods are cross-docked to small electric vehicles before last-mile distribution inside geofenced zones. These vehicles enter and exit regulated areas governed by digital policies defining speed limits, access permissions, time-based restrictions and potential fees. Policies are created by the city and distributed through mobility data platforms to

fleet-management systems, which in turn enforce them at vehicle level, while telemetry data are pushed back to public authorities for monitoring compliance and performance

Demonstrations include vehicles dynamically adapting their speed when entering restricted zones, the application of time-window-based policies, and on-route swap-box exchanges between vans and small electric vehicles, while collecting high-resolution trip and compliance data for analytics purposes

In Oslo, the pilot concentrates primarily on the operational deployment of the modular swap-box logistics model. BPM flows describe a multi-stage distribution process in which linehaul vehicles deliver consolidated freight to city hubs, followed by secondary sorting and loading of last-mile vehicles. These vehicles operate until empty, return to hubs or micro-depots for exchange of full and empty swap boxes, and continue distribution rounds without returning to the main terminal. Exchange operations may occur both at fixed locations and on route, enabling high flexibility in fleet deployment and supporting dense urban coverage with reduced use of large vehicles in central areas. Routing optimisation, charging scheduling, cargo loading and vehicle-energy-consumption models are explicitly foreseen as supporting tools for planning and simulation activities at this site

Figure 3. Bergen pilot supply chain BPM

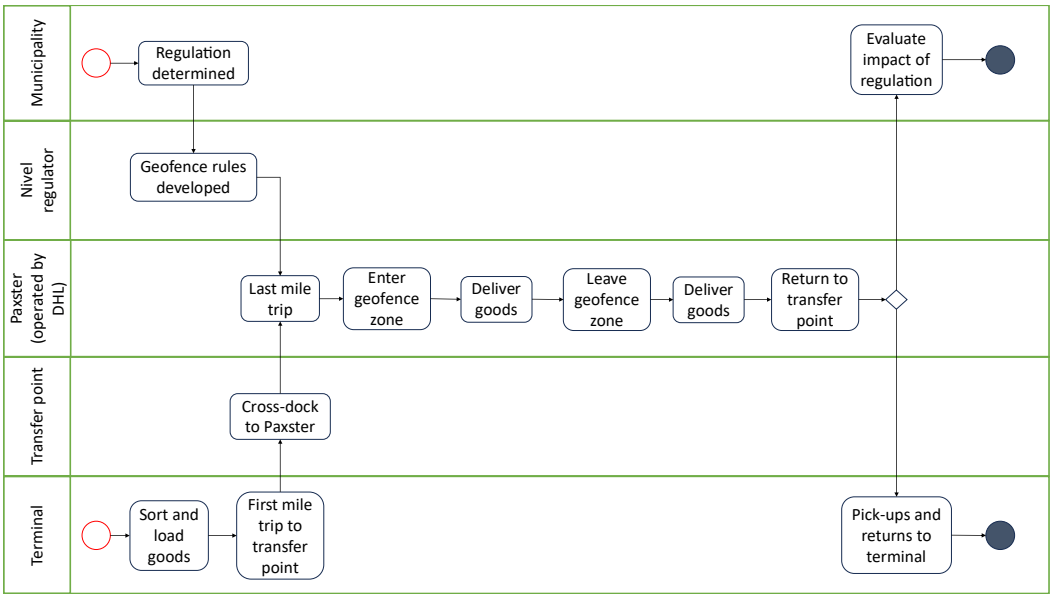
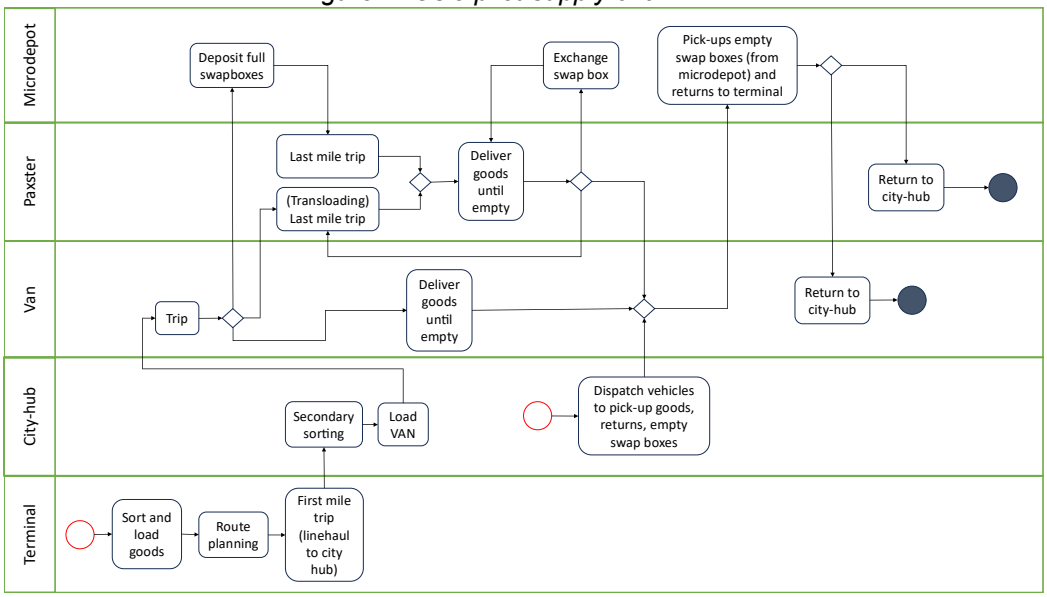


Figure 4. Oslo pilot supply chain BPM



3.1.2 Wrocław: Synchromodality including e-HDV & APMs, & UVARs

The Wrocław pilot, led by Poznan Institute of Technology in collaboration with technology partners and the City of Wrocław, focuses on the implementation of synchromodal urban logistics operations combining electric heavy-duty vehicles, light commercial vehicles and an extensive network of Automated Parcel Machines (APMs), in anticipation of the city's forthcoming Clean Transport Zone and related Urban Vehicle Access Regulations (UVARs). The pilot aims to demonstrate how heterogeneous delivery streams, covering parcels, fresh food and returns can be consolidated through modular, multi-temperature cargo bodies and dynamically optimised routing strategies, increasing fleet utilisation while reducing the total number of urban trips required.

Operationally, the BPM highlights a multi-layer logistics chain in which orders are first consolidated and pre-sorted at logistics hubs according to destination zones and regulatory constraints, including low-emission areas. Swappable cargo units are prepared and loaded onto first-mile vehicles, which transport them to city hubs where goods undergo qualitative and quantitative checks before being transferred to last-mile electric vehicles. These vehicles operate within regulated urban areas, delivering both to end customers and to APMs, while also collecting returns that are subsequently reintegrated into the upstream logistics flow. The modular transshipment concept plays a central role in this configuration, reducing loading and unloading times and enabling rapid exchange of temperature-controlled cargo boxes between vehicles and facilities.

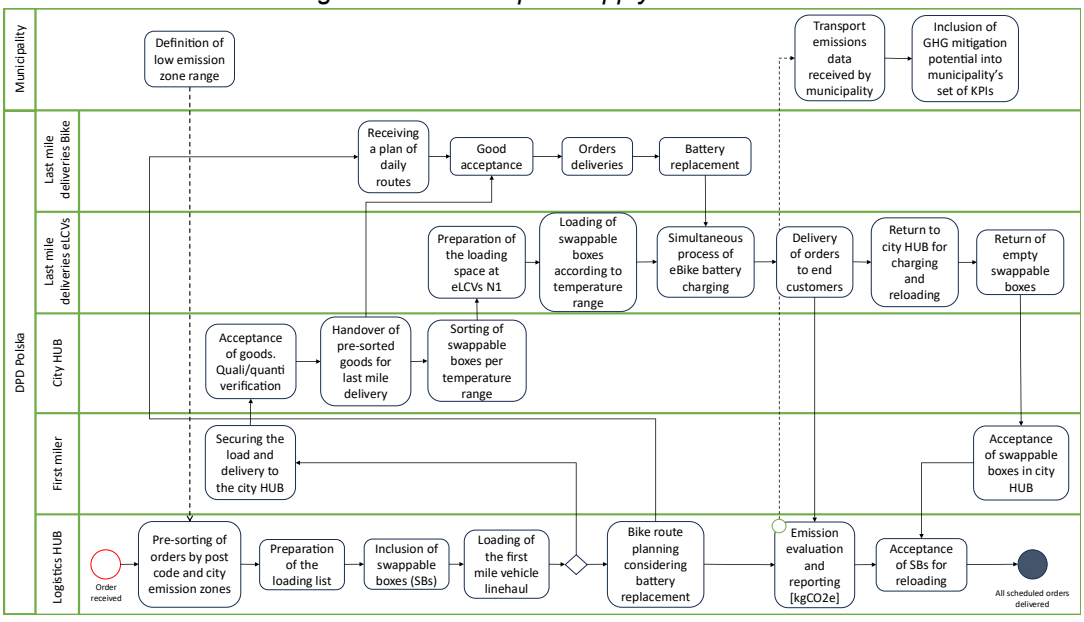
A defining feature of the Wrocław pilot is the deployment of advanced energy-management strategies for cold-chain operations. Electric vehicles equipped with thermal-controlled cargo bodies serve not only as transport assets but also as mobile energy resources, supporting two-way charging operations in which APMs can be supplied directly from vehicle batteries. This vehicle-to-infrastructure interaction is intended to improve charging efficiency in dense urban areas and to increase operational

resilience during peak demand periods or adverse weather conditions. Driver comfort and safety are also addressed through optimised thermal-comfort systems integrated into vehicle cabins and cargo compartments, allowing sustained operations during harsh winter conditions.

From a regulatory and governance perspective, the pilot is explicitly aligned with Wrocław's forthcoming Clean Transport Zone. The BPM illustrates how access rules, emission-related performance indicators and zone definitions provided by municipal authorities influence route planning, vehicle allocation and cargo consolidation decisions upstream in the logistics chain, while emissions and operational data generated by fleet operators are fed back to the city for monitoring and KPI calculation. This closed digital loop supports both compliance with UVAR policies and evidence-based refinement of urban freight strategies.

Given InPost's extensive national network, comprising more than 20,000 APMs and millions of end users, the Wrocław pilot is conceived as a scalable demonstration capable of rapid replication across other Polish cities. The combination of synchromodal vehicle deployment, modular cargo units, cold-chain electrification, bidirectional charging and data-driven urban access management is expected to generate transferable operational and regulatory models applicable to a wide range of dense urban contexts within and beyond the S2Z consortium.

Figure 5. Wroclaw pilot supply chain BPM



3.1.3 Bologna: Transhipment – (e)HDV to eLCV, geofencing & UVARs

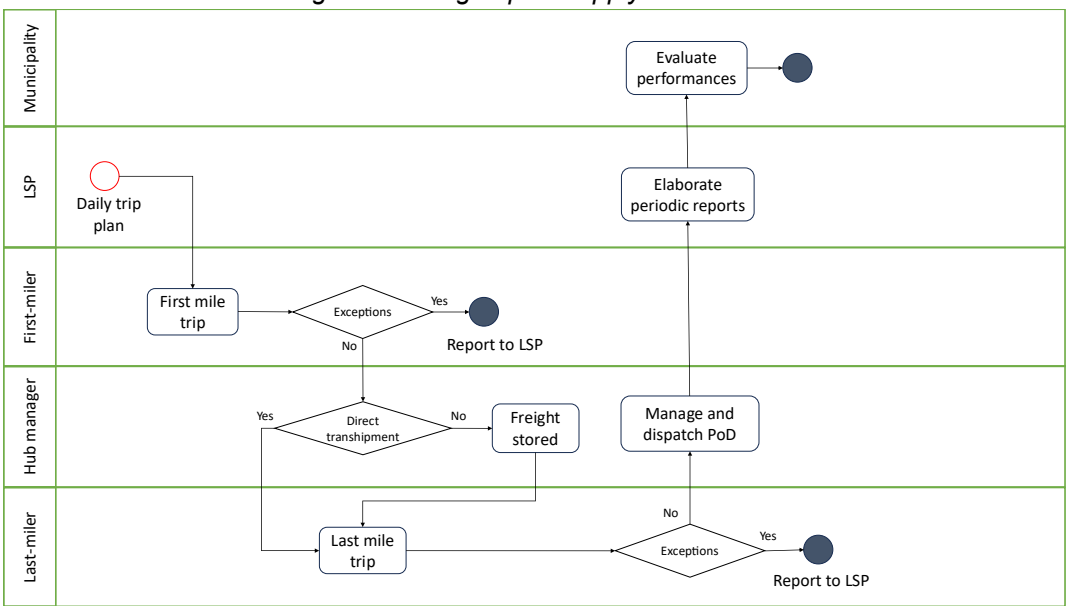
The Bologna pilot focuses on the assessment of innovative urban logistics configurations enabled by electric light commercial vehicles and modular operational concepts. The main objective is to compare alternative logistics models against current operations in terms of cost efficiency, operational performance, and suitability for dense and pedestrianised urban environments. In particular, the pilot aims to evaluate new vehicle

typologies optimised for city logistics, featuring payload capacities exceeding 600–1000 kg, ranges between 200 and 300 km, and reduced gross vehicle weights, as well as the feasibility of micro-hub–based distribution schemes with cargo transshipment between vehicles dedicated to different legs of the supply chain.

A central element of the Bologna demonstration is the exploration of a two-tier logistics model, in which first-mile vehicles transport goods to intermediate facilities or micro-hubs, where consignments are consolidated and transferred to smaller electric vehicles operating in restricted traffic zones. This configuration is compared with the current single-leg distribution approach, allowing the pilot to assess impacts on route structures, vehicle utilisation, delivery schedules and emissions.

Operational processes in Bologna have been formalised using Business Process Modelling techniques, covering both physical flows of goods and information flows preceding and following delivery activities, as represented in the following figure.

Figure 6. Bologna pilot supply chain BPM



The pre-shipment phase is currently based on experience-driven planning practices: load lists are digitally simulated at office level and subsequently confirmed during warehouse operations. Shipments are categorised into same-day “non-stop” deliveries and pre-rotated consignments with defined time windows (24–48 hours). During warehouse preparation and loading, pallets are manually assigned to vehicles according to delivery areas, weight, volume and timing constraints, while fleet composition includes tractors and vans characterised by predefined service zones and variable numbers of daily tours depending on operational complexity.

Delivery operations in the urban area include last-mile distribution in restricted zones, proof-of-delivery management, and post-delivery reporting activities. The pilot also considers exception handling, return flows, and performance evaluation processes as part of the overall logistics cycle. At the time of reporting, the Bologna site is positioned

in an initial assessment phase, with baseline operational practices documented and candidate optimisation scenarios being prepared for future testing.

Figure 7. Schematic representation of Bologna pilot delivery operations

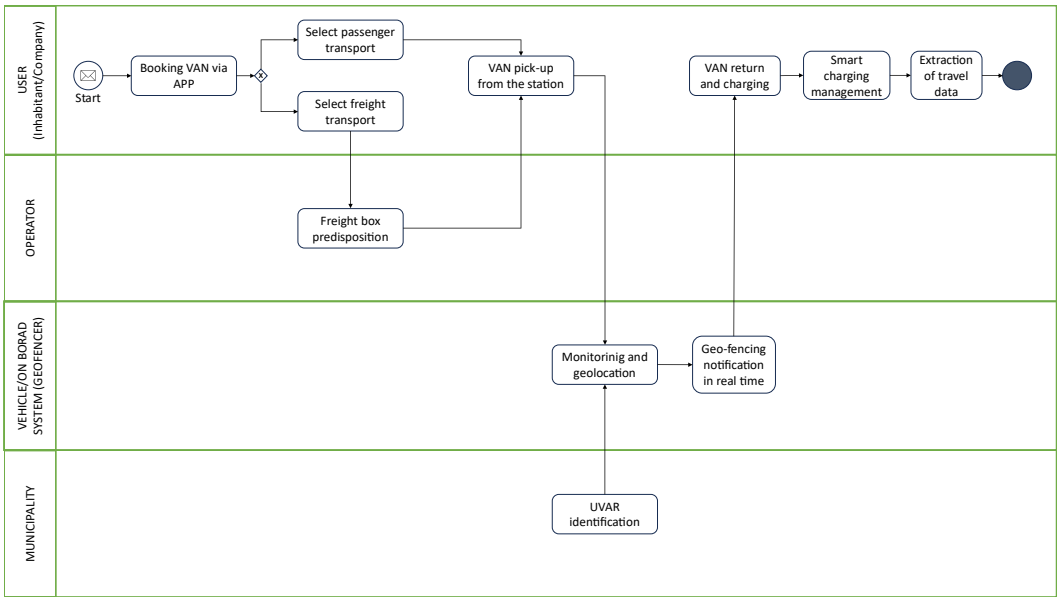


3.1.4 Brussels: Logistics as a service, business model diversification

The Brussels pilot focuses on the assessment of an innovative van sharing service designed for occasional urban logistics, catering to local companies and inhabitants. The main objective is to evaluate the feasibility of a shared electric fleet for non-professional logistical needs in urban environments. In particular, the pilot aims to test modular vehicle configurations, allowing users to choose between goods or passenger transport setups, while monitoring real-time operational performance through variables such as State of Charge (SoC) and trip length.

A central element of the Brussels demonstration is the integration of real-time geofencing and smart charging infrastructure. The system is designed to provide users with instant alerts via a dedicated app when entering restricted areas, such as Low Emission Zones (LEZ) or pedestrianized roads, where specific access conditions apply. Regarding energy management, the pilot implements a V1G smart charging scheduling system, which enables the operator to actively manage the timing of energy supply after the vehicle has been returned to the station. Rather than initiating charging immediately upon plugin, the operator decides the optimal start time for each session to synchronize energy demand with the peak production of on-site solar panels or to shift consumption to off-peak electricity hours, thereby maximising energy efficiency. Operational processes for the Brussels site are represented in the following BPM diagram, mapping the interactions between users, the operator, and municipal stakeholders.

Figure 8. Brussels pilot supply chain BPM



Due to the nature of the van sharing service, where destinations are not predefined by the operator, the information flow relies on post-trip journey data extraction from on-board black boxes. This data is subsequently utilised to analyse vehicle model consumption and support Decision Analytics, providing the municipality with insights into the impact of traffic restrictions and the suitability of electric mobility for local inhabitants.

The pre-booking and execution phases are managed through a digital platform that integrates municipal MaaS (Mobility as a Service) data, ensuring that urban restrictions are accurately reflected in the user interface. During the assessment phase, the pilot also incorporates qualitative feedback loops, where the municipality facilitates communication with local businesses and conducts surveys to evaluate user satisfaction and the overall social impact of the shared logistics mode.

3.1.5 Thessaloniki: Transhipment (e)HDV to eLCV, UVARs, Digital Twin

The Thessaloniki pilot focuses on the demonstration of an integrated urban logistics configuration enabled by right-sized electric light commercial vehicles, modular transshipment operations, and digital decision-support tools. Its main objective is to assess how multi-temperature, energy-efficient eLCVs can support more flexible and sustainable city logistics in a dense urban environment while maintaining operational reliability for mixed delivery profiles. In particular, the pilot examines how a modular cargo body capable of accommodating both dry and refrigerated products can respond to fluctuating demand patterns, and how standardized swappable load units can improve the interface between heavy-duty vehicle operations and smaller zero-emission vehicles deployed for urban distribution.

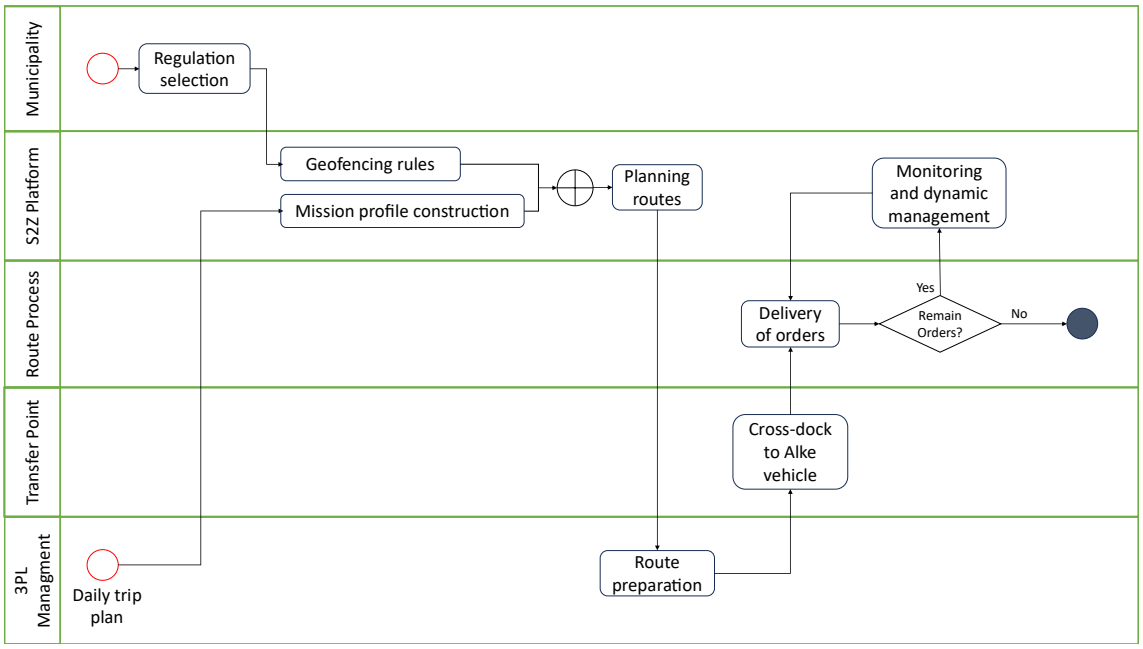
A central element of the Thessaloniki demonstration is the development of a two-tier operational model linking extra-urban and urban freight legs through a transhipment point. In this configuration, larger vehicles feed an Urban Consolidation Center, where consignments are reorganized and transferred to Alkè eLCVs for final delivery within the

city. This setup allows the pilot to test operational synergies between HDVs and eLCVs, evaluate the suitability of modular swappable concepts for seamless cargo transfer, and explore how fleet composition and route allocation can be redesigned to better reflect the characteristics of urban demand. The pilot also incorporates geofenced vehicle operations, allowing N1 right-sized vehicles to circulate more safely and efficiently in restricted or sensitive urban areas under predefined access and operational rules.

Operational processes in Thessaloniki have been formalized through BPMN covering the interaction between municipal regulation, platform-based planning functions, transfer-point operations, and daily fleet execution. As illustrated in the BPMN flow, the process begins with the definition of the daily trip plan and the selection of the applicable regulatory framework. These inputs feed the S2Z platform, where geofencing rules and mission profile construction are combined to support route planning. The resulting delivery plan is then operationalized through route preparation and cross-docking to the Alkè vehicle at the transfer point. Once deliveries are underway, the system supports monitoring and dynamic management of operations, including the possibility of adapting execution based on remaining orders and operational conditions. This process representation captures both the physical movement of goods and the digital control logic needed for dynamic fleet orchestration.

The integration with the Thessaloniki Digital Twin is a further distinctive feature of the pilot. It provides the analytical basis for transportation network design, route optimization, and dynamic traffic-aware management, while also supporting broader strategic decisions on fleet sizing, use of space, and service configuration. In this sense, the pilot does not only test a vehicle or a delivery scheme, but an integrated logistics management concept in which regulatory conditions, urban space allocation, routing intelligence, and vehicle capabilities are jointly considered. At the current stage, the Thessaloniki pilot is positioned as a structured demonstration case where the core operational logic, platform functions, and pilot workflows have been defined, forming the basis for subsequent real-life testing and evaluation.

Figure 9. Thessaloniki pilot supply chain BPM



3.2 Operational, Technical and Economic Data Needs

The analysis of pilot activities reveals a strong convergence in data requirements across all demonstration sites, despite differences in regulatory context, vehicle mix, and operational scale. All pilots share a synchromodal logic in which electric light commercial vehicles (eLCVs), heavy-duty vehicles (e-HDVs), micro-vehicles (e.g. L7), cargo bikes, and in some cases Automated Parcel Machines (APMs), operate within structured first-mile, transhipment and last-mile configurations.

The identified data needs can be structured into three main categories: **operational**, **technical**, and **economic**, each contributing to modelling, optimisation and KPI computation.

3.2.1 Operational Data Needs

Operational data constitute the backbone of simulation and optimisation activities. Across pilots, the following recurrent data domains have been identified:

1. **Demand and Order Characteristics**
   - Order volumes (daily/weekly, seasonal variability)
   - Delivery and return flows
   - Parcel typology (size, weight, temperature requirement)
   - Delivery time windows
   - Destination typology (B2B, B2C, APM, hub)

2. **Network and Infrastructure Configuration**

- Hub and micro-hub locations
- Mobility hubs and swap points
- APM locations and capacity (where applicable)
- Charging infrastructure location and availability
- Geofenced or regulated areas (UVARs, LEZs)

3. **Routing and Service Execution**

- Trip duration and distance
- Stop frequency and dwell times
- Loading and unloading times
- Transhipment times (including modular swap operations)
- Return trip flows
- Vehicle-to-vehicle or hub-based swap events

4. **Urban Access and Regulatory Context**

- Clean Transport Zone boundaries
- Vehicle access restrictions by category or emission class
- Time-based access rules
- Dynamic parking availability
- Data exchange specifications (e.g. mobility data standards where applicable)

These operational data are necessary to model fleet utilisation, route optimisation, consolidation potential, geofence compliance and hub workload balancing. Across pilots, increasing attention is given to dynamic routing and adaptive logistics, especially where geofencing or urban vehicle access regulations influence vehicle behaviour.

3.2.2 Technical Data Needs

Technical data enable modelling of vehicle performance, energy consumption and infrastructure interaction. Although vehicle typologies differ slightly across pilots, the required technical parameters are largely consistent.

1. **Vehicle Characteristics**

- Vehicle category (eLCV, e-HDV, L7, cargo bike)
- Payload capacity and volume
- Battery capacity
- Energy consumption rate (kWh/km)
- Range under different load conditions
- Thermal-controlled cargo specifications (where relevant)

2. **Energy and Charging**

- Charging power and duration
- Charging infrastructure compatibility
- Battery degradation parameters
- Simultaneous charging constraints
- Bidirectional charging capabilities (V2X, V2-APM)
- Cold-chain energy requirements

3. **Modular and Swappable Components**

   - Swap body dimensions and capacity
   - Temperature ranges
   - Folding/storage characteristics
   - Loading/unloading compatibility between vehicle classes

4. **Environmental Performance Parameters**

   - Emission factors (for baseline comparison)
   - Electricity mix assumptions
   - Well-to-wheel emission coefficients

In pilots such as Norway and Wrocław, additional data relate to modular swap concepts and energy management integration, while in others the focus is primarily on optimised eLCV deployment. However, the underlying modelling logic remains comparable: linking vehicle technical characteristics with operational routes to estimate performance and energy demand.

3.2.3 Economic Data Needs

Economic data are required to evaluate business viability, total cost of ownership (TCO), and scalability potential.

1. **Investment Costs**

   - Vehicle acquisition cost
   - Swap body acquisition cost
   - Charging infrastructure investment
   - Hub or micro-hub setup costs
   - APM installation costs (where relevant)

2. **Operational Costs**

   - Energy costs (electricity pricing assumptions)
   - Maintenance costs
   - Driver labour costs
   - Leasing or rental costs
   - Parking and access fees
   - Insurance and regulatory compliance costs

3. **Productivity Indicators**

   - Deliveries per vehicle per day
   - Average load factor
   - Vehicle utilisation rate
   - Transhipment efficiency gains
   - Trip reduction rates through consolidation

4. **External Cost and Societal Impact Inputs**

   - Emission reduction valuation

- Congestion-related cost assumptions
- Noise reduction proxies (if applicable)

Across pilots, the economic assessment aims not only to compare electric versus conventional vehicles, but also to quantify the impact of operational innovations such as modular swap bodies, hub-based consolidation, synchromodality and dynamic access management.

3.3 Cross-Pilot Convergence

Although the pilots differ in regulatory context, vehicle mix, scale of operations and technological maturity, the analysis of data requirements highlights a strong structural convergence across all demonstration sites.

In all cases, the logistics system can be described through the same core data layers:

1. Demand Layer: information on orders, deliveries, returns and service requirements.
2. Operational Execution Layer: routing, trip execution, loading/unloading, transhipment and access constraints.
3. Vehicle & Energy Layer: vehicle technical characteristics, energy consumption, charging behaviour and thermal management.
4. Economic Layer: investment costs, operating costs and productivity indicators.
5. Regulatory & Impact Layer: geofencing, UVARs, emission accounting and alignment with municipal KPIs.

Across pilots, the modelling logic consistently links these layers:

- Demand data determine vehicle allocation and routing choices.
- Operational data determine distance travelled, stop frequency and time use.
- Technical parameters determine energy consumption and performance.
- Energy use and vehicle deployment determine emissions and environmental impact.
- Operational productivity and technical performance determine economic viability.

While specific implementations vary (e.g. modular swap bodies in Norway and Wrocław, geofencing integration in Bergen, cold-chain optimisation in Wrocław, hub-based consolidation in Bologna and Thessaloniki), the underlying data structure required to model these innovations remains fundamentally comparable.

This convergence confirms the feasibility of defining a harmonised core data architecture applicable across pilots, complemented by modular extensions addressing pilot-specific features such as bidirectional charging, dynamic parking interaction or multi-temperature cargo management.

The common structure emerging from the cross-pilot analysis provides the foundation for the definition of a unified and extensible data model architecture, detailed in Chapter 4.

4. Data Models Definition

The definition of data models is fundamental to structure and organise the diverse data collected from pilots, ensuring semantic consistency and interoperability. This chapter presents the architecture of the proposed data models, detailing core entities, their relationships, and how these models accommodate pilot-specific requirements.

4.1 Architecture and Structure

This section describes the architecture of the Shift2Zero data models and the supporting information infrastructure. The architecture is designed to operationalise the functional requirements collected from pilot sites through the eLCV Fleet Management Functional Requirements Template handed out during the GA of S2Z in Bergen. It provides a structured framework that translates operational needs into data structures, interfaces, and analytical workflows that can be consistently implemented across pilots.

The architecture supports the organisation, storage, and integration of heterogeneous data originating from operational, technical, and economic domains. It ensures that data required by the Toolbox is available in a harmonised and traceable form for optimisation engines, monitoring components, and simulation modules (described in Chapter 2). These modules are later evaluated through pilot-specific functional prioritisation exercises.

The design supports both real-time operational control and offline analytical use cases. It enables live telemetry ingestion for routing, charging, and monitoring functions, while also supporting batch-oriented datasets for total cost of ownership, lifecycle assessment, and scenario-based simulation. Clear traceability is preserved between raw data, transformed records, derived indicators, and Key Performance Indicators used for impact evaluation.

The architecture is modular and iterative. It allows individual engines to evolve based on pilot feedback without disrupting the overall system. This approach reflects the co-development logic established through the three-stage functional requirements methodology, which includes baseline assessment, toolbox presentation, and structured feature prioritisation.

4.1.1 Information flow architecture

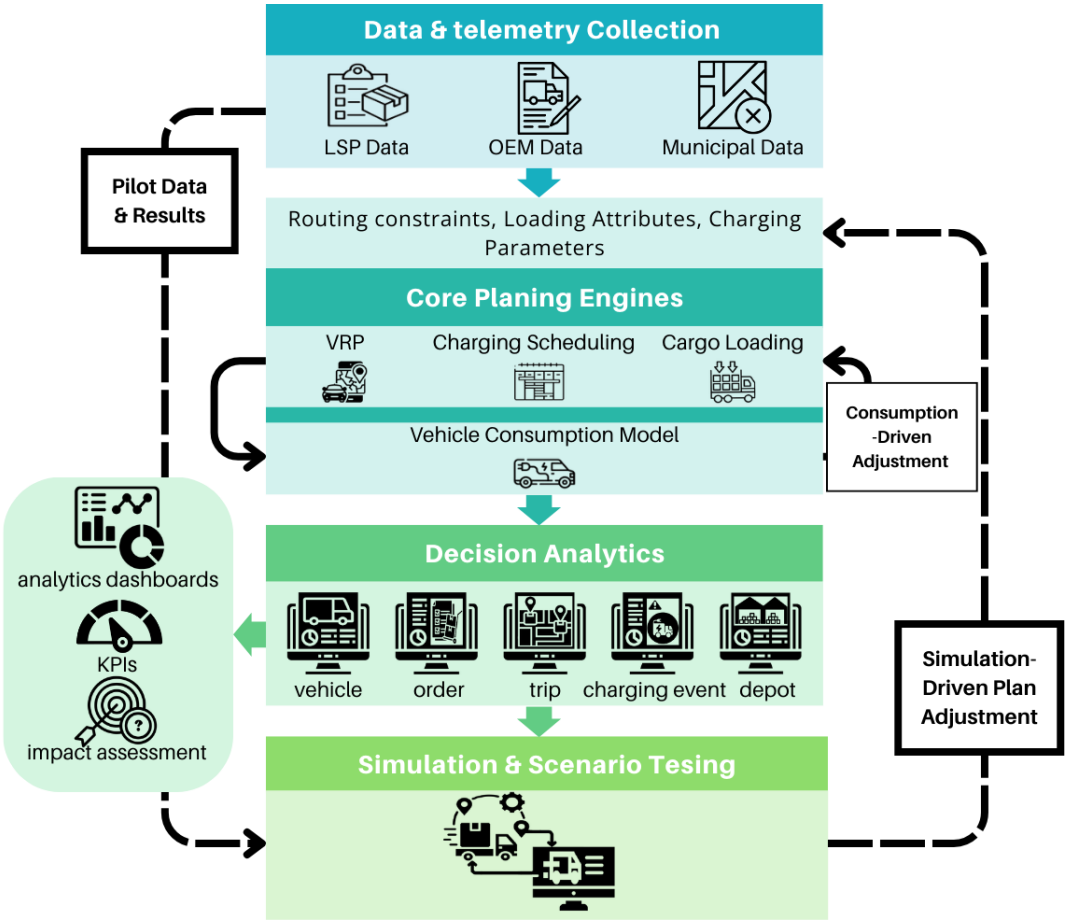
The data architecture follows four design principles that align with the functional requirements process and the methodological framework defined in Sections 2.1 to 2.4.

Engine-oriented semantics define data elements based on the analytical engines that consume them. Each data field is linked to a specific functional requirement derived from pilot input. This includes routing constraints, charging parameters, loading attributes, consumption models, and simulation variables. This approach ensures that all stored data has a defined operational or analytical purpose.

Layered modularity structures data flows according to the toolbox logic, progressing from data and telemetry collection to core planning, decision analytics, and simulation. This

separation supports independent development and testing of engines such as VRP, charging scheduling, loading optimisation, and scenario simulation, while maintaining interoperability through shared interfaces.

Figure 10. Information flow architectural scheme



Harmonisation through a minimal canonical schema ensures consistency across pilots while allowing controlled extensions. Core entities such as vehicle, order, trip, charging event, depot, and economic record form a common foundation that supports cross-pilot comparison. Optional extensions are introduced to reflect site-specific functional requirements identified during the feature selection stage.

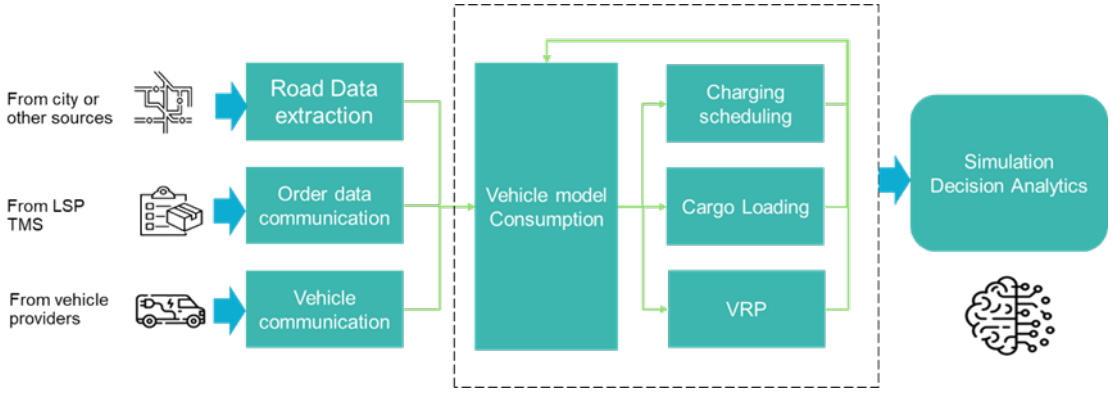
Iterative validation and traceability support feedback loops between pilots, model development, and impact evaluation. Data schemas, transformation rules, and KPI definitions are versioned. Lineage metadata links analytical outputs to source data and model configurations. This enables reproducibility of results and supports transparent impact assessment activities.

4.1.2 Engine-Oriented Architecture

The system architecture places a central processing core and model repository between engines and the Fleet Management Platform. The core hosts canonical data, model

versions, and scenario definitions. Standardised APIs expose services for energy estimation, route feasibility checks, charging schedules, and loading plans. The platform provides user interfaces for planners and managers and supports two-way cloud communication with vehicle fleets for live telemetry and command messages. Road Data Extraction enriches routes with elevation, grade, speed limits, and access restrictions to improve routing and consumption accuracy. Vehicle Communication supplies continuous location, speed, and state-of-charge data to enable dynamic rerouting and opportunistic charging.

Figure 11. System architecture logical scheme



The system architecture is organised around a central processing core and model repository that mediates all interactions between engines and the Fleet Management Platform. This core stores canonical datasets, validated model versions, and scenario definitions, ensuring that all engines operate on consistent and traceable information. Standardised application programming interfaces expose services for routing, charging scheduling, cargo loading, and energy estimation, enabling controlled data exchange across the system.

At the entry point, the Road Data Extraction, Order Data Communication, and Vehicle Communication engines act as the primary data providers. Order Data Communication supplies structured demand information, including delivery locations, time windows, and parcel attributes. Vehicle Communication provides live and historical telemetry, such as vehicle position, speed, and battery state of charge. Road Data Extraction enriches the transport network with elevation profiles, gradients, speed limits, congestion indicators, and access restrictions. Together, these engines feed harmonised operational and technical inputs into the core planning layer.

These inputs are consumed by the core operational planning engines. The Vehicle Routing Problem engine generates feasible and optimised routes based on orders, network constraints, and vehicle availability. The Cargo Loading Engine uses order attributes and vehicle capacities to produce loading plans and payload distributions. The Charging Scheduling Engine determines charging locations, timing, and durations by combining route plans, battery state, and charging infrastructure constraints. The outputs of these engines are mutually dependent and exchanged through the central core, ensuring consistency across routing, loading, and charging decisions.

The Vehicle Model Consumption Engine refines the operational plans by estimating route-level and segment-level energy consumption. It combines routing outputs, payload information, vehicle specifications, and enriched road attributes to produce detailed energy demand and state-of-charge profiles. These refined estimates feed back into routing and charging decisions when infeasibilities or inefficiencies are detected, supporting iterative plan adjustment.

The resulting operational plans and performance indicators are made available to the Decision Analytics layer for monitoring and reporting. In parallel, the Simulation Engine consumes the same canonical data, operational plans, and calibrated models to evaluate alternative scenarios. These scenarios include changes in demand, fleet composition, charging infrastructure, or policy constraints. Simulation outputs can be analysed independently or reintegrated into planning and analytics workflows, enabling systematic testing and progressive refinement of operational strategies.

This architecture supports a progressive flow from raw data ingestion to executable plans and, finally, to analytical and simulation-based refinement, while maintaining a single, coherent data and model backbone.

4.1.3 Integrated Data Governance

Operational, technical, and economic domains are integrated through shared identifiers and aligned temporal references. Vehicle specifications and telemetry data are combined with route and road attributes to generate energy consumption profiles. Operational activities are linked to economic records to enable per-route and fleet-level cost attribution. Technical lifecycle parameters support scenario-based analysis of battery degradation and maintenance impacts within total cost and lifecycle assessment models.

Data governance is supported through a maintained data requirements registry that reflects the functional requirements template. Each data element and KPI is assigned clear ownership and validation responsibility. Automated quality checks and anomaly detection ensure readiness for analytical use.

Privacy and security controls support regulatory compliance through data minimisation, pseudonymisation, role-based access, and encrypted storage and transfer.

The architecture supports continuous iteration. Feedback from pilot sites informs updates to functional requirements, data schemas, and engine configurations. These updates propagate through modelling, simulation, and impact evaluation activities. This iterative loop ensures that the architecture evolves in alignment with operational reality and validated pilot needs.

4.2 Core Entities and Relationships

The definition of the Shift2Zero core data model is the result of a structured, two-stage analytical process designed to move from specific functional needs to a generalised technical architecture.

In the first step, the project mapped the data points required by each engine and organised them in a shared dataset including the following fields: Engine; Data Point; Priority; Category; Layer; Data Provider; Frequency. This dataset was populated using information collected from the pilots and complemented, where needed, with additional technical sources. Since the same data point can be relevant for more than one engine, this first mapping provided an engine-oriented view of the data requirements, but not yet a unified data model. This approach is fully consistent with the methodology already introduced in the deliverable, where data collection is engine-driven and aimed at supporting interoperable optimisation and simulation tools.

In a second step, the full set of data points was analysed across engines in order to identify a smaller number of generic entities that describe the logistics system as a whole. The data points were no longer treated only as inputs for individual engines, but as attributes of broader real-world objects. This made it possible to move from an engine-specific inventory to a common conceptual model. The result is an entity-relationship (ER) structure that generalises the data layer, reduces dependence on any single pilot configuration and creates a clearer basis for future pilot replication and technical onboarding. In this sense, the model is not only a representation of current pilot needs, but also a reusable reference for understanding the technical data requirements of future implementations. This logic also reflects the semantic harmonisation approach described earlier in the deliverable, which aims to define a common conceptual layer across heterogeneous pilots while keeping room for pilot-specific extensions. The resulting core data model represents eLCV operations as a combination of three dimensions:

- planning objects
- vehicle and energy behaviour
- operating context

supporting the main WP5 needs, because it allows operational, technical and economic information to be connected through shared entities and relationships, instead of remaining separated within individual engine.

The following picture details the attributes of each entity and shows related relationships, using the Entity-Relationship diagram:

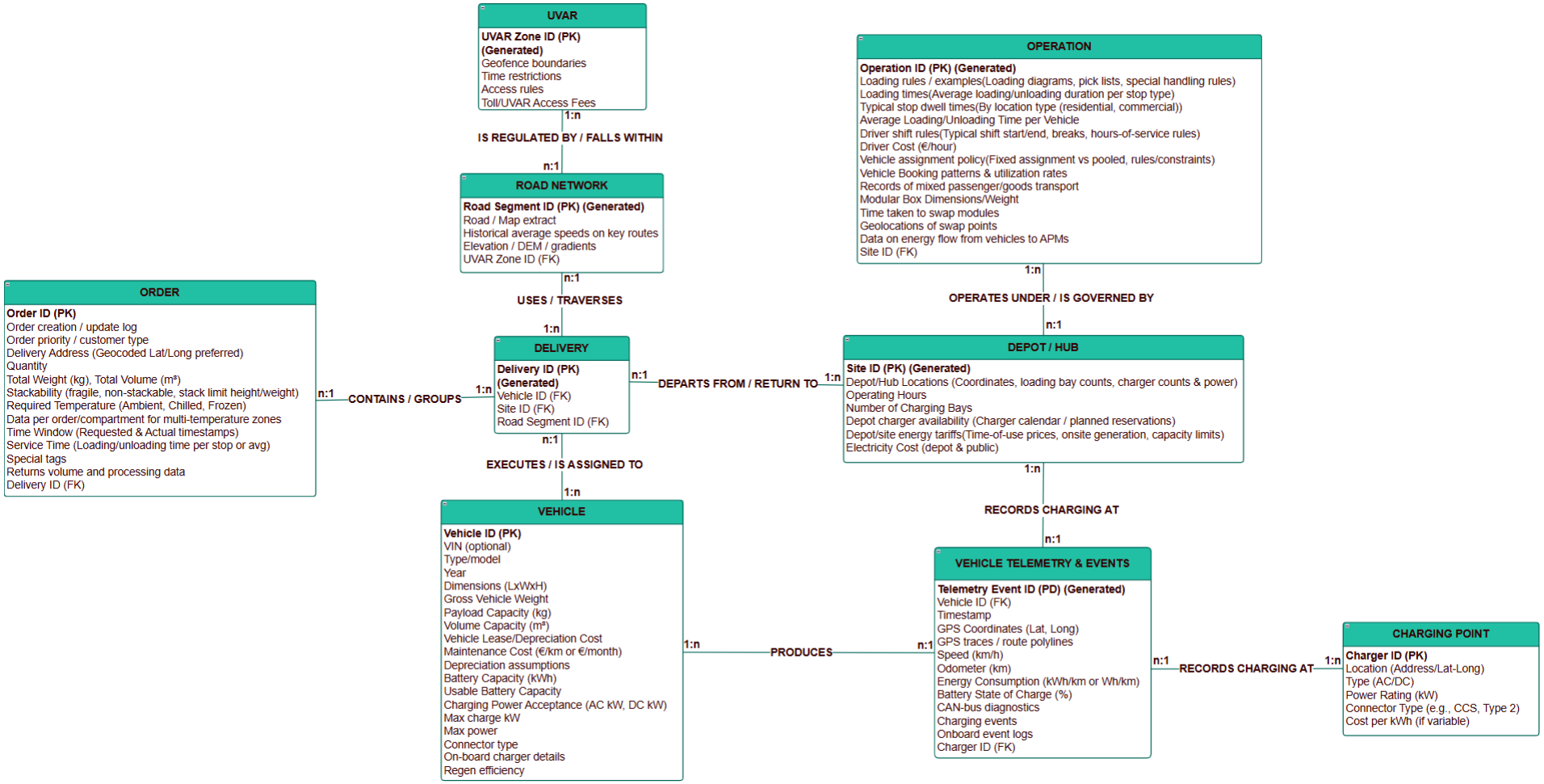


Figure 12. S2Z Data model

Co-funded by the European Union

The Shift2Zero project has received funding from the European Union Horizon Europe Programme: project num. 101192375. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Below, each entity is described:

- **Order**

The Order entity represents the commercial or logistical demand to be served. It contains the information needed to define what must be delivered and under which service constraints, including destination, quantity, weight and volume, temperature requirements, time windows, service time, priority, and other delivery-specific conditions. An order may generate one or more execution tasks, depending on the operational configuration of the pilot.

- **Delivery**

The Delivery entity represents the operational execution unit linked to an order. It captures what is actually performed in the field and acts as the main bridge between planning and execution. Through its links to vehicles, sites and network context, it allows the model to connect planned demand with the observed operational reality.

- **Vehicle**

The Vehicle entity describes the static or slowly changing characteristics of the eLCV or other relevant vehicle types involved in the pilot(s). It includes technical and economic parameters such as model, dimensions, payload and volume capacity, gross vehicle weight, battery capacity, charging acceptance, connector type, power, depreciation assumptions and maintenance-related values. These attributes are essential because they define the feasibility boundaries of routing, loading, charging and simulation functions.

- **Vehicle Telemetry & Events**

The Vehicle Telemetry & Events entity describes what happens during operations over time. It includes time-stamped observations such as GPS traces, speed, odometer, battery state of charge, energy consumption, charging events, CAN-bus diagnostics, onboard event logs and other event-based data. This entity is important for validation and calibration, because it makes it possible to compare planned operations with actual execution and to compute performance indicators from real operational traces.

- **Depot / Hub**

The Depot / Hub entity represents the operational base from which logistics activities are organised. It includes physical and operational characteristics such as site location, operating hours, charging-bay availability, electricity cost, charging reservations and site-level energy constraints. In practice, this entity provides the local context within which routes start, vehicles are loaded or charged and operational resources are managed.

- **Charging Point**

The Charging Point entity represents an individual charging asset. It standardises the description of charging infrastructure by including information such as location, charger identifier, charging technology, power rating, connector type, and, where relevant, charging cost. This entity allows the same data structure to support both depot-based and public charging scenarios.

- **Road Network**

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The Road Network entity describes the transport environment in which deliveries are executed. It includes the network elements needed for realistic routing and energy modelling, such as map or road references, elevation or gradients and historical average speeds on key routes. Through its connection to access-control information, this entity also supports the representation of regulation-sensitive route planning.

- **UVAR**

The UVAR entity makes urban access regulation computable. It contains the main policy-related constraints that may affect vehicle circulation, such as geofenced boundaries, time-based restrictions, access rules and toll or access-fee conditions. Linking UVAR information to the road network allows regulatory constraints to influence routing, scheduling, and scenario analysis in a structured way.

- **Operation**

The Operation entity captures the local operating logic that cannot be fully explained through vehicles, orders or infrastructure alone. It includes parameters such as loading rules, loading and unloading times, dwell times, shift rules, vehicle-assignment policies, driver cost, swap-point locations, modular-box properties and other process-specific constraints. This entity represents how a pilot actually works in practice. In other words, it translates a technically feasible plan into a realistic operational plan.

Taken together, these entities define a model in which relationships are as important as attributes. Orders generate deliveries; deliveries are executed by vehicles; vehicles generate telemetry and charging events; deliveries interact with depots, hubs, charging points, and road segments; road segments are subject to UVAR constraints; and operations define the local rules that shape timing, labour use, and execution logic. The entity-relationship diagram therefore does more than list data objects: it shows how the different data domains interact inside the logistics system.

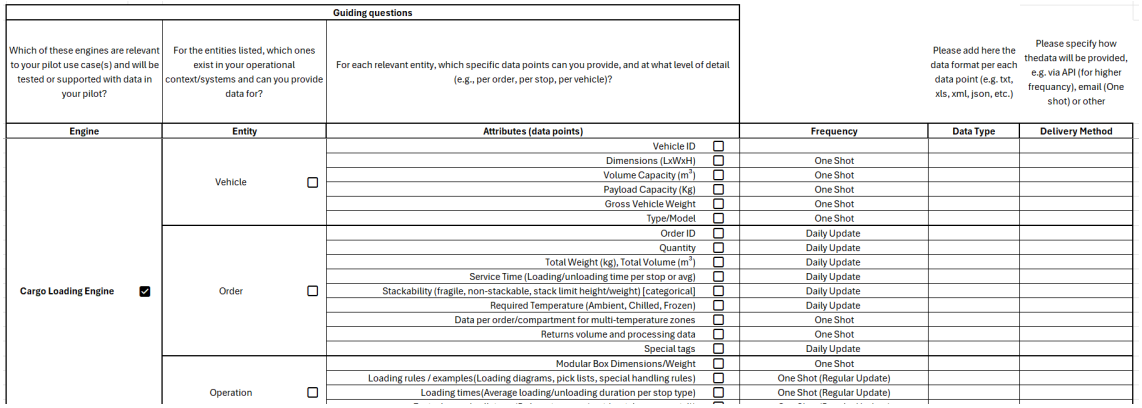
4.3 Mapping Data Models against S2Z Engines

After defining the core entities and relationships of the S2Z data model, the next step was to connect this conceptual structure to the concrete needs of the different engines and pilots. For this purpose, a spreadsheet was developed to map the data points against both the ER entities and the reference engines. This file combines the two logical steps followed in the work so far:

- the engine-based identification of required data points
- the reorganisation of those same data points into a common set of generic entities

In this way, the spreadsheet links the common data model to the specific technical needs of each engine.

Figure 13. Pilot data collection spreadsheet



Guiding questions						
Which of these engines are relevant to your pilot use case(s) and will be tested or supported with data in your pilot?	For the entities listed, which ones exist in your operational context/systems and can you provide data for?	For each relevant entity, which specific data points can you provide, and at what level of detail (e.g., per order, per stop, per vehicle)?			Please add here the data format per each data point (e.g. txt, xls, xml, json, etc.)	Please specify how thedata will be provided, e.g. via API (for higher frequancy), email (One shot) or other
Engine	**Entity**	**Attributes (data points)**		**Frequency**	**Data Type**	**Delivery Method**
	Vehicle ☐	Vehicle ID	☐			
		Dimensions (LxWxH)	☐	One Shot		
		Volume Capacity (m^3)	☐	One Shot		
		Payload Capacity (Kg)	☐	One Shot		
		Gross Vehicle Weight	☐	One Shot		
		Type/Model	☐	One Shot		
Cargo Loading Engine ☑	Order ☐	Order ID	☐	Daily Update		
		Quantity	☐	Daily Update		
		Total Weight (kg), Total Volume (m^3)	☐	Daily Update		
		Service Time (Loading/unloading time per stop or avg)	☐	Daily Update		
		Stackability (fragile, non-stackable, stack limit height/weight) [categorical]	☐	Daily Update		
		Required Temperature (Ambient, Chilled, Frozen)	☐	Daily Update		
		Data per order/compartment for multi-temperature zones	☐	One Shot		
		Returns volume and processing data	☐	One Shot		
		Special tags	☐	Daily Update		
	Operation ☐	Modular Box Dimensions/Weight	☐	One Shot		
		Loading rules / examples(Loading diagrams, pick lists, special handling rules)	☐	One Shot (Regular Update)		
		Loading times(Average loading/unloading duration per stop type)	☐	One Shot (Regular Update)		

The main purpose of the spreadsheet was to support a structured and comparable mapping of the technical requirements emerging from the pilots. The file was designed to help connect pilot use cases with the relevant S2Z engines and with the data points needed to support them. Alongside the identification of the required data, the exercise also captures practical information on how these data are expected to be handled and the actor responsible for providing them.

This additional layer of information is important because it shifts the work from a purely conceptual exercise towards a more implementation-oriented perspective. It helps clarify not only which data are needed, but also how they can realistically be made available within the pilot context and used by the corresponding S2Z engines.

The engine-level tables resulting from this activity are included in the Appendix of this deliverable. They should be read as part of a broader methodological effort to translate pilot needs into a common technical framework. This mapping approach makes it possible to analyse requirements in a consistent way across different use cases, while also providing a clearer view of the conditions needed to support the implementation of each engine. As additional pilot inputs become available, the mapping will be progressively refined and expanded.

5. KPIs Definition and Alignment

The definition and alignment of Key Performance Indicators (KPIs) represent a key step to evaluate the impacts generated by the Shift2Zero pilots and to support the impact assessment activities carried out in Task 7.1. While the comprehensive evaluation framework is developed under T7.1, this deliverable provides the necessary data foundation and mapping between the data models defined in Task 5.1 and the KPIs used for impact evaluation.

The approach adopted in Shift2Zero builds upon the integration of **primary operational data** collected from pilot activities and **secondary data** generated through the project's analytical engines and simulation tools. This dual approach ensures that KPIs can reflect both observed operational performance and modelled scenarios for system optimisation and scalability assessment.

The data requirements identified in Section 3 and structured through the data models described in Section 4 are organised into three main categories:

- **Operational data**, describing logistics operations and mobility activities;
- **Technical data**, describing vehicle and infrastructure characteristics;
- **Economic data**, describing cost structures and financial performance.

These categories provide the fundamental inputs required to compute the KPIs defined in the impact assessment framework and allow consistent evaluation across all pilot sites.

5.1 KPI Catalogue by Type

The KPI catalogue that will be adopted in Shift2Zero follows a multidimensional approach reflecting the different impact areas addressed by the project. KPIs are grouped into categories that capture the performance of urban logistics operations from operational, technical, economic and environmental perspectives.

The three data domains defined in Task 5.1 contribute to the calculation of KPIs in different ways:

Operational data support KPIs related to logistics efficiency and service performance. These include indicators describing operational characteristics such as delivery times, number of stops, trip duration, vehicle utilisation rates, and delivery success rates. These indicators provide insights into **how logistics services operate within the pilot environments and how operational efficiency evolves** as new vehicle concepts, digital tools or operational strategies are deployed.

Technical data contribute to KPIs measuring vehicle performance and technological efficiency. This includes parameters such as vehicle range, energy consumption, charging times, payload capacity, temperature control requirements for goods, and interoperability with charging infrastructure. These variables are essential for **evaluating the technical feasibility and operational suitability of electric light commercial vehicles** and associated logistics technologies.

Economic data provide the basis for KPIs related to economic performance and cost efficiency. These include indicators linked to the total cost of ownership (TCO), operational costs, maintenance costs, energy costs, and potential savings associated with optimised logistics operations or the deployment of new vehicle technologies.

These three domains will be reflected into relevant impact areas defined in the project Impact Assessment Framework addressing the project objectives which in addition includes indicators related to Environmental, Societal & Safety aspects such as energy consumption per delivery, emissions reduction compared to baseline operations, or improvements in urban environmental performance.

The KPI catalogue therefore reflects a multi-layer structure, where each KPI is derived from one or more of the three data domains defined in the data model.

5.2 Pilot Priorities and Use Case Relevance

Although a common KPI framework is defined at project level, the relevance and prioritisation of specific indicators may vary depending on the characteristics of individual pilots and the operational solutions being demonstrated.

Each pilot focuses on particular aspects of urban logistics innovation, including modular vehicle concepts, geofencing technologies, synchromodal logistics operations, or integration with automated parcel machines. As a result, the relative importance of different KPI categories may differ across pilot sites.

For instance, pilots focusing on vehicle innovation and modular vehicle concepts place greater emphasis on technical KPIs related to vehicle performance, energy management and interoperability between vehicle classes. Pilots addressing urban access regulations or geofencing systems prioritise operational KPIs related to route optimisation, access compliance, and interaction with urban space management systems. Other pilots focusing on logistics consolidation and synchromodality may emphasise indicators related to fleet utilisation, delivery efficiency and multimodal integration.

Despite these differences, the use of a common data structure and harmonised KPI definitions ensures that results remain comparable across pilots. The common data model defined in Section 4 allows each pilot to contribute data to the same analytical framework while maintaining flexibility to capture pilot-specific operational characteristics.

5.3 Alignment with Impact Assessment Framework

The KPI framework presented in this deliverable supports the broader impact evaluation methodology developed in Task 7.1. While Task 7.1 defines the evaluation logic and the set of indicators used to assess the impacts of Shift2Zero innovations, Task 5.1 provides the data architecture and input variables required for their calculation.

In this perspective, Task 7.1 defines the "*what*" of the evaluation framework (the KPIs and impact domains), whereas Task 5.1 defines the "*how*", ensuring that the data required to compute these indicators can be systematically collected, structured and processed across all pilots.

The operationalisation of this framework relies on a structured workflow combining business process modelling of pilot operations, stakeholder consultations with logistics operators and public authorities, and the development of a mapping between KPIs and the data elements required for their estimation. This mapping ensures that each KPI is associated with specific variables defined within the data model described in Section 4.

The approach is **engine-driven**, meaning that data elements are specified according to the analytical components that use them within the Shift2Zero ecosystem, such as routing optimisation tools, energy consumption models, charging management engines or operational monitoring systems. In this way, outputs generated by modelling and optimisation tools can be reused for KPI estimation, ensuring methodological consistency across work packages.

KPI calculation relies on both **primary and secondary data sources**. Primary data originate from pilot operations and are provided by logistics service providers, vehicle manufacturers, public authorities and other local stakeholders. These include operational logistics data, vehicle telemetry, charging infrastructure usage and cost-related information. Secondary data are generated through the analytical engines developed within the project, which process operational data to produce derived indicators and evaluate alternative operational scenarios.

To guarantee interoperability across pilots, the entities and relationships identified through the data requirements analysis are formalised through semantic data models describing key elements of the Shift2Zero logistics ecosystem, such as vehicles, deliveries, routes, charging infrastructure, depots and operational events. These structures are integrated into the Shift2Zero platform, which enables the systematic collection, processing and analysis of operational data.

The overall workflow is represented in the following figure:

Figure 14. Data retrieval and alignment with Impact assessment framework



This alignment establishes the data foundation necessary to evaluate the impacts of Shift2Zero innovations across all pilot sites.

6. Conclusions

This section summarises the main outcomes of the interaction with pilot sites and identifies the remaining gaps, risks and recommendations that will guide the next phases of the project.

This deliverable presents the results of Task 5.1, which focused on defining the data requirements, governance structures and KPI alignment necessary to support the evaluation of Shift2Zero pilot activities.

The work conducted during this task enabled the identification of key operational, technical and economic data needed to support modelling activities and KPI estimation across pilot sites. Based on these inputs, a structured data model has been defined to ensure semantic consistency and interoperability across datasets originating from different pilots and stakeholders.

The deliverable also established the link between the data models defined in WP5 and the KPI framework developed in WP7. While Task 7.1 provides the methodological approach for evaluating the impacts of Shift2Zero innovations, Task 5.1 ensures that the necessary data structures and input variables are available to support KPI computation.

Although the current work provides a solid foundation for data integration and impact assessment, several aspects will continue to evolve as the project progresses. These include the detailed design of pilot operations in WP6, the refinement of analytical engines and digital tools in WP5, and the further development of the impact evaluation framework in WP7.

The outcomes of this deliverable will therefore support the subsequent development of the Shift2Zero platform in Task 5.4, the integration of digital solutions and monitoring tools in Task 5.2, and the implementation and evaluation of pilot activities in WP6 and WP7. Through this coordinated process, the project will progressively refine the data ecosystem required to evaluate the performance and impacts of zero-emission urban logistics solutions.

6.1 Data Availability and Gaps

All pilot sites actively contributed to the activities of Task 5.1 by responding to the requests from the task leader and by providing preliminary information on the operational scenarios to be tested, the partners involved, and the deployment of zero-emission vehicles according to the schedule defined in WP6.

The interaction with pilots enabled the identification of the main data providers, the expected operational workflows and the potential sources of operational, technical and economic data required for modelling activities and KPI estimation. In most cases, the pilots were able to confirm the availability of key operational datasets such as vehicle usage information, delivery operations data, charging activities and basic cost parameters.

However, as the pilot design process is still ongoing, several aspects remain partially defined. The current phase therefore highlighted some gaps and uncertainties, which are

considered normal at this stage of the project and will be progressively addressed during the detailed design and implementation of pilot activities in WP6.

In particular, the following aspects require further clarification or refinement:

- **Operational process definition**. In several pilots the detailed sequence of logistics operations is still under refinement. As a consequence, the exact analytical engines to be deployed in each pilot and the specific integration modalities have not yet been fully finalised. Depending on the operational configuration, data may be provided either synchronously (e.g. through APIs) or asynchronously (e.g. batch uploads or manual data imports) and may include both real operational data and simulated datasets. This flexible approach allows the project to ensure reliable KPI calculation while avoiding disruptions to real logistics operations involving commercial actors.
- **Progressive definition of analytical engines**. In some cases, pilot partners are not yet fully familiar with the capabilities of the analytical engines currently under development in WP5. The selection and integration of these engines therefore remain partly provisional and will be refined as their functionalities become clearer and demonstrable to the pilot partners.
- **Alignment with the KPI framework**. The definition and prioritisation of KPIs are currently being refined within WP7. As a result, the alignment between the KPI catalogue and the data models defined in WP5 is still evolving. This alignment will be further refined during Task 5.2 and through continued coordination with WP7 in order to ensure consistency between data collection, modelling activities and impact evaluation.
- **Data standardisation and format heterogeneity**. Preliminary interactions with pilots revealed that operational data may be available in heterogeneous formats depending on the information systems used by logistics operators or municipalities. Additional work will therefore be required to ensure harmonisation and interoperability within the data models implemented in the Shift2Zero platform.

Despite these remaining gaps, the information collected during Task 5.1 provides a solid basis for the definition of the data architecture supporting the Shift2Zero pilots

6.2 Risks and Mitigation Actions

The collaboration with pilot partners, local authorities and technical stakeholders has been generally positive and characterised by a good level of responsiveness and engagement. This cooperation allowed the activities of Task 5.1 to progress without delays.

Nevertheless, considering the complexity of the project and the interdependencies between work packages, several potential risks have been identified that may influence the effectiveness of data collection, modelling activities and KPI evaluation. Monitoring these risks and implementing appropriate mitigation actions will be important to ensure the successful implementation of pilot activities.

The main risks identified at this stage include:

R1: Misalignment between WP5, WP6 and WP7 timelines. The activities related to data model refinement and engine development in WP5, pilot implementation in WP6, and KPI definition and evaluation in WP7 are closely interconnected. Any significant temporal misalignment between these activities may affect the ability to collect the necessary data or to apply analytical tools during pilot operations.

Mitigation: establish a coordinated planning and monitoring process across the three work packages, including regular checkpoints, joint technical meetings and progressive validation milestones to ensure alignment between data requirements, pilot implementation and impact evaluation activities.

R2: Limited availability or sensitivity of operational data. Certain operational datasets may be difficult to share due to technical limitations, confidentiality concerns or commercial sensitivity. This could limit the availability of real operational data required to run analytical engines or computing specific KPIs.

Mitigation: conduct a detailed mapping of operational processes and data providers in each pilot, identify potential data-sharing constraints early in the process, and develop alternative data acquisition strategies such as anonymisation procedures, aggregated datasets, or the use of simulated data where necessary.

R3: Heterogeneity of data sources and IT systems. Different logistics operators and cities rely on diverse information systems, data formats and reporting standards. This heterogeneity may complicate the integration of datasets within the Shift2Zero platform and increase the effort required for data harmonisation.

Mitigation: define common data structures and semantic models within WP5 and implement flexible data ingestion mechanisms within the platform capable of supporting both API-based and batch-based data exchange.

R4: Progressive development of analytical engines. Some analytical engines and digital tools developed in WP5 are still under development. This may temporarily limit the ability of pilots to assess their potential usefulness or to integrate them in operational workflows.

Mitigation: organise demonstration sessions and technical exchanges with pilot partners as the development of engines progresses, allowing pilots to progressively evaluate their applicability and prepare the required data flows.

These risks will be discussed at project level and included in the risk register managed in WP1.

6.3 Recommendations for Integration in S2Z Platform

The analysis carried out in Task 5.1 provides several recommendations for the effective integration of pilot data within the Shift2Zero platform, which will be further developed in subsequent tasks.

First, the platform should support **flexible data ingestion mechanisms**, allowing pilots to provide data through multiple channels depending on their technical capabilities. These mechanisms may include direct API connections, automated batch uploads or manual data imports. Such flexibility is essential to accommodate the diversity of information systems used by logistics operators and city authorities.

Second, the platform architecture should ensure **semantic interoperability across datasets**, building upon the data models and ontologies defined in this deliverable. Standardised entities describing vehicles, deliveries, routes, charging infrastructure and operational events should serve as the common reference framework for integrating pilot data and supporting analytical processes.

Third, the integration of **analytical engines and digital tools** should follow a modular architecture aligned with the Physical Internet principles adopted by the project. This approach will allow different engines to access shared datasets within the platform while maintaining flexibility to adapt to the specific needs of each pilot.

Finally, the platform should support the **systematic generation and monitoring of KPIs**, enabling the integration between operational data, analytical outputs and the impact evaluation framework developed in WP7. This will allow data collected during pilot operations to be processed efficiently and reused for both real-time monitoring and scenario analysis.

7. Appendix

Table 1. Cargo loading engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Vehicle ID		OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
	Dimensions	One Shot	OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
	Volume Capacity		OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
	Payload Capacity		OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
	Gross Vehicle Weight		OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
	Type/Model		OEM technical specifications / existing vehicle records (LSPs)	OEMs + LSPs
Order	Order ID	Daily Update	Excel file + API (LSPs)	LSPs
	Quantity		Excel file + API (LSPs)	LSPs
	Total Weight, Total Volume		Excel file + API (LSPs)	LSPs
	Service Time		Excel file + API (LSPs)	LSPs
	Stackability		Excel file + API (LSPs)	LSPs
	Required Temperature		Excel file + API (LSPs)	LSPs
	Special tags		Excel file + API (LSPs)	LSPs
	Data per order/compartment for multi-temperature zones	One Shot	API (LSPs)	LSPs + pilot partner(s)

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	Returns volume and processing data		API (LSPs)	LSPs + pilot partner(s)
Operation	Modular Box Dimensions/ Weight	One Shot		
	Time taken to swap modules			LSPs
	Loading rules / examples	One Shot (Regular Update)	New tested software (LSPs)	LSPs
	Loading times		New tested software (LSPs)	LSPs
	Typical stop dwell times		New tested software (LSPs)	LSPs
Depot / Hub	Depot/Hub Locations	One Shot (Regular Update)		transshipment hubs TBD (LSPs)

Table 2 Charging scheduling engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Battery Capacity	One Shot	tbd	OEMs
	Usable Battery Capacity		tbd	OEMs
	Charging Power Acceptance		tbd	OEMs
	max charge		tbd	OEMs
	on-board charger details		tbd	OEMs
	connector type		tbd	OEMs
Vehicle Telemetry & Events	Battery State of Charge	Live Connection, Historical Data	New tested software (LSPs)	LSPs
	Charging events		New tested software (LSPs)	LSPs
Charging Point	Charger ID	One Shot (Regular Update of Infrastructure)	tbd	Public authority TBD / transshipment hubs TBD
	Type, Power Rating		tbd	Public authority TBD / transshipment hubs TBD

	Connector Type		tbd	Public authority TBD / transshipment hubs TBD
	Location		tbd	Public authority TBD / transshipment hubs TBD
	Cost per kWh		tbd	Public authority TBD / transshipment hubs TBD
Depot / Hub	Number of Charging Bays	One Shot (Regular Update)	tbd	Public authority TBD / transshipment hubs TBD
	Operating Hours		tbd	Public authority TBD / transshipment hubs TBD
	Depot/Hub Locations		tbd	Public authority TBD / transshipment hubs TBD
	Depot charger availability		tbd	Public authority TBD / transshipment hubs TBD
	Electricity Cost		tbd	Public authority TBD / transshipment hubs TBD
	Depot/site energy tariffs			Public authority TBD / transshipment hubs TBD
Operation	Geolocations of swap points	One Shot	New tested software (LSPs)	LSPs
	Data on energy flow from vehicles to APMs		New tested software (LSPs)	LSPs

Table 3 Decision Analytics engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Vehicle ID		tbd	OEMs + LSPs
	VIN	One Shot	tbd	OEMs
	type/model		tbd	OEMs + LSPs
	Year		tbd	OEMs + LSPs
	Gross Vehicle Weight		tbd	OEMs + LSPs
	Payload Capacity		tbd	OEMs + LSPs

	Volume Capacity		tbd	OEMs + LSPs
	Battery Capacity		tbd	OEMs
	Usable Battery Capacity		tbd	OEMs
	Regen efficiency		tbd	OEMs
	max power		tbd	OEMs
	Vehicle Lease/Depreciation Cost	One Shot (Regular Update)	tbd	OEMs
	Maintenance Cost		tbd	OEMs
	Depreciation assumptions		tbd	OEMs
Vehicle Telemetry & Events	Battery State of Charge	Live Connection, Historical Data	New tested software (LSPs)	LSPs
	Energy Consumption		New tested software (LSPs)	LSPs
	Odometer		New tested software (LSPs)	LSPs
	Speed		New tested software (LSPs)	LSPs
	CAN-bus diagnostics		New tested software (LSPs)	LSPs
	Onboard event logs		New tested software (LSPs)	LSPs
	GPS Coordinates		New tested software (LSPs)	LSPs
	GPS traces / route polylines		New tested software (LSPs)	LSPs
	Charging events		New tested software (LSPs)	LSPs
	Timestamp		New tested software (LSPs)	LSPs
Order	Order ID	Daily Update	Excel file + API	LSPs + pilot partners
	Order priority / customer type		Excel file + API	LSPs + pilot partners
	Order creation / update log		API	LSPs + pilot partners
	Quantity		Excel file + API	LSPs + pilot partners
	Total Weight, Total Volume		Excel file + API	LSPs + pilot partners

	Required Temperature		Excel file + API	LSPs + pilot partners
	Special tags		Excel file + API	LSPs + pilot partners
	Delivery Address		API	LSPs + pilot partners
	Service Time		Excel file + API	LSPs + pilot partners
	Time Window		Excel file + API	LSPs + pilot partners
	Data per order/compartment for multi-temperature zones	One Shot	API	LSPs + pilot partners
	Returns volume and processing data		API	LSPs + pilot partners
Operation	Loading rules / examples	One Shot (Regular Update)	New tested software	LSPs
	Loading times		New tested software	LSPs
	Typical stop dwell times		New tested software	LSPs
	Vehicle assignment policy			LSPs
	Driver shift rules			LSPs
	Driver Cost			LSPs
	Modular Box Dimensions/ Weight	One Shot		Other partners
	Records of mixed passenger/goods transport			LSPs
	Geolocations of swap points		New tested software	LSPs
	Time taken to swap modules		New tested software	LSPs
	Data on energy flow from vehicles to APMs		New tested software	LSPs
	Vehicle Booking patterns &		New tested software	LSPs

	utilization rates			
Depot / Hub	Number of Charging Bays	One Shot (Regular Update)	tbd	Public authority TBD / transshipment hubs TBD
	Depot charger availability		tbd	Public authority TBD / transshipment hubs TBD
	Depot/Hub Locations		tbd	Public authority TBD / transshipment hubs TBD
	Operating Hours		tbd	Public authority TBD / transshipment hubs TBD
	Electricity Cost		tbd	Public authority TBD / transshipment hubs TBD
	Depot/site energy tariffs		tbd	Public authority TBD / transshipment hubs TBD
Charging Point	Location	One Shot (Regular Update of Infrastructure)	tbd	Public authority TBD / transshipment hubs TBD
	Charger ID		tbd	Public authority TBD / transshipment hubs TBD
	Type, Power Rating		tbd	Public authority TBD / transshipment hubs TBD
	Cost per kWh		tbd	Public authority TBD / transshipment hubs TBD
UVAR	Toll/UVAR Access Fees	One Shot (Regular Update)		
	UVAR details			
Road Network	Historical average speeds on key routes	One Shot (Regular Update)		

Table 4 VRP engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Order	Order ID	Daily Update	Excel file + API	LSPs + pilot partners
	Order priority / customer type		Excel file + API	LSPs + pilot partners
	Quantity		Excel file + API	LSPs + pilot partners

	Total Weight, Total Volume		Excel file + API	LSPs + pilot partners
	Required Temperature		Excel file + API	LSPs + pilot partners
	Special tags		Excel file + API	LSPs + pilot partners
	Delivery Address		API	LSPs + pilot partners
	Time Window		Excel file + API	LSPs + pilot partners
	Service Time		Excel file + API	LSPs + pilot partners
Operation	Loading times	One Shot (Regular Update)	New tested software	LSPs
	Typical stop dwell times		New tested software	LSPs
	Driver shift rules			LSPs
	Vehicle assignment policy			LSPs
	Driver Cost			LSPs
	Records of mixed passenger/goods transport	One Shot		
	Geolocations of swap points		New tested software	LSPs
	Time taken to swap modules		New tested software	LSPs
	Modular Box Dimensions/ Weight		New tested software	LSPs
	Vehicle Booking patterns & utilization rates		New tested software	LSPs
Depot / Hub	Depot/Hub Locations	One Shot (Regular Update)		Public authority TBD / transshipment hubs TBD
	Number of Charging Bays			Public authority TBD / transshipment hubs TBD
	Operating Hours			Public authority TBD / transshipment hubs TBD
Vehicle	Vehicle ID			OEMs + LSPs
	type/model	One Shot		OEMs + LSPs
	Dimensions			OEMs + LSPs

	Payload Capacity			OEMs + LSPs
	Gross Vehicle Weight			OEMs + LSPs
	Volume Capacity			OEMs + LSPs
	Maintenance Cost	One Shot (Regular Update)		OEMs
Vehicle Telemetry & Events	GPS Coordinates	Live Connection, Historical Data	New tested software	LSPs
	GPS traces / route polylines		New tested software	LSPs
Road Network	Road / Map extract	One Shot (Regular Update)		Public authority (LSPs)
	Elevation / DEM / gradients			Public authority (LSPs)
	Historical average speeds on key routes			Public authority (LSPs)
UVAR	Toll/UVAR Access Fees	One Shot (Regular Update)		Public authority (LSPs)
	UVAR details			Public authority (LSPs)
Charging Point	Location	One Shot (Regular Update of Infrastructure)		Public authority TBD / transshipment hubs TBD

Table 5 Order data communication engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Order	Order ID	Daily Update	Excel file + API	LSPs + pilot partners
	Quantity		Excel file + API	LSPs + pilot partners
	Order priority / customer type		Excel file + API	LSPs + pilot partners
	Total Weight, Total Volume		Excel file + API	LSPs + pilot partners
	Delivery Address		API	LSPs + pilot partners
	Time Window		Excel file + API	LSPs + pilot partners
	Service Time		Excel file + API	LSPs + pilot partners

	Order creation / update log		API	LSPs + pilot partners
	Required Temperature		Excel file + API	LSPs + pilot partners
	Special tags		Excel file + API	LSPs + pilot partners
	Data per order/compartment for multi-temperature zones	One Shot	Excel file + API	LSPs + pilot partners
	Returns volume and processing data		API	LSPs + pilot partners

Table 6 Road data extraction engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Road Network	Road / Map extract	One Shot (Regular Update)		Public authority
	Elevation / DEM / gradients			Public authority
	Historical average speeds on key routes			Public authority
UVAR	UVAR details	One Shot (Regular Update)		Public authority
Order	Delivery Address	Daily Update	API	LSPs + pilot partners
Vehicle Telemetry & Events	GPS Coordinates	Live Connection, Historical Data	New tested software	LSPs
Charging Point	Location	One Shot (Regular Update of Infrastructure)		Public authority TBD / transshipment hubs TBD
Operation	Geolocations of swap points	One Shot	New tested software	LSPs

Table 7 Simulation engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Battery Capacity	One Shot	tbd	OEMs
	Year		tbd	OEMs + LSPs
	Regen efficiency		tbd	OEMs
	Vehicle Lease/Depreciation Cost	One Shot (Regular Update)	tbd	OEMs
	Maintenance Cost		tbd	OEMs
	Depreciation assumptions		tbd	OEMs
Vehicle Telemetry & Events	CAN-bus diagnostics	Live Connection, Historical Data	New tested software	LSPs
	Energy Consumption		New tested software	LSPs
	Onboard event logs		New tested software	LSPs
	Speed		New tested software	LSPs
	GPS traces / route polylines		New tested software	LSPs
	Timestamp		New tested software	LSPs
Order	Time Window	Daily Update	Excel file + API	LSPs + pilot partners
	Order creation / update log		API	LSPs + pilot partners
	Order priority / customer type		Excel file + API	LSPs + pilot partners
	Returns volume and processing data	One Shot	API	LSPs + pilot partners
Depot / Hub	Depot charger availability	One Shot (Regular Update)	tbd	Public authority TBD / transshipment hubs TBD
	Electricity Cost		tbd	Public authority TBD / transshipment hubs TBD
	Depot/site energy tariffs		tbd	Public authority TBD / transshipment hubs TBD
Operation	Data on energy flow	One Shot	New tested software	LSPs

	from vehicles to APMs			
	Vehicle Booking patterns & utilization rates		New tested software	LSPs
	Records of mixed passenger/goods transport			
	Modular Box Dimensions/ Weight			OEMs
	Time taken to swap modules		New tested software	LSPs
	Driver shift rules	One Shot (Regular Update)	tbd	LSPs
	Vehicle assignment policy		tbd	LSPs
	Driver Cost		tbd	LSPs
UVAR	Toll/UVAR Access Fees	One Shot (Regular Update)	tbd	Public authority
	UVAR details		tbd	Public authority
Charging Point	Cost per kWh	One Shot (Regular Update of Infrastructure)	tbd	Public authority TBD / transshipment hubs TBD

Table 8 Vehicle communication engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Vehicle ID		Tbd	OEMs
	VIN	One Shot	Tbd	OEMs / LSPs
	Battery Capacity		Tbd	OEMs / LSPs
	Charging Power Acceptance		Tbd	OEMs / LSPs
	max charge		Tbd	OEMs / LSPs
	connector type		Tbd	OEMs / LSPs
	Battery State of Charge	Live Connection,	Tbd	OEMs / LSPs

Vehicle Telemetry & Events	Energy Consumptio	Historical Data	Tbd	OEMs / LSPs
	Odometer		Tbd	OEMs / LSPs
	Speed		Tbd	OEMs / LSPs
	Timestamp		Tbd	OEMs / LSPs
	CAN-bus diagnostics		Tbd	OEMs / LSPs
	Onboard event logs		Tbd	OEMs / LSPs
	GPS Coordinates		Tbd	OEMs / LSPs
	GPS traces / route polylines		Tbd	OEMs / LSPs
	Charging events		Tbd	OEMs / LSPs
Charging Point	Charger ID	One Shot (Regular Update of Infrastructure)	Tbd	LSPs / public authority
	Connector Type		Tbd	LSPs / public authority
Operation	Data on energy flow from vehicles to APMs	One Shot	Tbd	LSPs / pilots

Table 9 Vehicle model consumption engine

Entity	Attributes (data points)	Frequency	Delivery Method	Data Provider
Vehicle	Vehicle ID	One Shot	tbd	OEMs + LSPs
	type/model		tbd	OEMs + LSPs
	Gross Vehicle Weight		tbd	OEMs + LSPs
	Payload Capacity		tbd	OEMs
	Battery Capacity		tbd	OEMs
	Usable Battery Capacity		tbd	OEMs
	Regen efficiency		tbd	OEMs
	Charging Power Acceptance		tbd	OEMs

	on-board charger details		tbd	OEMs
	max charge		tbd	OEMs
	max power		tbd	OEMs
Vehicle Telemetry & Events	Battery State of Charge	Live Connection, Historical Data	New tested software	LSPs
	Odometer		New tested software	LSPs
	Speed		New tested software	LSPs
	Energy Consumption		New tested software	LSPs
Order	Total Weight, Total Volume	Daily Update	Excel file + API	LSPs + pilot partners
	Data per order/compartment for multi-temperature zones	One Shot	Excel file + API	LSPs + pilot partners
Road Network	Road / Map extract	One Shot (Regular Update)	tbd	Public authority
	Elevation / DEM / gradients		tbd	Public authority
	Historical average speeds on key routes		tbd	Public authority
Charging Point	Type, Power Rating	One Shot (Regular Update of Infrastructure)	tbd	Public authority TBD / transshipment hubs TBD