# D5.2 Governance models & digital solutions for S2Z pilots

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# Executive summary

Project summary

*Shift2Zero, Shifting to zero-emission logistics through right-sized, mission-focused, N1 e-LCVs*

***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 e-LCVs".***

***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: Gruber, 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 5.2, Digital solutions and monitoring platforms integration for Physical Internet compliance, carried out within Work Package 5 of the Shift2Zero project. Its purpose is to define the organisational, functional and technical conditions required to connect pilot operations, existing information systems, vehicle data sources, optimisation tools and the S2Z Urban Logistics Management Platform.

D5.2 represents the second step in the WP5 implementation sequence. D5.1 established the common data and KPI foundations by identifying the information required by the pilots, defining preliminary data models and linking operational, technical and economic data to the project impact assessment framework. D5.2 builds on these results and shifts the focus from data definition to data integration. It examines who owns and provides the required data, how and when they can be exchanged, which software component uses them, which outputs are generated and under which governance and access conditions the information can be processed.

This position in the project work plan makes D5.2 a bridge between requirements definition and operational implementation. Its results provide input to Task 5.3, which develops the software, algorithms and Internet of Things-enabled decision analytics tools; Task 5.4, which integrates tools and data streams into the S2Z Urban Logistics Management Platform; and Task 5.5, which uses pilot data and simulation models to assess alternative and scaled-up scenarios. The deliverable also supports WP6 in preparing and documenting the real-life demonstrations and WP7 in ensuring that the data generated during pilot execution can be transformed into consistent, traceable and comparable impact indicators.

The methodological approach combined the review of D5.1 results with pilot-specific interviews and technical exchanges involving logistics operators, municipalities, vehicle providers and WP5 partners. The Business Process Models developed in D5.1 were reviewed and updated to identify the relevant S2Z engines, data production points, system interactions and information flows. The findings were then consolidated into a common governance, functional and connector framework.

The analysis was organised around a common reference architecture that groups the S2Z engines into three functional macro-blocks:

- the Data Ingestion macro-block collects and prepares road and regulatory information, order and mission data, and vehicle or telemetry data;
- the Planning and Execution macro-block supports routing, vehicle energy assessment, cargo loading and charging decisions where these functions are relevant to the pilot;
- the Completion and Evaluation macro-block uses planned and executed information for monitoring, KPI calculation, operational reporting and scenario simulation.

This architecture provides a common way to describe the pilots without assuming that all sites will use the same engines, interfaces or operational workflows. A central conclusion of D5.2 is that the S2Z integration model must remain modular and proportional to the needs and digital maturity of each pilot. In some sites, selected engines may support operational planning or execution directly. In others, logistics operators will continue to use their existing planning systems and will provide planned and executed data to S2Z for monitoring, benchmarking or ex-post assessment. Simulation and strategic analysis will mainly operate offline, using representative, historical or pilot-generated data to assess alternative operational, regulatory, infrastructure or fleet configurations.

The methodology also distinguishes between two main data exchange patterns:

- machine-to-machine integration includes application programming interfaces, database connections, message-based communication and other automated mechanisms suitable for recurring or frequently updated data;
- human-in-the-loop integration includes the manual upload of structured files, manual configuration of rules and operator interaction with the platform interface. This second pattern is relevant where a full automated connection

would require disproportionate development effort or where the demonstration can be supported effectively through controlled file-based exchanges.

Both patterns are part of the proposed architecture and can coexist within the same pilot.

A major result of the deliverable is the development of a federated and multi-level governance framework for collaborative urban logistics. The framework recognises that logistics operators, municipalities, vehicle manufacturers and technology providers have different responsibilities, information needs and commercial interests. Data therefore remain under the control of their original owners, while access is granted for defined project purposes and according to specific roles. The framework covers data ownership, permitted uses, sensitivity levels, access rights, data minimisation, anonymisation or pseudonymisation, quality control and responsibilities for updating information.

A Pilot Data Governance Matrix is proposed as the main practical instrument for applying these principles. It identifies the required data or output, its owner, authorised users, intended purpose, sensitivity level, sharing conditions and restrictions. The matrix will support the identification of missing datasets, the management of access rights and the validation of information used for KPI calculation, simulation and impact assessment. The deliverable also defines mitigation measures for risks related to commercially sensitive information, proprietary vehicle data, poor data quality, outdated regulatory layers, connector failures and changes in pilot configuration.

D5.2 therefore defines a minimum viable data exchange for each pilot including the smallest structured dataset needed to activate the relevant S2Z functions. It typically covers order or trip information, road and regulatory data, vehicle or execution data and delivery outcome information. The platform must support different levels of integration maturity, from structured manual uploads to secure file transfer, application programming interfaces and database-level connections. Engine outputs must also remain reusable through different channels. They may be displayed in the S2Z platform, exported to the operator's systems, processed by technical partners or transferred to WP7 for KPI calculation.

The connector architecture translates these functional needs into a common technical framework. It provides an interoperability layer between the S2Z platform and heterogeneous external systems without requiring project partners to replace or redesign their existing software environments. Three main connector categories are defined: pilot system connectors for order, mission and operational information; vehicle connectors for telemetry and vehicle communication; and city infrastructure connectors for road, regulatory, geospatial and access-management information.

The deliverable specifies several communication patterns, including request-response communication, batch file exchange, event-driven communication and scheduled synchronisation. These patterns reflect the different operational characteristics of the data. Order files may be exchanged once or several times per day. Vehicle events may require more frequent or near-real-time communication. Municipal geographic or regulatory datasets may be updated only when rules change. Proof-of-delivery and

execution data may be provided after route completion where real-time transmission is not required.

For each engine macro-block, D5.2 identifies the main data inputs, expected outputs, potential providers, exchange frequency and technical considerations. The deliverable also defines a progressive connector development and validation roadmap. This roadmap moves from data availability and structural mapping to platform communication, engine interoperability, operational execution and evaluation readiness. The objective is to avoid deploying connectors before the required datasets, responsibilities and use cases have been sufficiently validated.

Some implementation choices remain open at the time of completion of this deliverable, such as final file schemas for some pilots, data extraction procedures, transfer frequencies, access arrangements, telemetry interfaces. These issues reflect the progressive preparation of the demonstrations and the different maturity levels of the partner systems. They do not alter the common architecture or governance principles defined in D5.2.

The deliverable also establishes the basis for the handover to WP6 and WP7. Before each demonstration, pilot leaders, data providers, WP5 technical partners and WP7 representatives will need to consolidate practical data collection protocols. These protocols will define the purpose, source, format, frequency, responsible provider, quality requirements, sensitivity and access conditions for each critical dataset. They will also distinguish the operational baseline from the S2Z intervention so that changes in performance can be interpreted consistently.

No substantive deviation from the objectives of Task 5.2 in the Grant Agreement has been introduced. The deliverable retains the three complementary elements foreseen in the Description of Action: governance models for collaborative operations, a unified architectural reference integrating user, system and vehicle requirements, and connector design for platform, company, vehicle and urban infrastructure integration. The detailed organisation of the engines into functional macro-blocks, the pilot-specific integration patterns, the governance matrix and the readiness framework operationalise these objectives and provide a more concrete basis for implementation. They do not change the scope of the task.

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# Terminology and Acronyms

| | |
|---|---|
| API | Application Programming Interface |
| APM | Automated Parcel Machine |
| BPM | Business Process Modelling |
| CAN | Controller Area Network |
| EC | European Commission |
| ERP | Enterprise Resource Planning |
| *eHDV* | *electric Heavy Duty Vehicle* |
| *eLCV* | *electric Light Commercial Vehicle* |
| *ETA* | *Estimated Time of Arrival* |
| *EU* | *European Union* |
| *FP* | *Framework Programme* |
| *GIS* | *Geographic Information System* |
| *GPS* | *Global Positioning System* |
| *IT* | *Information Technology* |
| *KPI* | *Key Performance Indicator* |
| *LCA* | *Life Cycle Assessment* |
| *LCV* | *Light Commercial Vehicle* |
| *LSP* | *Logistics Service Provider* |
| *LEZ* | *Low Emission Zone* |
| *MDS* | *Mobility Data Specification* |
| *OBU* | *On-Board Unit* |
| *OEM* | Original Equipment Manufacturer |
| *OSRM* | Open-Source Routing Machine |
| *PI* | Physical Internet |
| *PoD* | Proof of Delivery |
| *SoC* | State of Charge |
| *SULP* | Sustainable Urban Logistics Plan |
| *SUMP* | Sustainable Urban Mobility Plan |
| S2Z | Shift2Zero |
| TCO | Total Cost of Ownership |
| *TMS* | Transport Management System |
| *TOMP* | *Transport Operator to Mobility-as-a-Service Provider* |
| UVAR | Urban Vehicle Access Regulations |
| VRP | Vehicle Routing Problem |
| WMS | *Warehouse Management System* |
| WP | Work Package |
| ZEZ | Zero Emission Zone |

# 1. Introduction

This deliverable presents the work carried out in Task 5.2 of WP5. Its purpose is to define how governance arrangements, digital solutions and data exchange mechanisms can support the preparation, execution and evaluation of the Shift2Zero pilots. Building on the data models, process descriptions and KPI requirements developed in D5.1, the deliverable moves from identifying which information is needed to defining how that information can be governed, exchanged and used by the S2Z engines and platform.

The deliverable therefore connects pilot operations with the digital and analytical components developed in WP5. It provides a common integration framework while recognising that the pilots differ in operational organisation, existing information systems, data availability and technical maturity. This work supports the development and integration of the S2Z tools, prepares the information flows required for the WP6 demonstrations and establishes a traceable link between pilot data, analytical outputs, simulations and the WP7 impact assessment.

## 1.1 Objectives of the deliverable

The objective of this deliverable is to define the governance, functional and technical foundations required to integrate pilot systems, data sources and S2Z digital solutions. More specifically, it updates the pilot process models to identify where the S2Z engines interact with operational activities, defines governance principles for collaborative data sharing, describes the functional role of the S2Z platform and establishes the connector architecture required to exchange information between pilot actors and project tools.

The deliverable also specifies the main data exchange requirements associated with the S2Z engine macro-blocks and proposes a progressive approach to connector development, validation and deployment. It does not impose a single integration model across all pilots. Instead, it supports different levels of technical maturity, ranging from manual exchange of structured files to automated system-to-system connections. In this way, the deliverable provides a common basis for the remaining WP5 developments, the organisation and documentation of the WP6 demonstrations and the production of consistent and traceable evidence for WP7.

## 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** presents the methodological framework used to update the pilot process models, organise the S2Z engines into functional macro-blocks and analyse data exchange and platform integration requirements.
- **Chapter 3** defines the data governance framework for collaborative urban logistics, including the relevant actors, potential data-sharing conflicts, governance principles, sensitivity levels and mitigation mechanisms.

- **Chapter 4** consolidates the functional integration between pilot systems and the S2Z Platform and outlines the end-to-end information flows required to support the WP6 demonstrations. Detailed pilot-specific analyses are provided in Annex A.
- **Chapter 5** presents the connector architecture, communication patterns, technical specifications, platform usage modes, replicability principles and the proposed validation and deployment pathway. Detailed data exchange requirements associated with the individual S2Z engines are provided in Annex B.
- **Chapter 6** concludes the deliverable by consolidating its contribution to pilot readiness, defining the basis for data production and collection during WP6 and explaining how observed, derived and simulated evidence will support the WP7 impact assessment.
- **Annex A** provides the detailed pilot integration fiches, including the updated BPMs, actors, data exchanges, engine macro-blocks and open implementation issues.
- **Annex B** provides the detailed data exchange requirements associated with the individual S2Z engines.

# 2. Methodological Framework for Data Integration and Operational Deployment

This chapter describes the methodological approach used to move from the data and process foundations defined in D5.1 to the operational integration logic required for the S2Z pilots. The purpose is to define a common method to understand how pilot operations, data sources and the S2Z Platform can interact during preparation, execution and evaluation of the pilot activities.

The starting point is the outputs provided in D5.1, providing the initial structure for identifying which operational, technical and economic data are relevant for the pilots and how such data can support routing, charging, loading, vehicle consumption modelling, decision analytics and simulation. D5.2 builds on this basis by shifting the focus from data definition to data integration. The key methodological question is therefore not only which data are needed, but also who can provide them, when they can be provided, in which format, through which exchange mechanism, and under which governance conditions.

## 2.1 Pilot interview process and update of operational process models

The methodological work was based on pilot interviews with logistics operators, municipalities, vehicle partners and technical partners for each pilot. The interviews were used to validate the operational processes mapped in D5.1, identify changes in the pilot configuration, and understand where the S2Z engines should enter the process.

The BPM models developed in D5.1 were then revised to include the interaction with the S2Z engines. The updated BPMs are not intended to provide a complete operational manual for each pilot. They are simplified process views designed to show where data are produced, where data are consumed, which actor is responsible for each relevant information flow, and which engine block uses or provides the information. For this reason, the updated diagrams reduce the number of operational activities compared with the original BPMs and add a dedicated engine lane.

## 2.2 Reference architecture and engine macro-blocks

The methodology adopts a common reference architecture structured around three functional phases: data ingestion, planning and execution, and completion and evaluation. This architecture, reported in the figure below using the component diagram, provides the general logic for reading pilot processes in a consistent way while preserving the specificities of each pilot. It also avoids presenting the S2Z engines as isolated tools. Instead, the engines are grouped into macro-blocks that correspond to the main information flows of the pilots.

1. The first macro-block is **Data Ingestion**. It includes the Road Data Extraction Engine, the Order Data Communication Engine and the Vehicle Communication Engine. This block collects and prepares the main data streams required by the toolbox: road and regulatory data from municipalities or public sources, order and mission data from logistics operators, and vehicle or telemetry data from OEMs or vehicle systems.

2. The second macro-block is **Planning and Execution**. It includes the Vehicle Model Consumption Engine, the VRP Engine, the Cargo Loading Engine and the Charging Scheduling Engine. This block supports route planning, energy feasibility checks, vehicle assignment, loading logic and charging decisions, depending on the operational relevance of each function for the specific pilot.
3. The third macro-block is **Completion and Evaluation**. It includes the Decision Analytics Engine and the Simulation Engine. This block uses planned and executed data to support monitoring, KPI calculation, operational reporting and scenario assessment. The Simulation Engine is treated mainly as an offline or strategic component, useful for testing alternative operational, regulatory or infrastructure scenarios before or after pilot execution.

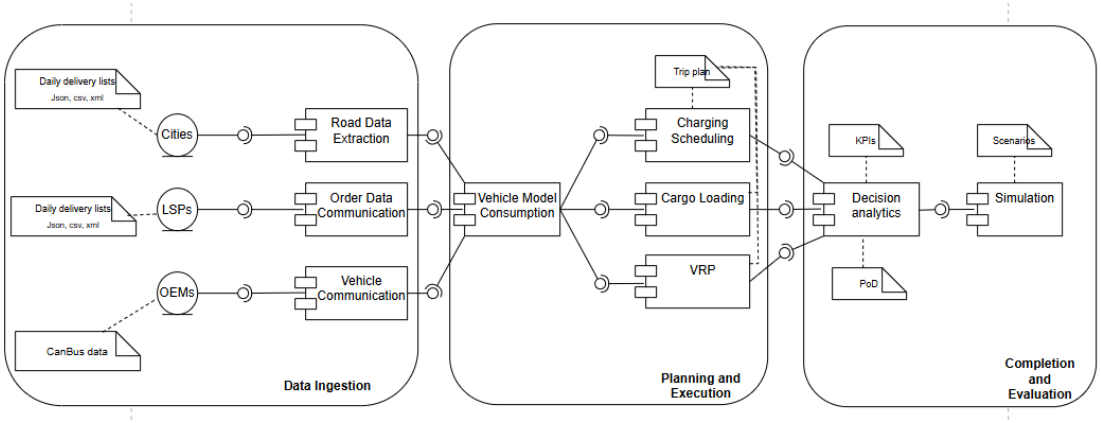



*Figure 1. S2Z Reference Architecture*

The S2Z Platform is intended as a transversal layer across these three macro-blocks. The platform is the access point through which users may upload data, consume engine outputs, visualise monitoring information, inspect route progress, access vehicle status, manage geofencing information, and use operational analytics. Its final implementation will depend on pilot-specific data availability and on the integration choices that emerge from the D5.2 analysis.

## 2.3 Data exchange and platform integration logic

A core part of the methodology concerns the identification of possible data exchange mechanisms between pilot actors and the S2Z platform. D5.2 does not assume that all pilots will be able to provide data in the same way or at the same frequency. The analysis therefore distinguishes between two main integration patterns:

- **Machine-to-machine exchange**, including APIs, structured database connections, message-based exchange or other automated mechanisms. This pattern is more suitable where pilot systems can provide structured and recurring data flows, for example order datasets, telemetry feeds, or proof-of-delivery records. It is also the preferred direction for more advanced integration, especially where the same data need to be updated frequently or used close to real time.

- **Human-in-the-loop exchange**, including manual upload of structured files to the platform, operator use of the platform interface, manual configuration of rules or manual download of engine outputs. This pattern is relevant for pilot demonstration phases where full system-to-system integration would be disproportionate, unavailable or premature. It allows the project to test the S2Z engine logic even when pilots cannot yet provide live data connections.

This approach reflects the current maturity of the pilots and keeps the methodology realistic.

## 2.4 Methodological output for pilot analysis

The output of this methodology is a pilot-by-pilot integration analysis provided in Annex A. Each pilot has been analysed through the same structure, but with different levels of detail depending on the information available. The updated BPMs are used as visual entry points to the analysis. For each pilot, Annex A describes the operational configuration, the relevant engine macro-blocks, the main data exchanged, the expected platform interaction and the open issues still to be resolved. Where sufficient information is available, the analysis specifies data provider, data consumer, expected format, frequency, transfer mechanism, sensitivity and responsible actor. Where this information is not yet available, the chapter identifies the missing decision and explains why it matters for platform integration, connector design or pilot readiness.

# 3. Data Governance Framework for Collaborative Urban Logistics

Shift2Zero introduces a collaborative urban logistics environment in which new N1 eLCV concepts, pilot operations, optimisation engines, simulation tools and impact assessment activities are connected through a common digital architecture. The governance framework developed in this chapter builds directly on the data foundations defined in D5.1 and extends them towards the operational, organisational and decision-making conditions required for pilot implementation.

## 3.1 Governance Scope and Challenges in S2Z Collaborative Logistics Ecosystems

The scope of governance in D5.2 concerns the set of rules, responsibilities and procedures through which S2Z partners can share, process and reuse data in a controlled manner, while preserving the autonomy of logistics operators, vehicle manufacturers, municipalities and technology providers. The objective is to define a common governance layer allowing the S2Z platform and related engines to access the minimum information required for agreed purposes, such as routing optimisation, charging scheduling, cargo loading, energy consumption modelling, simulation, KPI calculation and urban logistics monitoring.

This section therefore addresses governance models for collaborative operations, integration with user and system requirements, and connector design between the S2Z platform and pilot platforms to enhance Physical Internet (PI) led operations. The governance framework must therefore act as a bridge between operational needs emerging from the pilots, user and system requirements developed in WP2, vehicle and component innovations developed in WP3, and the digital tools and platform architecture developed in WP5.

The **governance challenge** is particularly relevant because S2Z pilots involve heterogeneous operational configurations, different types of logistics actors, different levels of digital maturity and different regulatory contexts. As identified in D5.1, the project covers operational data, such as routing information, delivery volumes and service times; technical data, such as vehicle characteristics, battery performance and charging behaviour; and economic data, such as total cost of ownership components, operational costs and productivity indicators. Despite this diversity, D5.1 also identifies a convergence of data structures across pilots, allowing the development of a harmonised core architecture while maintaining flexibility for pilot-specific features.

This convergence creates the foundation for collaborative digital integration, but it also generates governance issues:

- **operational data** may reveal commercially sensitive information on delivery volumes, customer locations, service patterns or fleet productivity
- **technical data** may include proprietary information on vehicle design, energy management, battery behaviour, charging strategies or modular cargo body performance;

- **municipal data** may define access restrictions, geofencing rules, loading areas, curbside constraints or regulatory conditions;
- **analytical outputs** generated by the S2Z engines may themselves become sensitive, since optimised routes, charging plans, loading plans, simulation scenarios or KPI dashboards can indirectly reveal business-relevant information.

The governance scope also includes the relationship between data and physical assets in order to support decisions on the allocation, use and optimisation of vehicles, charging infrastructure, depots, hubs, loading areas, lockers, curbside space and urban access rights. This perspective is reinforced by the DISCO project, which frames urban logistics innovation around the coordinated use of underused lands, urban and peri-urban spaces, shared infrastructure and data-driven planning, supported by standards, connectors and voluntary data sharing. DISCO also highlights that logistics networks should be interconnected without forcing operators to change their internal operating models, but by requiring adherence to interconnection standards.

The URBANE project also provides a useful reference for S2Z governance, especially for the organisation of collaborative urban logistics in Living Lab environments. Its main contribution to this deliverable is the idea that PI-oriented governance should combine local adaptability with common interoperability rules. For S2Z, this means defining pilot-specific arrangements while maintaining shared rules for interfaces, data exchange, access rights and output visibility. This logic is reflected in the following sections through the proposed federated governance model and the distinction between pilot, urban and platform governance layers.

This is particularly relevant for S2Z: the interface-level approach reduces the burden on pilot partners, supports interoperability across heterogeneous systems, and limits the risk of exposing commercially sensitive information.

The governance framework must therefore address five main challenges that have been identified during WP5-WP6 activities and interviews with pilot stakeholders:

1. **Data availability and controlled disclosure**: S2Z requires operational, technical and economic data to feed the platform, the optimisation and simulation engines, and the KPI framework. Governance must ensure that these data are available for agreed project purposes while applying safeguards for confidential, commercially sensitive and privacy-relevant information.
2. **Cross-pilot harmonisation and local flexibility**: S2Z needs a common data model to support interoperability, engine development and cross-pilot comparability. At the same time, each pilot must retain the possibility to represent its specific operational process, actor configuration, vehicle concept, urban regulation and logistics constraints.
3. **Access rights for input data and digital outputs**: S2Z governance must define who can access each category of input data and who can use the outputs generated by the platform and engines. This applies both to operational execution and to ex-post simulation. Optimised routes, charging plans, loading plans, simulation results, dashboards and KPI analyses should be governed according to role, purpose, sensitivity and level of aggregation. Detailed operational outputs should remain visible to the concerned operator and authorised technical profiles,

while aggregated or indicator-based outputs can support pilot monitoring, impact assessment and policy discussion.

4. **Data quality, validation and update responsibility**: the reliability of S2Z optimisation, simulation and impact assessment depends on the accuracy, completeness and timeliness of the data provided by pilots and technical partners. Governance must assign clear responsibilities for data ownership, validation, update cycles, quality checks, anomaly management and traceability, building on the D5.1 data requirements registry and integrated data governance logic.
5. **Public-sector involvement and proportional information sharing**: municipalities require evidence to support urban access regulation, space management, geofencing, sustainability policies and SULP/SUMP-related planning. In the S2Z platform, cities may also define regulatory areas directly through the interface, for example by drawing polygons, or by uploading geospatial layers such as shapefiles. Governance must therefore address the accuracy, validity, versioning and responsibility of these regulatory inputs, since incorrect or outdated rules may affect route planning and operational efficiency. Cities should receive policy-oriented evidence through aggregated, anonymised or indicator-based outputs, while raw operational datasets owned by logistics operators remain protected.

The following sections translate these challenges into a structured actor mapping, conflict analysis, governance model and set of operational tools for S2Z pilots.

## 3.2 Actors, Objectives and Data-Sharing Conflicts

The S2Z collaborative logistics ecosystem includes several categories of actors whose roles, incentives and data positions differ. Governance must start from these differences. A data-sharing arrangement that is technically feasible may still fail if it does not address **commercial confidentiality, operational responsibilities, public policy needs, technical ownership or perceived value for participants**.

The main actor groups involved in S2Z have been classified as follows:

- Logistics service providers (LSP) and fleet operators
- Municipalities and public authorities
- OEMs and vehicle technology partners
- S2Z platform and technical integration partners

Pilot operators, cities and technology partners were involved in workshops and technical meetings to map logistics operations and identify the information flows needed to support WP5 digital optimisation tools and simulation engines. The governance framework must now clarify how these actors interact around data and outputs.

*Table 1. Actors, roles and potential conflict areas*

| Actor group | Main role in S2Z governance | Main objectives | Main data position | Potential conflict areas |
|---|---|---|---|---|
| **Logistics service providers and fleet operators** | Provide operational data and validate pilot feasibility | • Improve operational efficiency, reduce costs,<br>• test eLCV concepts,<br>• protect commercial position | Owners or providers of logistics operation data | • Commercial sensitivity, customer confidentiality,<br>• route disclosure,<br>• productivity benchmarking,<br>• exposure of operational weaknesses |
| **Municipalities and public authorities** | Define local regulatory context and support urban policy alignment | • Reduce emissions,<br>• manage access,<br>• improve urban space use,<br>• monitor impacts,<br>• support evidence-based planning | Providers of regulatory data and users of aggregated outputs | • Need for policy evidence versus protection of operator data;<br>• liability of access rules;<br>• update frequency of UVAR, geofencing or curbside information |
| **OEMs and vehicle technology partners** | Provide vehicle-related technical parameters and validate vehicle innovations | • Test right-sized mission-focused eLCV concepts,<br>• protect technical know-how,<br>• support performance assessment | Owners or providers of vehicle specifications, energy parameters, design constraints, component data, charging and performance data | • Protection of proprietary technical data,<br>• disclosure of performance limits,<br>• use of technical data beyond agreed purposes |
| **S2Z platform and technical integration partners** | Integrate data sources and provide controlled access to engines and dashboards | • Ensure interoperability, harmonised data flows, platform reliability and traceability | Processors and integrators of operational, technical, regulatory and analytical data | • Access control,<br>• data storage responsibility,<br>• security, traceability,<br>• integration with heterogeneous pilot systems |

The table shows that conflicts do not arise simply because actors are unwilling to share data. They arise because the same data can have different meanings depending on the user, purpose and level of granularity. A route dataset, for example, may be a technical input for the VRP engine, a performance indicator for OEMs, a compliance element for a city, and a commercially sensitive asset for the operator. A battery state-of-charge profile may be required for charging optimisation, but it may also reveal operational constraints or vehicle performance characteristics. A simulation output may support policy discussion, but it may also expose assumptions on costs, service levels or fleet productivity.

The main data-sharing conflicts in S2Z can be grouped into six categories:

1. **Commercial sensitivity of operational data**. Operational data are central to the S2Z platform and engines. Orders, delivery locations, delivery windows, service times, stops, trip sequences, vehicle utilisation, depot activities and cost data are required to model logistics operations, estimate KPIs and support optimisation. At the same time, these data can reveal market position, customer density, service patterns, route design, resource allocation and operational efficiency.
   The governance response should be based on purpose limitation, minimisation and tiered access. Detailed operational data should be accessible only where required for an agreed analytical function, such as route optimisation or simulation. For impact assessment and policy reporting, the preferred approach should be aggregation by time window, area, route category, vehicle type or pilot-level indicator. Operator-level comparison should be avoided unless explicitly agreed by the concerned partners.
2. **Operational confidentiality and competitive exposure**. Several S2Z use cases require information on fleet availability, loading operations, transhipment, charging schedules and operational constraints. These data support the testing of S2Z innovations, but they may also expose weaknesses or inefficiencies in the logistics process. This is relevant in collaborative scenarios where multiple operators, public authorities or technology partners interact through common tools.
   Governance should therefore distinguish between data needed for internal engine processing and information that can be shared across actors. For instance, an engine may need detailed vehicle availability to produce an optimised plan, while other partners may only need to see the resulting aggregated utilisation rate or KPI. This distinction reduces the risk that the platform becomes a channel for unintended disclosure among operators.
3. **Technical proprietary data from vehicle and component innovations**. WP3 introduces vehicle-related innovations that include modular and multipurpose cargo body designs, energy management, component optimisation, ergonomic and safety design, and vehicle control strategies. Some related deliverables are classified as sensitive in the Grant Agreement, which confirms the need to protect specific technical outputs and knowledge generated in vehicle design and testing activities.

This means that technical data required by S2Z engines should be limited to the parameters needed for modelling and decision support. The platform may need vehicle range, payload, energy consumption parameters, charging compatibility or relevant operational constraints. It does not necessarily need access to proprietary design details, component specifications or confidential test results unless explicitly required and authorised. Technical data governance should therefore apply parameter minimisation and controlled access.

4. **Regulatory and municipal data**. Municipalities provide or validate data on access rules, UVARs, LEZs/ZEZs, geofencing, loading areas, curbside restrictions, traffic conditions and other urban constraints. These data are essential for routing, simulation and compliance-related use cases. Their governance challenge is different from commercial data: the issue is not primarily confidentiality, but reliability, validity, update frequency and liability.
   If a regulatory layer is outdated or interpreted incorrectly, the resulting route plan or simulation may be misleading. Governance must therefore assign responsibility for validating municipal datasets and documenting their version, date of validity and scope of application. Where municipal data are used for optimisation or simulation, assumptions should be explicitly recorded.
5. **Analytical outputs and dashboard visibility**. S2Z governance must cover not only data inputs, but also outputs generated by the platform and engines. Optimised routes, charging plans, loading plans, consumption profiles, scenario results and KPI dashboards can contain sensitive information or support decisions with operational consequences.
   The visibility of outputs should be role-based. A logistics operator should see the route, charging or loading plan relevant to its own operations. A municipality should see aggregated results supporting urban policy, such as emissions reduction, access compliance, use of urban space or traffic-related effects. WP7 should receive the level of detail required for impact assessment, preferably through harmonised indicators and aggregated datasets. Cross-operator comparisons should be treated as sensitive and should not be produced without explicit agreement.
6. **Data quality, responsibility and update cycles**. The reliability of the S2Z platform depends on the quality of input data and the transparency of transformations. D5.1 already defined a governance logic based on a data requirements registry, ownership and validation responsibility for each data element and KPI, automated quality checks, anomaly detection, data minimisation, pseudonymisation, role-based access and encrypted storage and transfer.
   Building on this logic, each pilot should clarify who owns the data, who provides it, who validates it, how often it is updated, what happens when data are missing or inconsistent, and which mitigation measures are applied.

These conflict areas confirm the need for a structured governance model. The following section defines the federated and multi-level governance approach proposed for S2Z pilots, translating the actor and conflict analysis into roles, decision rights and operational procedures.

## 3.3 Federated and Multi-Level Governance Model for S2Z Pilots

The S2Z governance model is based on a federated and multi-level approach. This approach reflects the diversity of pilot contexts and the need to connect local operations, urban regulation, platform integration and cross-pilot evaluation within a coherent framework.

The model is based on three assumptions:

- pilot partners retain control over their internal systems, commercial data and operational procedures;
- the S2Z platform governs data exchange at the interface level, through connectors, data templates, APIs, access profiles and agreed processing purposes;
- public authorities support urban logistics governance through validated regulatory inputs and aggregated evidence.

The governance model is organised into the three following levels.

1. **Pilot level**, managing data exchange and engine use within each pilot. Governance focuses on operational feasibility and to define the specific scope, each pilot has been asked to clarify:
    - which S2Z engines will be used;
    - whether engines will support real operations, ex-post simulation, or both;
    - which datasets are required;
    - who owns and validates each dataset;
    - which data must be anonymised or pseudonymised at source;
    - which users can access detailed inputs and outputs;
    - which fallback procedures apply when data are missing or delayed.

    This layer is particularly relevant when S2Z engines support real pilot operations. In these cases, outputs such as route plans, loading sequences, charging schedules or feasibility checks may influence daily execution. The concerned operator should retain responsibility for accepting, adapting or rejecting these outputs before implementation, unless a different arrangement is explicitly agreed.
2. **Urban and regulatory level**, managing the role of cities and public authorities. Governance focuses on the accuracy and operational validity of city inputs. During the next period, Municipalities will provide or configure:
    - UVAR, LEZ or ZEZ rules;
    - geofencing areas;
    - access windows;
    - loading and curbside restrictions;
    - speed limits;
    - temporary restrictions;

    The main risk for these inputs concerns accuracy, validity and liability. A wrong polygon, outdated access rule or incomplete geospatial layer may affect routing, simulation results and operational efficiency. Municipalities or authorised public-

sector profiles should therefore validate the geographical scope, applicable rule, time validity and update cycle of each regulatory input.

3. **Platform level,** ensuring common rules across pilots. Governance focuses on interoperability. The S2Z platform should provide a controlled integration environment where pilot systems, engines, dashboards and KPI processes can interact. Its role is to organise data flows, connect pilot systems with the relevant engines, manage access to outputs and support monitoring, optimisation and assessment. Data ownership remains with the partner or entity that generates, controls or validates the data.

## 3.4 Governance Principles for Data, Assets and Digital Outputs

The S2Z governance framework is based on operational principles that apply to three categories of governed objects:

- **data**, including operational, technical, economic, regulatory and geospatial data;
- **physical assets**, including vehicles, hubs, depots, lockers, charging points, loading areas and access-controlled zones;
- **digital outputs**, including route plans, cargo loading sequences, charging schedules, energy estimates, simulation results, dashboards and KPIs.

The principles, outlined in the following table, translate the work developed in D5.1, the WP5 platform architecture and the inputs collected from pilot stakeholders into practical rules for data exchange and platform integration.

*Table 2. Governance principles and related operation meanings*

| Governance principle | Operational meaning for S2Z |
|---|---|
| Purpose limitation | Each dataset or output should be linked to a defined project function, such as routing, loading, charging, simulation, KPI calculation, monitoring or policy assessment |
| Data minimisation at source | The S2Z platform and engines should receive only the data required for the agreed purpose. Customer names, personal contacts and unnecessary identifiers should be removed before ingestion |
| Role-based and tiered visibility | Raw, processed, aggregated and anonymised data should have different access levels. Detailed outputs should be visible only to authorised users |
| Interface-level interoperability | Governance should focus on connectors, APIs, templates, upload modes, geospatial layers and validation procedures rather than on partners' internal systems |
| Federated data control | Data owners retain control over their data while the S2Z platform provides controlled access for agreed project purposes |
| Accuracy and versioning of regulatory inputs | City-defined polygons, shapefiles and access rules should be validated, versioned and documented before being used by the platform or engines |

| Governance principle | Operational meaning for S2Z |
|---|---|
| Traceability | Inputs, transformations, outputs, dashboards and KPIs should be traceable across the platform |
| Reciprocity | Data providers should receive operational or analytical value from S2Z tools, such as optimised routes, loading plans, charging support, KPI feedback or simulation results |
| Proportional governance by pilot | Governance intensity should reflect each pilot's complexity, engine use, data sensitivity and regulatory interaction |

These principles should guide the configuration of each pilot and contribute as non-functional requirements of the S2Z platform. Their application depends on the operational mode of the engines:

- **Operational execution**: engines process live or near-real data and return outputs used during pilot operations.
- **Ex-post simulation**: engines process historical or post-operational data to compare S2Z outputs with those produced by existing operator systems.

Both modes require safeguards. Operational execution requires reliable data flows and restricted visibility of detailed outputs. Ex-post simulation requires documented datasets, clear assumptions and protection of commercially sensitive historical data.

## 3.5 Governance Tools and Mitigation Mechanisms

The governance model requires a practical tool that can be used by pilot sites, technical partners and WP5-WP6 coordinators during pilot preparation, execution and assessment to translate governance principles into operational rules for data sharing, engine use, platform access, output management and regulatory inputs.

The proposed S2Z governance tool is the **Pilot Data Governance Matrix,** together with attributes and recommendations relating sensitivity classification, access rights, anonymisation and pseudonymisation rules, and data quality.

The matrix should be completed progressively with each pilot site and used in three phases:

- **before pilot execution**, to identify required data, available data, missing data and sharing limitations;
- **during pilot execution**, to monitor data flows, update responsibilities and access needs;
- **after pilot execution**, to validate datasets used for ex-post simulation, KPI calculation and impact assessment

*Table 3. Pilot Data Governance Matrix*

| Data / output needed | Who owns it? | Who will use it? | For what purpose? | Sensitivity | Can it be shared? | Conditions / limitations |
|---|---|---|---|---|---|---|
| Order lists, trip plans, delivery points | LSP | VRP engine, Decision Analytics, Simulation Engine | Route optimisation, delivery planning, Operational monitoring, simulation, travel time analysis, service performance assessment KPI calculation | Commercially sensitive; customer-related | Yes, under restrictions | Customer identifiers should be removed or pseudonymised. Raw data should be accessible only to authorised platform and engine roles. Aggregated data can be used for KPI reporting |
| Vehicle specifications, payload, range and battery parameters | OEM | Vehicle Consumption Model, Charging Scheduling Engine | Energy estimation, route feasibility, charging planning, operational constraints modelling | Technical proprietary | Yes, partially | Only modelling parameters required by the engines should be shared. Proprietary design details, component-level specifications and confidential test results should remain restricted |
| State of charge and charging events | LSP, OEM | Charging Scheduling Engine, Decision Analytics | Charging optimisation, energy KPI calculation, route feasibility checks | Operationally sensitive | Yes, under restrictions | Aggregated charging indicators can be used for reporting and impact assessment |
| UVAR, ZEZ, geofencing rules and access windows | Municipality | VRP, Simulation Engine | Routing constraints, compliance checks, policy scenario testing | Regulatory | Yes | Municipality should validate version, geographical scope and period of validity. |

| Data / output needed | Who owns it? | Who will use it? | For what purpose? | Sensitivity | Can it be shared? | Conditions / limitations |
|---|---|---|---|---|---|---|
| Micro-hub, locker, loading bay or transhipment slot availability | Municipality, LSP or infrastructure manager | VRP engine, Cargo Loading Engine, Decision Analytics | Slot allocation, transhipment planning, operational monitoring | Operationally sensitive | Yes, under restrictions | Access should be role-based. |
| KPI dashboard | Decision Analytics | Pilot partners | Pilot monitoring, impact assessment, reporting, policy discussion | Internal project data; aggregated evaluation data | Yes, depending on aggregation | Access should be role-based. |
| Simulation scenarios and results | Simulation Engine | Pilot partners | Policy assessment, scale-up analysis, operational scenario testing | Internal / policy-sensitive | Yes, under restrictions | Scenario assumptions, input data sources and aggregation level should be documented. Results should avoid exposing commercially sensitive operator-specific information |

The matrix is intended to be completed record by record for each pilot. Each row represents a specific data category, digital output or information flow relevant to the interaction between pilot operations and the S2Z engines. During the completion phase, the attributes included in the matrix should be filled by selecting or specifying the appropriate governance values for each record.

The following paragraphs provide the reference values and practical guidance to support this completion process. They define:

- the possible sensitivity levels to be assigned to each dataset or output;
- the role-based profiles that may access or use the information;
- the anonymisation and pseudonymisation measures to be applied where needed;
- the data quality checks required before data are used by the platform or engines.

These values should not be treated as abstract categories, but as operational attributes of each matrix record. For example, an order list, a vehicle telemetry dataset, a geofencing layer or a KPI dashboard should each be associated with a sensitivity level, an access profile, a sharing condition, a preparation rule and a validation requirement.

Each dataset or output included in the matrix should be assigned to a **sensitivity level**. The classification should remain simple and usable during pilot interviews and technical meetings, as follows:

- **Public / open**: data that can be shared without confidentiality restrictions
- **Internal project**: data that can circulate within the S2Z consortium for project purposes
- **Commercially sensitive**: data that may reveal business position, operational strategy or cost structure
- **Personal or customer-related**: data linked to customers, receivers, drivers or identifiable individuals
- **Technical proprietary**: data related to vehicle design, components, performance parameters or confidential testing
- **Regulatory / policy data**: data defining rules, restrictions or policy conditions
- **Aggregated evaluation data**: data processed for monitoring, KPI assessment or policy discussion

Access to data and outputs should be managed through **role-based profiles**, as follows:

- **Data owner**: full access to own data and related outputs
- **Authorised engine / platform technical profile**: access to data required for processing
- **Logistics operator / fleet user**: access to operational outputs concerning its own activities
- **Municipality / public authority**: access to regulatory inputs and aggregated policy outputs
- **WP7 impact assessment partner**: access to harmonised datasets and KPIs needed for evaluation
- **Pilot partners**: access to information needed to coordinate pilot execution
- **Dissemination / public reporting profile**: access to approved public outputs

**Anonymisation and pseudonymisation** should be applied at source whenever detailed identification is not required by the S2Z function. The following rules should guide pilot data preparation:

- customer names should be removed before data ingestion;
- personal contact details should be excluded from S2Z datasets;
- customer identifiers should be replaced by pseudonymous IDs when linkage across records is required;
- vehicle IDs should be pseudonymised when individual identification is unnecessary;
- precise addresses should be used only when required for routing or simulation;
- address-level data should be aggregated when used for reporting or policy discussion;
- operator-specific cost data should be aggregated before cross-pilot analysis unless detailed access has been agreed;
- technical proprietary data should be converted into modelling parameters whenever possible.

**Data quality** is a core condition for reliable optimisation, simulation and KPI calculation. D5.1 already identifies the need for data ownership, validation responsibility, quality checks, anomaly detection and traceability. Each pilot should check:

- completeness;
- consistency;
- format compliance;
- time validity;
- geographical validity;
- plausibility of values;
- duplicate records;
- missing identifiers;
- inconsistent units;
- outdated regulatory layers.

The Pilot Data Governance Matrix provides the operational instrument to be transferred to WP6 and to the pilot sites for the next implementation steps. Its purpose is to support each pilot in defining, with the necessary level of detail, the governance conditions associated with each type of data, digital output or information flow. The matrix should therefore be adapted to the specific characteristics of each pilot, including the engines used, the operational mode, the available datasets, the level of platform integration, the role of the municipality and the sensitivity of the information exchanged.

In the next WP6 activities, the matrix can be used to validate data availability, clarify responsibilities, identify missing information and document the conditions under which data can be exchanged or processed during pilot preparation, execution and assessment. At the same time, the matrix should remain aligned with WP5 activities, especially with the development of the S2Z Platform, the definition of connectors, the configuration of access profiles and the implementation of engine-related data flows.

The following mitigation mechanisms summarise the main governance safeguards that WP5 and WP6 should consider jointly when moving from data definition to pilot implementation.

*Table 4. Risks and Mitigation Mechanisms*

| Risk or criticality | Mitigation mechanism |
|---|---|
| Disclosure of customer information | Remove names and contact details at source; pseudonymise customer IDs; restrict address-level visibility |
| Disclosure of commercial strategy | Limit raw operational data access; aggregate outputs for WP7 and cities; avoid operator ranking unless agreed |
| Misuse of detailed engine outputs | Apply role-based visibility; restrict route, loading and charging outputs to concerned operator profiles |
| Exposure of proprietary vehicle data | Share modelling parameters only; restrict component-level and confidential test information |
| Inaccurate municipal regulatory input | Validate polygons, shapefiles and rules; document version, scope, time validity and responsible authority |
| Outdated geospatial layer | Assign update responsibility; record version used by platform and engines |
| Change in pilot configuration | Use change records for datasets, connectors, outputs, KPIs and access rules |
| Conflicts over access rights | Use access matrix and escalation procedure |
| Excessive governance burden | Apply proportional governance according to pilot complexity, engine use and data sensitivity |

# 4. Pilot processes and S2Z Engines Integration

This chapter presents the operational results of the methodology described in Chapter 2. It translates the pilot process analysis into an integration-oriented view of the S2Z digital ecosystem, focusing on how pilot systems, local data sources, S2Z engines and the S2Z Platform are expected to interact. The chapter consolidates the available digital systems, expected data sources, data exchange mechanisms, engine macro-blocks, platform interactions and remaining open points relevant to the preparation of the WP6 demonstrations. Detailed pilot-specific analyses, including the updated BPMs, descriptions of actors and digital systems, available and expected data exchanges, relevant engine macro-blocks and unresolved implementation issues, are provided in Annex A. The main chapter focuses on the common and transferable findings emerging from the pilots, including the functional integration logic and the end-to-end information flows required for demonstration readiness.

## 4.1 Functional Integration between Pilot Systems and the S2Z Platform

This section consolidates the functional integration logic between existing pilot systems and the S2Z Platform. The analysis builds on the pilot-specific digital ecosystems described in Annex A and identifies how data, engine outputs and operational feedback may circulate between logistics operators, municipalities, vehicle systems, S2Z engines and the platform. The role of the S2Z platform is to provide a common integration and access layer through which pilot data can be made available to the S2Z engines, engine outputs can be consumed by end users and post-execution information can support monitoring, analytics, KPI calculation and simulation.

Functional integration is therefore defined around four main platform functions:

1. **Data access and upload**. The platform must support the ingestion of operational, municipal and vehicle-related datasets, including order lists, trip plans, delivery points, GIS layers, access rules, geofencing zones, vehicle traces, energy data and proof-of-delivery information. Depending on the pilot, these data may be uploaded manually, transferred as structured files, exchanged through automated connectors.
2. **Engine orchestration**. Once pilot data are available in a usable format, the platform acts as the operational entry point for the S2Z engine macro-blocks. Data ingestion engines prepare and harmonise the input datasets. Planning and execution engines support routing, energy feasibility, cargo loading and charging logic. Analytics and simulation engines use planned and executed data to support performance monitoring, KPI analysis and scenario assessment.
3. **User interaction and output consumption**. Pilot users may interact with the platform in two different ways, as introduced in section 2.3. Some pilots may use the platform directly to upload files, configure scenarios, visualise dashboards, monitor vehicle status or inspect geofencing information. Other pilots may prefer to export engine outputs and reuse them within their own operational systems. This distinction is important because the same engine output can be consumed either through the S2Z interface or through a pilot-specific downstream workflow.

4. **Feedback for monitoring and evaluation**. After operations, the platform must support the collection of execution data. These data are needed to compare planned and executed routes, identify deviations, assess delivery performance, calculate KPIs, validate energy consumption assumptions and feed simulation activities. The expected level of detail depends on pilot data availability and on the demonstration needs.

At this stage, the baseline integration approach should remain flexible. A structured file-based exchange (some of them already provided as samples) or controlled platform upload is considered sufficient for several pilot activities, provided that the data are complete, consistent and machine-readable. More advanced connectors can be developed where the pilot has the required system maturity, data availability and operational need.

**Functional integration by pilot**

- Bologna. The platform may support both operational planning and simulation activities. Gruber's mission data should feed the order ingestion process, while municipal GIS and access regulation data support road and regulatory modelling. Engine outputs may support route planning, transhipment assessment, loading logic and scenario comparison. The platform should be considered a planning-support and evaluation layer, not a replacement for Gruber's TMS. The first practical integration step is expected to rely on structured mission files and municipal GIS datasets, while more automated data exchange remains dependent on Gruber's system export capabilities.
- Norway. The S2Z platform should mainly support monitoring, analytics and simulation, while DHL Express will continue to manage daily route planning through its internal systems. The two Norwegian pilots have different integration priorities. In Bergen, the focus is on combining DHL Express route data, Paxster execution data and municipal geofencing information to assess compliance, energy use, planned versus executed operations and the use of urban space. In Oslo, the focus is on the modular swap-box model, transhipment options, reloading processes and the operational use of Paxster vehicles. Here, the platform should support the assessment of different city-hub, micro-depot and vehicle-to-vehicle transfer scenarios, together with their effects on efficiency, vehicle utilisation and delivery operations.
- Thessaloniki. The platform may play a more direct operational role. The expected flow includes upload of daily order or trip data, possibly through CSV extracted from the operator's ERP environment, configuration of geofencing or access rules, generation of route planning outputs, and collection of execution status. Depending on the final operational choice, route outputs may be consumed directly through the S2Z platform or exported for reuse in the operator's own systems. Manual upload is acceptable for demonstration purposes, while system-to-system integration may be assessed later.
- Wroclaw. The platform should support planning, monitoring and post-operation assessment, but the final integration mechanism depends on DPD's internal IT

verification. The expected integration includes daily delivery lists, proof-of-delivery data, municipal road and low-emission-zone information, and vehicle or e-bike data where available. Until data sources, formats and transfer methods are confirmed, the platform role consists in a flexible integration layer able to support file-based exchange, manual upload or future automated connectors.

- Brussels. The functional integration is described at a general level until pilot-specific technical details are consolidated. The platform is expected to support data ingestion from the logistics or mobility operator, interaction with municipal or regulatory datasets, planning or optimisation support where relevant, and post-execution analytics. The exact balance between platform-based operation, data upload and external system reuse will be refined at a later stage during WP6 preparatory activities.

The following table summarises the functional integration logic.

*Table 5. Functional integration logic*

| Integration function | Main purpose | Typical data or output | Possible mechanism | Pilot relevance |
|---|---|---|---|---|
| **Data access and upload** | Make pilot data available to the S2Z environment | Orders, trip plans, GIS layers, telemetry, PoD | Manual upload, structured file, API | All pilots |
| **Data harmonisation** | Convert heterogeneous data into usable inputs for engines | Clean order dataset, road layer, vehicle status data | Platform ingestion layer, data preparation module | All pilots |
| **Planning support** | Produce operational planning outputs | Routes, stop sequence, loading logic, charging checks, energy feasibility | Platform interface or exported output | Bologna, Thessaloniki, Wroclaw, partly Brussels |
| **Monitoring support** | Compare planned and executed operations | GPS traces, vehicle status, delivery progress, geofence events | Dashboard, telemetry feed, file upload | Norway, Thessaloniki, Wroclaw, Bologna |
| **Post-execution analytics** | Support KPIs and operational assessment | Delivery outcomes, deviations, energy use, exceptions | Dashboard, analytics engine, structured export | All pilots |
| **Simulation support** | Test operational or policy scenarios | Baseline data, pilot data, regulatory | Offline simulation, scenario configuration | All pilots |

| Integration function | Main purpose | Typical data or output | Possible mechanism | Pilot relevance |
|---|---|---|---|---|
| | | scenarios, fleet assumptions | | |

## 4.2 End-to-End Information Flows Supporting WP6 Demonstrations

This section translates the pilot-specific integration analysis into an operational readiness framework for WP6 demonstrations. The objective is to define the minimum conditions that must be met before pilot activities can generate usable operational evidence for monitoring, KPI calculation and simulation.

The end-to-end information flow is therefore interpreted as a readiness sequence. Each pilot must be able to provide the data required for operations and demonstration, exchange or upload them through an agreed mechanism, activate the relevant S2Z engine macro-blocks, collect execution evidence during or after operations and make the resulting information available for analytics and evaluation.

The readiness framework is organised around five gates.

*Table 6. Readiness framework - Five gates*

| Readiness gate | Purpose | Minimum condition before WP6 demonstration | Main output |
|---|---|---|---|
| **Data readiness** | Confirm that the required information exists and can be accessed | The pilot has identified the minimum operational, municipal, vehicle and post-execution datasets needed for the relevant engine macro-blocks | Minimum dataset confirmed |
| **Platform readiness** | Confirm how data will reach the S2Z environment | The pilot has selected a feasible exchange mechanism, such as manual upload, structured file exchange, API | Data exchange mode confirmed |
| **Engine readiness** | Confirm which S2Z functions are relevant for the pilot | The active engine macro-blocks are identified, and non-relevant engines are excluded from the operational workflow | Engine scope confirmed |
| **Execution readiness** | Confirm how field evidence will be collected | The pilot has defined how executed routes, vehicle traces, delivery outcomes, geofence events, exceptions or energy data will be captured | Demonstration evidence plan confirmed |
| **Evaluation readiness** | Confirm how post-execution data will be reused | The pilot has defined how collected data will support Decision Analytics, KPI | Evaluation input confirmed |

| Readiness gate | Purpose | Minimum condition before WP6 demonstration | Main output |
|---|---|---|---|
| | | calculation and Simulation activities | |

This framework reflects the different maturity levels and operational choices of the pilots. In some cases, the S2Z platform may support operational planning before the mission. In other cases, existing operator systems will remain the main planning environment and the S2Z platform will mainly support monitoring, benchmarking, analytics or simulation. Both configurations are acceptable, provided that the data flow is clear and the collected evidence is usable.

For WP6, the practical value of this framework is the definition of a common handover structure from WP5 to the pilot demonstrations. Before each demonstration, the following points should be checked:

- Pilot process model → Updated BPM including the S2Z engine macro-blocks
- Minimum data package → List of datasets required for the active engine macro-blocks
- Data provider → Actor responsible for each dataset
- Data format → Expected machine-readable format or other where still open
- Exchange mechanism → Manual upload, file exchange, API or other
- Platform role → Operational interface, upload layer, monitoring dashboard, analytics layer or simulation support
- Execution evidence → Data to be collected during or after the pilot operation
- Open issues → Items that must be solved before or during WP6 preparation

The framework also clarifies the boundary between integration and demonstration. D5.2 identifies what must be exchanged, who should provide it and how the platform may be used. WP6 will validate these assumptions in the field, confirming whether the proposed data exchanges are sufficient for real-life demonstration, monitoring and post-pilot assessment.

# 5. Connector Architecture

Chapter 4 has examined the pilot-specific processes, actors, data sources, expected exchanges and open integration issues. Building on this operational analysis, Chapter 5 adopts a cross-pilot technical perspective and defines the common connector principles, communication patterns, specifications and validation steps required to exchange data between heterogeneous pilot systems and the S2Z environment.

Specifically, this chapter provides the architectural guide through which logistics service providers, municipalities and vehicles connect to the Shift2Zero Urban Logistics Management Platform. It explains the information that crosses each system boundary, the available communication channels, the common processing applied by the platform and the way in which the resulting data are used by operational and decision-support services. Detailed engine-level data exchange requirements and implementation considerations are provided in Annex B, organised according to the three functional macro-blocks introduced in Chapter 2.

The architecture starts from a practical industry condition. Logistics operators already use planning, warehouse, dispatch or fleet systems. Municipalities maintain urban rules through different combinations of GIS layers, portals and specialised services. Vehicles expose different levels of digital information depending on the manufacturer, installed equipment and operational agreement. S2Z connects these environments without requiring them to become identical and without requiring an operator to replace a functioning planning process.

## 5.1 Connecting vehicles, logistics operations and cities

The purpose of the architecture is to place the vehicle mission, the logistics mission and the urban operating conditions in one common operational environment. The logistics service provider describes what has to be transported and how the operation is organised. The municipality describes where and when the mission can take place and which access or loading conditions apply. The vehicle connector describes which vehicle is available, what it can carry, how it consumes energy and which operational observations can be exchanged.

This common environment is wider than a conventional fleet-management service. It links operational data to routing, cargo loading, vehicle-energy estimation, charging, geofencing, monitoring, simulation and decision analytics. The platform therefore acts as a coordination and intelligence layer between existing solutions. It can generate a complete plan, assess a plan produced elsewhere, or use historical information to examine a future fleet or policy scenario.

Within WP5, the connector architecture defines the stable pathway from heterogeneous pilot data to the S2Z engines. The subsequent software and platform-integration activities configure the adapters, endpoints and operational workflows for each pilot. This separation keeps the architectural principles reusable while allowing each connection to follow the access rights, update frequency and digital maturity of the responsible partner.

Four design principles guide the architecture. Source-specific differences are isolated in adapters. A common information schema is used by the platform engines. Each pilot activates only the data and services needed for its selected use case. Data ownership, provenance, versions and access conditions remain visible throughout processing. These principles support a gradual implementation that can begin with a controlled file and later move to an automated connection without changing the internal engine contracts.

## 5.2 Overall connector architecture

The architecture is organised around three connector layers. The LSP and operational-system layer handles demand, resources, constraints, plans and execution records. The municipality and urban-infrastructure layer handles geofences, access rules, loading conditions and temporary measures. The vehicle layer handles vehicle characteristics and the operational data available from the driver application, vehicle cloud, telematics system or onboard equipment. The three layers meet in a common connector, the data and orchestration layer.

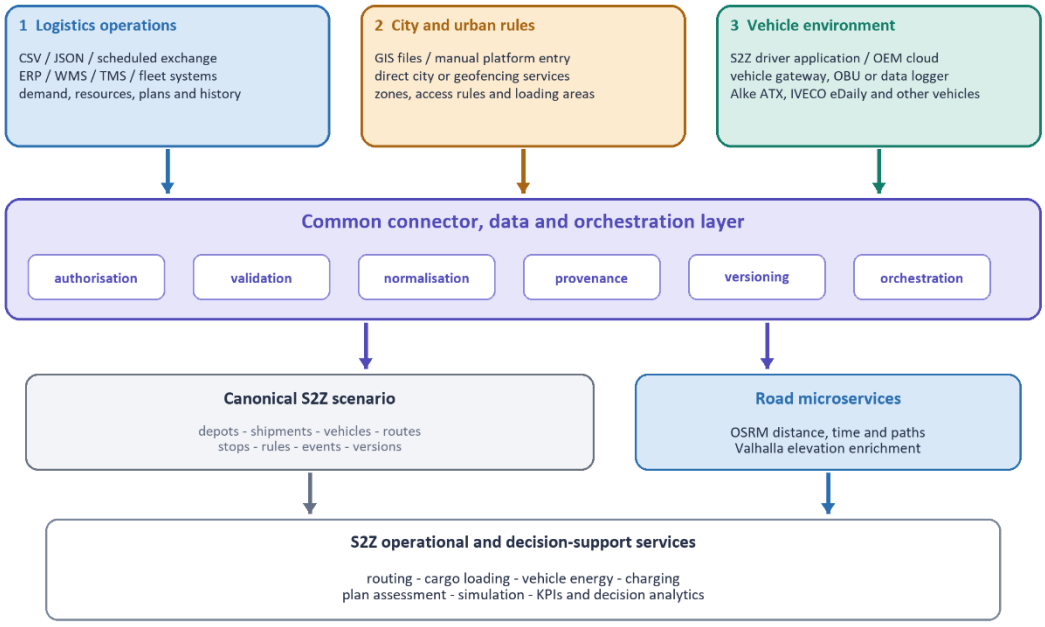



*Figure 2. S2Z common operational environment and connector architecture*

A connector is an adapter and a controlled exchange point. It authenticates the source where required, checks the structure and minimum content, converts source identifiers and units, records the source and creates or updates the corresponding S2Z entities. The platform engines receive the same internal representation whether the original information arrived as a CSV file, a JSON payload, a maintained API call or a vehicle message.

Each exchange follows a versioned technical commit. The common message unit records the scenario identifier, schema version, source system, creation time, effective

time, data owner and correlation identifier. Entity records retain their source identifier, S2Z identifier, unit, coordinate reference where applicable and data-quality status. The connector response states whether the dataset was accepted, accepted with warnings or rejected, and returns field-level diagnostics together with the scenario or processing-job identifier. These controls allow file-based and automated exchanges to be tested against the same acceptance rules and make every engine result traceable to the exact input version used.

This separation is the main reason for using a modular architecture. A source-specific interface is not embedded inside the routing, loading or energy algorithm. When another vehicle, city service or LSP system is introduced, the new work is concentrated in the adapter and mapping configuration. The common scenario, road services, engine requests, diagnostics and output structures remain reusable.

*Table 7. Responsibilities and connection options of the three connector layers*

| Connector layer | Information responsibility | Supported connection options | Use within S2Z |
|---|---|---|---|
| **LSP and operational systems** | Demand, depots, resources, operating constraints, existing plans, execution and history | Predefined CSV, structured JSON, file upload or scheduled exchange, ERP/WMS/TMS/fleet API or middleware | Planning, plan reconstruction, feasibility checks, improvements, KPIs and simulation inputs |
| **Municipality and urban infrastructure** | Geofences, UVAR/LEZ/ZEZ rules, street or area restrictions, access periods, loading areas and temporary measures | GIS or GeoJSON file, municipality-user entry, maintained municipal API or specialised geofencing service | Vehicle eligibility, routing restrictions, compliance events and policy scenarios |
| **Vehicle environment** | Vehicle configuration, availability, position, speed, odometer, State of Charge, status, energy and selected payload or auxiliary data | S2Z driver application, OEM or vehicle-cloud API, fleet platform, OBU/CAN-bus gateway, external data logger or structured export | Monitoring, route comparison, energy calibration, operational alerts and vehicle-specific feasibility |

### *5.2.1 LSP and operational-system connector layer*

The LSP connector is the entry point for the transport mission. It accepts information from Enterprise Resource Planning (ERP), Warehouse Management System (WMS), Transport Management System (TMS), dispatch and fleet-management environments, as well as operational files prepared by a planner. The connector keeps the existing system as the operational source and transfers only the information required for the selected S2Z service.

Three exchange profiles are defined. The first uses predefined CSV templates for transparent batch exchange. The second uses structured JSON for platform requests and repeatable machine-to-machine exchange. The third uses an API or middleware adapter connected to the operator's ERP, WMS, TMS or fleet system. File upload and scheduled folder exchange remain available as controlled operating channels, especially during pilot preparation and schema validation.

The connector maps the source data to a canonical S2Z scenario. Stable references link depots, vehicles, shipments, parcels, stops, routes, urban rules and scenario versions. Missing information remains explicitly missing. It is not replaced by an assumed measured value. Optional data activate additional services. Parcel dimensions activate three-dimensional loading checks, battery and auxiliary-load data activate vehicle-energy checks, and charger data activate charging optimisation.

*Table 8. Indicative S2Z scenario inputs and their operational purpose*

| Input group | Indicative fields | Why the platform needs it | Applicable use |
|---|---|---|---|
| **Scenario and service context** | scenario_id, schema_version, service date, planning horizon and timezone | Keeps all inputs and outputs on the same dated and versioned planning case | All modes |
| **Depots and operating points** | depot ID, coordinates, operating window, transhipment or consolidation point | Defines route origins, returns, transfer locations and operating availability | Planning, assessment and simulation |
| **Demand and shipments** | shipment/order ID, location, weight, volume, time window, service time and priority | Defines what has to be served and the main routing and capacity constraints | All operational modes |
| **Parcels and cargo profile** | parcel dimensions, stackability, fragility, temperature requirement and modular-unit ID | Activates loading, compartment and innovation-specific cargo checks | Loading-enabled cases |
| **Fleet and vehicle availability** | vehicle ID, class, fuel type, capacity, cargo geometry, availability and access class | Determines assignment eligibility and the resources available to the mission | Planning, assessment and simulation |
| **Electric-vehicle profile** | usable battery, initial SoC, reserve, charging power, curb weight and auxiliary demand | Supports route-energy and battery-feasibility calculations under stated assumptions | Energy-enabled cases |
| **Existing operational plan** | route ID, vehicle assignment, ordered stops, planned times and depot association | Allows S2Z to reconstruct and assess a plan produced by the pilot's own tools | Plan assessment and improvement |
| **Executed routes and history** | actual stop order, timestamps, distance, energy, exceptions and completion status | Supports planned-versus-executed comparison, KPI calculation and representative simulations | Analytics and simulation |
| **Charging resources** | charger, connector, power, availability, vehicle plug-in window and target SoC | Supports charging feasibility and next-mission readiness | Charging-enabled cases |

An indicative daily workflow begins with the operator providing the next service date, depot, available vehicles and delivery list. The connector validates identifiers and coordinates, reports incomplete records and builds the common scenario. The platform then returns the output appropriate to the selected mode. This output can be a complete operational plan, a feasibility report on the submitted plan, a set of targeted improvement recommendations, or a scenario dataset for strategic analysis.

### 5.2.2 Municipality and urban-infrastructure connector layer

The municipality connector places the logistics mission within its urban operating context. Relevant information includes geofences, Urban Vehicle Access Regulations, low- and zero-emission zones, restricted streets, validity periods, delivery windows, loading and stopping areas, curbside conditions and temporary measures. Each rule is stored together with its authoritative source, geometry, policy meaning, validity and update time.

The architecture provides three ways to connect city information.

- GIS and structured-file exchange accepts GeoJSON, shapefiles or other agreed spatial datasets containing zones, streets, loading areas and rule attributes.
- Municipality-user entry allows an authorised city user to create or update a rule through the platform when no maintained machine interface exists. The platform records the author, validity and version of the entry.
- Direct city-service connection uses a maintained municipal API or a specialised geofencing service. In the Bergen case, the connector pattern covers the Nivel-related regulation environment and accepts Mobility Data Specification or another agreed service schema. Endpoint activation, authentication and update responsibility are assessed during pilot implementation.

All three channels produce the same internal rule representation. The connector first determines which locations, or road paths intersect the rule geometry. It then evaluates the time validity and the vehicle or activity conditions. During planning, the result becomes a vehicle-eligibility or routing constraint. After a route path is available, the same rule is used to record entry, exit, traversal and compliance events for each route leg.

For example, a city-centre zone can allow only zero-emission vehicles between 09:00 and 11:00. The connector links delivery locations to the zone and preserves the original rule. The routing engine assigns an eligible vehicle or schedules the visit outside the active period when the delivery window permits it. The final route records which rule was applied and whether the vehicle is compliant. This gives both the operator and the municipality a transparent interpretation of the same urban condition.

### 5.2.3 Vehicle connector layer

The vehicle connector combines project-specific adapters for the Alkè ATX and IVECO eDaily platforms with a reusable vehicle-data pattern. The common pattern separates the vehicle source from the S2Z representation. This allows another vehicle or vehicle innovation to be introduced by adding an adapter and mapping its available fields, while the routing, energy, monitoring and analytics services continue to use the same vehicle, trip and event structures.

Three communication channels are supported by the architecture.

- The S2Z driver application provides route reception, driver-facing information and route-monitoring events when a direct vehicle interface is not required.

- OEM or vehicle-cloud communication receives authorised data through services such as the Alkè Cloud API or the corresponding IVECO, telematics or fleet interface available to the pilot.
- An onboard connection uses an authorised On-Board Unit, CAN-bus gateway or external data logger. This channel is activated only with the required vehicle-owner, OEM, data-protection and safety approvals.

The connector distinguishes vehicle characteristics from operational observations. Characteristics include capacity, cargo geometry, fuel or energy type, usable battery, charging limits, mass, emission or access class and innovation-specific equipment. Operational observations include location, speed, odometer, State of Charge, charging events, status alerts, energy consumption and the route or mission identifier. Each observation carries a timestamp, unit, source and quality status.

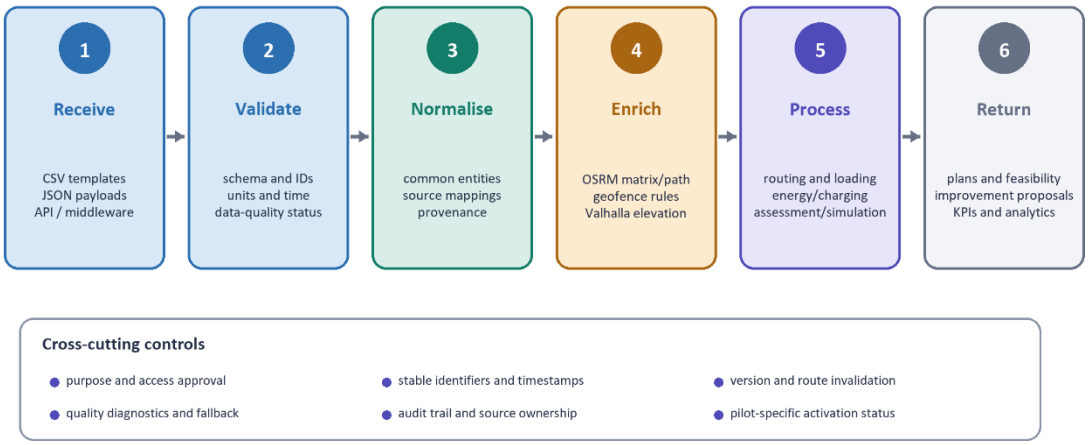
The exchange frequency follows the operational purpose. Near-real-time data support monitoring and alerts. Periodic data support daily planning and state updates. Ex-post data support route comparison, energy-model calibration, KPI calculation and simulation. Direct vehicle control is outside the connector's basic role. Any instruction returned to a vehicle or driver follows a separately validated operational and safety workflow.

The modular pattern also allows S2Z vehicle innovations to be represented as additional profiles. A multi-temperature cargo body adds compartment and thermal fields. A swappable unit adds modular-unit, compatibility and transfer-point fields. Holistic energy management adds auxiliary-load and control-strategy information. The core identity, availability, route and event structures remain unchanged.

### 5.2.4 Common integration and road-network microservices

The common integration layer prevents downstream services from depending on the original transport channel. As shown in

*Figure 3. Common connector data and processing flow*




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every accepted dataset follows the same sequence from reception to validation, normalisation, enrichment, processing and result delivery. The same checks therefore apply to a manually uploaded CSV file, a JSON request and a direct system connection.

Validation covers mandatory fields, identifiers, references, coordinates, units, timestamps and the minimum data required by the activated service. Normalisation resolves source-specific names, units, time zones and identifiers. The accepted scenario receives a version and provenance record. Rejected records and data-quality warnings remain visible to the submitting user or system.

Road data are provided as platform microservices. The Open-source routing machine (OSRM) matrix microservice receives depot, shipment and stop coordinates and returns the asymmetric distance and travel-time matrices used by the routing and simulation engines. The OSRM route microservice receives the final ordered stop sequence and returns road-following legs, geometry, distance and duration. The Valhalla elevation microservice receives the accepted path geometry and returns the elevation profile used by route and vehicle-energy calculations.

*Table 9. Road-network and route-enrichment microservice interfaces*

| Microservice | Main request | Returned information | Use and control |
|---|---|---|---|
| **OSRM matrix** | Depot, shipment and stop coordinates, road profile and request version | Node/index map, distance matrix, travel-time matrix and unreachable-point diagnostics | VRP, feasibility and simulation. Preserve the matrix-to-entity mapping, provider and timestamp. |
| **OSRM route** | Ordered stops, road profile and route version | Per-leg road geometry, distance, duration and complete route geometry where requested | Route presentation, ETA, geofence and energy services. Recalculate after each accepted route change. |
| **Valhalla elevation** | Accepted complete path or per-leg geometry and route version | Elevation samples, profile, gain, loss and route or leg references | Vehicle-energy and gradient-sensitive analysis. Preserve provider and configuration and reject stale profiles. |

The orchestration layer controls result validity. A change to vehicle assignment, route membership or stop sequence creates a new route version. The previous path, travel times, geofence events, loading plan, elevation profile and energy result are then invalid for the revised route. The orchestration layer requests the affected microservices and engines again before the revised plan is reported as feasible.

## 5.3 Platform usage modes and adoption pathways

The same connector architecture supports three practical user stories. The difference lies in the responsibility retained by the pilot and in the information submitted to S2Z. The common scenario and services remain the same, which allows a pilot to begin with a limited use and adopt additional functions without rebuilding the connection environment.

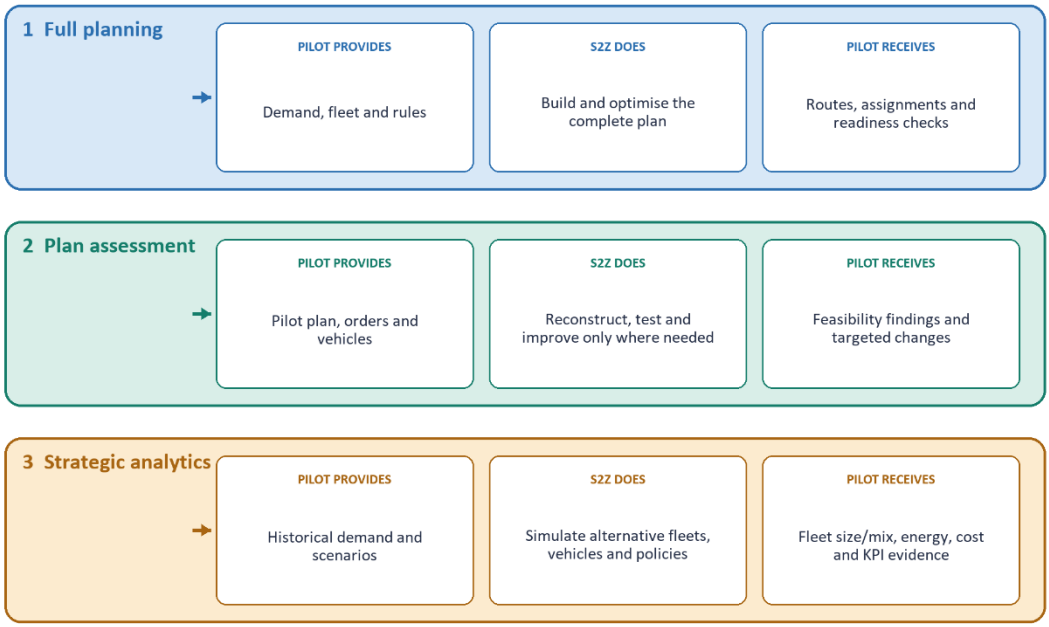



*Figure 4. Three practical S2Z adoption pathways*

### *5.3.1 Full planning mode*

Full planning mode is used when the pilot asks S2Z to construct the primary operational plan for a defined service day or planning horizon. The LSP connector supplies the demand, service locations, depots or transfer points, available vehicles, time windows, service times and operating constraints. The municipality connector adds the applicable access rules, restricted areas, loading conditions and validity periods. The vehicle connector adds capacity, cargo-space, battery, charging, access-class and innovation-specific characteristics for the resources available to the mission. Together, these inputs form one dated and versioned scenario rather than a collection of unrelated files.

After the scenario has passed validation, the road microservices calculate the node mapping, travel-time and distance matrices required by the routing engine. The engine assigns shipments to eligible vehicles and produces the ordered stop sequence. The route service then returns the road-following geometry and per-leg information. When the corresponding profiles are active, cargo loading checks the physical arrangement and unloading sequence, the vehicle-energy service evaluates route and auxiliary demand, and the charging service tests battery reserve and next-mission readiness. A route change creates a new route version and automatically invalidates dependent

paths, geofence events, loading results and energy estimates until they have been recalculated.

The result is returned as an operational plan package containing routes, assignments, ordered stops, planned times, distances, paths, feasibility status, warnings and the recommendations produced by the activated services. The pilot reviews and accepts the plan before it enters an operational dispatch process. This mode is suitable for an operator that does not possess an equivalent integrated planning environment or that wants to evaluate a mission-focused planning method adapted to right-sized electric vehicles and S2Z logistics innovations. Replication in another pilot relies on a new source mapping, local urban rules and vehicle profiles, while the validated planning chain and output contract remain unchanged.

### *5.3.2 Existing-plan assessment and improvement mode*

Existing-plan assessment and improvement mode is intended for an operator that already uses a TMS, an internal routing application or an established dispatcher workflow. The operator submits the plan that it intends to execute together with the associated orders or stops, vehicle assignments, depot or hub references, planned times and the constraints that are available. The submitted plan remains the authoritative operational proposal. S2Z first reconstructs the underlying demand and route structure so that each planned stop can be traced to its order, vehicle, route and source-system identifier. Records that cannot be matched are reported as explicit diagnostics rather than completed through hidden assumptions.

The reconstructed routes are enriched with road-following paths, travel times, distances, elevation and applicable city rules. The platform then evaluates the conditions selected by the pilot, including capacity, time-window compliance, vehicle access, cargo compatibility, loading sequence, battery reserve, charging readiness or innovation-specific constraints. The assessment can stop at a feasibility report, or it can generate a targeted alternative for the routes, assignments or stop sequences that caused a problem. The comparison preserves the original plan and reports the affected entities, expected benefit, operational consequence and reason for each proposed change. Unaffected routes remain unchanged.

This pathway provides the lowest-disruption route to practical adoption. Existing planning systems continue to perform their normal role, while S2Z supplies capabilities that are not commonly available in general-purpose logistics tools, particularly the combined treatment of right-sized electric vehicles, cargo innovations, geofenced access, route-energy feasibility and city conditions. An operator can therefore begin with one uploaded plan, verify the findings and accept only the modifications that create operational value. The same exchange can later be automated without changing the assessment logic or forcing the operator to replace its established planning process.

### *5.3.3 Strategic decision-analytics mode*

Strategic decision-analytics mode uses historical, pilot-generated or representative information to examine decisions that extend beyond the next operational day. The input

scenario combines a defined demand period, observed or reconstructed routes, fleet composition, vehicle technical profiles, depot and charging assumptions, urban rules and the KPI definitions required for comparison. A documented baseline records the current operational configuration and its data period. Alternative scenarios then change only the parameters under investigation, such as demand growth, vehicle class, fleet size, fleet mix, access policy, hub location, charging infrastructure or the use of a modular cargo concept.

The simulation environment repeatedly invokes the same road, routing, loading, vehicle-energy, charging, and city-rule services used in operational cases. This ensures that strategic scenarios are evaluated with compatible constraints and output definitions. Scenario runs preserve the model version, input dataset, random seed where stochastic elements are used, vehicle and infrastructure assumptions, and any fallback value introduced for unavailable data. The resulting evidence covers route kilometres and time, vehicle utilisation, unserved demand, service level, energy demand, charging requirements, loading or transfer performance, total-cost-of-ownership inputs, and the project KPIs selected for the analysis.

This mode supports decisions that cannot be demonstrated reliably through a limited physical pilot alone. A LSP can examine the number and mixture of vehicles required for a larger service area. A city can compare access rules or loading-area configurations. A vehicle or logistics partner can test whether a new S2Z innovation remains beneficial under different missions and demand levels. Because the connector model and scenario contract are common, the assumptions are transparent, and the experiment can be repeated for another pilot by replacing the local demand, policy, and vehicle profiles rather than rebuilding the analytical environment.

## 5.4 Replicability and interaction with S2Z innovations

Replicability is achieved by keeping the external connection, the common scenario, and the innovation services as separate modules. The source adapter handles local terminology and technical formats. The common contract expresses the basic last-mile problem through depots, shipments, vehicles, routes, stops, and urban rules. Selectable profiles, then add the data needed by a specific S2Z innovation or decision question.

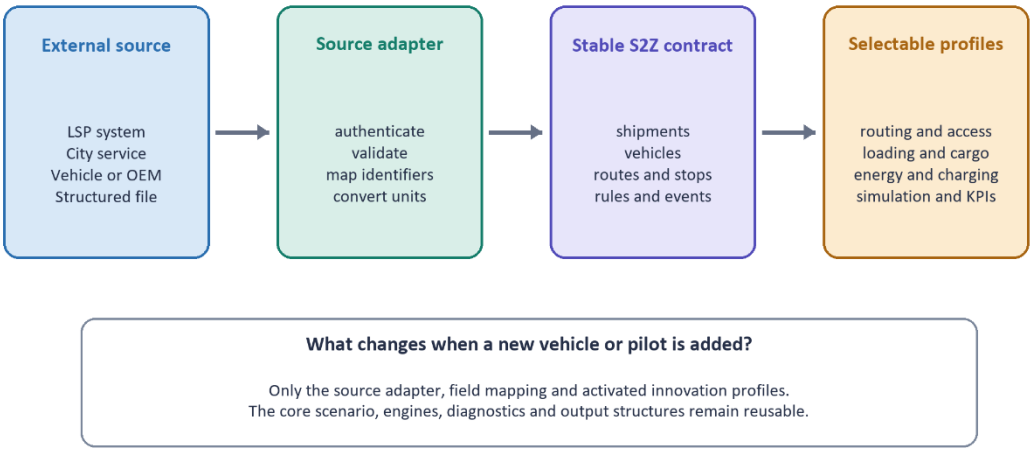



*Figure 5. Replicable modular connector pattern*

This design allows the platform to start from basic industry problems and extend them holistically. A basic routing case needs demand, vehicles, depots and operating constraints. An electric right-sized vehicle adds battery, mass, charging and access characteristics. A multi-temperature body adds cargo-zone and thermal requirements. A swappable or modular unit adds compatibility, transfer and handling information. A city policy case adds geofences and validity rules. These extensions use the same route, stop, vehicle and event references, so their results can be combined rather than managed as isolated tools.

The common environment also improves practical usability. A pilot can begin with one CSV template and the plan-assessment mode, validate the mapping and understand the returned findings. It can then automate the same exchange, activate vehicle observations, include city services or add innovation-specific profiles. Each step reuses the validated scenario structure and therefore reduces the technical and organisational change required for adoption.

## 5.5 Architectural status and derivation of the adoption pathway

The connector architecture results from the progressive WP5 design sequence. D5.1 established the common engine data models, pilot data requirements, simulation inputs and KPI mappings. D5.2 then finalised the integration-oriented Business Process Models, showing where information is produced, which S2Z toolbox service consumes it and which result returns to the pilot. Together, these outputs defined the connector layers, common scenario and service interfaces used as the architectural baseline.

The current technical baseline includes the canonical scenario concepts, JSON I/O logic, OSRM-supported routing workflow, geofence preprocessing, route reconstruction and modular optimisation chain. Source-specific adapters and communication channels become operational only after their owner and purpose are agreed, mappings and transfers are tested with representative data, failure and fallback behaviour is demonstrated, and access, retention and support responsibilities are assigned. The

same acceptance principle applies to LSP, municipality and vehicle connections, with source and result versions remaining traceable.

### 5.5.1 Replicable adoption, calibration and deployment pathway

The process followed in S2Z can be generalised as a five-stage pathway for another logistics operation, city or vehicle-innovation context. A new adopter does not reproduce the project organisation or deliverable sequence. It follows the same practical logic from problem definition and information modelling to modular connection, controlled validation and operational evidence. Each stage produces an accepted and traceable input for the next.

1) The adoption case is defined first. The adopter selects the platform usage mode, operational decisions, participating LSP, city and vehicle actors, authoritative data owners, S2Z services and KPIs or acceptance criteria. Only interfaces with an agreed operational purpose enter the implementation scope.
2) The existing process and information environment is then mapped. Demand, plans, routes, vehicle data, urban rules, simulation assumptions and KPI inputs are related to the common S2Z scenario with their source, frequency, quality and access conditions. The process model identifies who produces each item, which service consumes it, which result returns to the user and what minimum exchange is needed.
3) The required connection is configured through source adapters, field mappings and selectable service profiles. Each boundary uses the proportionate channel, from CSV or JSON transfer to an LSP interface, municipal GIS or API, vehicle cloud, driver application or authorised onboard gateway. Validation, security, versioning, diagnostics and fallback controls are added without changing the stable scenario and engine contracts.
4) Calibration and validation use representative controlled datasets before activation. Tests cover schemas, identifiers, units, coordinates and time, route reconstruction, urban-rule interpretation, vehicle and energy assumptions, errors and end-to-end results. Expected outputs, acceptance thresholds, mappings and parameters are agreed and versioned.
5) The validated configuration enters a controlled deployment and measurement period. Planned and executed routes, vehicle observations, delivery outcomes, energy, exceptions and city events support KPI assessment and model refinement. A later adoption repeats the pathway by replacing local adapters, mappings and innovation profiles, while reusing the common model, validation logic, road services and S2Z engines.

The five-stage pathway defines how an S2Z configuration can move from the identification of an adoption case to controlled deployment and operational measurement. Its practical implementation requires each selected S2Z service to be associated with the necessary input data, the responsible providers, appropriate exchange formats and frequencies, and the technical and organisational conditions governing the transfer. These detailed engine-level requirements are consolidated in Annex B.

# 6. Conclusions

D5.2 establishes the operational, governance and architectural basis required to move from the pilot concepts and data requirements defined in D5.1 to integrated digital services, physical demonstrations, scenario analysis and impact assessment. While D5.1 identified the main datasets, sources, analytical needs and links with project KPIs, D5.2 specifies how these data should be governed, exchanged and connected to the S2Z engines and Platform. Its main outputs include the updated pilot process models, the engine-oriented functional architecture, the federated governance framework, the connector architecture, the engine-level data exchange requirements and the progressive validation and deployment pathway.

The resulting integration framework combines common principles with pilot-specific implementation arrangements. The pilots differ in their operational organisation, existing information systems, data availability and sensitivity, technical maturity and expected use of the S2Z tools. Accordingly, the engines may directly support operational planning and execution, receive planned and executed data for monitoring, benchmarking or ex-post assessment, or operate offline using representative and historical data for simulation and strategic analysis. Detailed pilot configurations are documented in Annex A, while the corresponding engine-level information requirements are consolidated in Annex B.

Some implementation decisions remain open and will be finalised through representative data exchanges, connector development, engine testing and detailed pilot preparation. These open points do not affect the common architecture. They identify the local schemas, extraction procedures, transfer frequencies, access conditions, telemetry interfaces and operational roles that must be confirmed during the initial phases of WP6.

D5.2 provides a common handover framework for the remaining WP5 tasks, WP6 and WP7. WP5 will implement and integrate the engines, platform components, connectors and simulation models required by the pilots. WP6 will use the process models, governance arrangements and data requirements to prepare, execute and document the demonstrations. WP7 will combine physical pilot evidence and WP5 analytical or simulation outputs to assess operational, economic and total cost of ownership, environmental and life-cycle, societal and safety impacts, as well as aggregated results across the project sites.

Before each demonstration, the pilot leader, data providers, WP5 technical partners and WP7 representatives should consolidate a pilot data collection protocol. For each critical dataset, the protocol should define its purpose, source system, collection mechanism, format, frequency, responsible provider, quality requirements, sensitivity and access conditions. It should also distinguish the operational baseline from the S2Z intervention so that performance changes and impacts can be interpreted consistently. The baseline may represent current or historical operations, a conventional vehicle configuration or the existing regulatory context, while the intervention should document the combination of S2Z vehicles, operational models, platform functions, access rules and logistics configurations being tested.

Data provenance must be preserved from the original source through processing and KPI calculation. Each indicator should remain traceable to its source data, processing method, assumptions and level of aggregation, including where values are corrected, estimated or generated by analytical engines. The governance principles defined in Chapter 3 remain applicable throughout this process. Commercially sensitive information should be restricted to authorised users, personal or customer-identifying information should be removed when unnecessary, and municipality-facing or public outputs should use suitable levels of aggregation.

The transition from raw pilot data to WP7 evidence follows a common sequence: data production by pilot operations, vehicles, municipal systems and infrastructure; collection and validation through the agreed exchange mechanisms; harmonisation through the S2Z information model; processing through planning, analytics and simulation engines; and calculation and interpretation of indicators within the WP7 framework. Three evidence classes should be maintained. **Observed indicators** are calculated directly from physical demonstration data. **Derived indicators** result from processing or combining observed data through the S2Z engines. **Simulated indicators** represent alternative conditions, scaled-up operations or scenarios that were not directly observed. This classification is necessary to prevent simulated results from being interpreted as pilot measurements and to support transparent cross-pilot comparisons.

The next implementation steps are:

- each pilot should confirm its final operational configuration, baseline and alternative scenarios.
- pilot partners should provide representative sample files for all critical datasets. These samples should be used to validate fields, semantics, identifiers, spatial references, units and data quality before full-scale collection begins.
- WP5 technical partners should prioritise connectors and engine functions according to actual pilot needs. Operationally critical exchanges should be implemented first, while analytical and simulation-oriented connections may follow a staged deployment.
- WP6 data collection templates should be checked against the D5.2 data exchange requirements and the WP7 KPI framework. Each priority KPI should have an identified data source, provider, calculation method and contingency option.
- Joint WP5, WP6 and WP7 checkpoints should be organised before each demonstration and after an initial test period to verify data availability, connector performance, governance compliance, baseline validity and the feasibility of the planned indicators.

D5.2 should therefore be maintained as a controlled reference baseline for implementation. Changes to data sources, interfaces, engine roles, pilot configurations, baselines or KPI mappings should be recorded and shared across WP5, WP6 and WP7 to preserve the traceability, consistency and comparability of the evidence used for demonstration, simulation and impact assessment.

# 7. Annex A - Pilot Integration Fiches

This annex provides the detailed pilot-specific integration analysis supporting the cross-pilot findings presented in Chapter 4. It covers the Bologna, Bergen, Oslo, Thessaloniki, Wroclaw and Brussels pilot sites and documents how the operational processes, existing digital systems, local data sources, S2Z engines and the S2Z Platform are expected to interact during pilot preparation, execution and evaluation.

Each pilot fiche follows a common structure. It describes the operational configuration and the main actors involved, identifies the available and expected data sources, outlines the potential formats, frequencies and mechanisms of data exchange, and explains the role of the relevant S2Z engine macro-blocks. The fiches also identify the open technical, organisational and governance issues that must be resolved before the corresponding WP6 demonstrations.

The updated Business Process Models included in the fiches provide a simplified integration-oriented representation of each pilot. Building on the process models developed in D5.1, they highlight the main points at which data are produced, exchanged, processed and returned to pilot actors, while adding a dedicated S2Z engine layer. They are not intended to serve as complete operational manuals, but as visual references for defining the interfaces between pilot operations and the S2Z digital environment.

The level of detail varies according to the current maturity of each pilot and the information available at the time of preparation of this deliverable. Where sufficiently defined, the fiches specify data providers and users, expected formats, exchange frequencies, transfer mechanisms and intended uses. Where implementation choices remain open, they record the outstanding decisions and explain their relevance for connector development, platform integration, governance arrangements and demonstration readiness.

## 7.1 Bologna Pilot

The Bologna pilot is structured as a transhipment-based urban logistics case connecting Gruber's delivery operations, municipal access regulation data, S2Z vehicles and the S2Z platform. The operational configuration involves Gruber as logistics operator, the Municipality of Bologna and ITL as providers and validators of Geographic Information System (GIS), access regulation and urban logistics information and IVECO and ALKE as vehicle providers for the S2Z vehicle configuration. The BPM represents the integration sequence from Gruber's daily mission list to road and regulatory data preparation, route planning, loading support, possible transhipment between IVECO and ALKE vehicles, last-mile execution, PoD collection and post-execution assessment. In this configuration, the S2Z platform acts as the operational interface through which pilot data are uploaded, processed by the relevant engines and made available as route outputs, monitoring information, KPI inputs or simulation datasets.

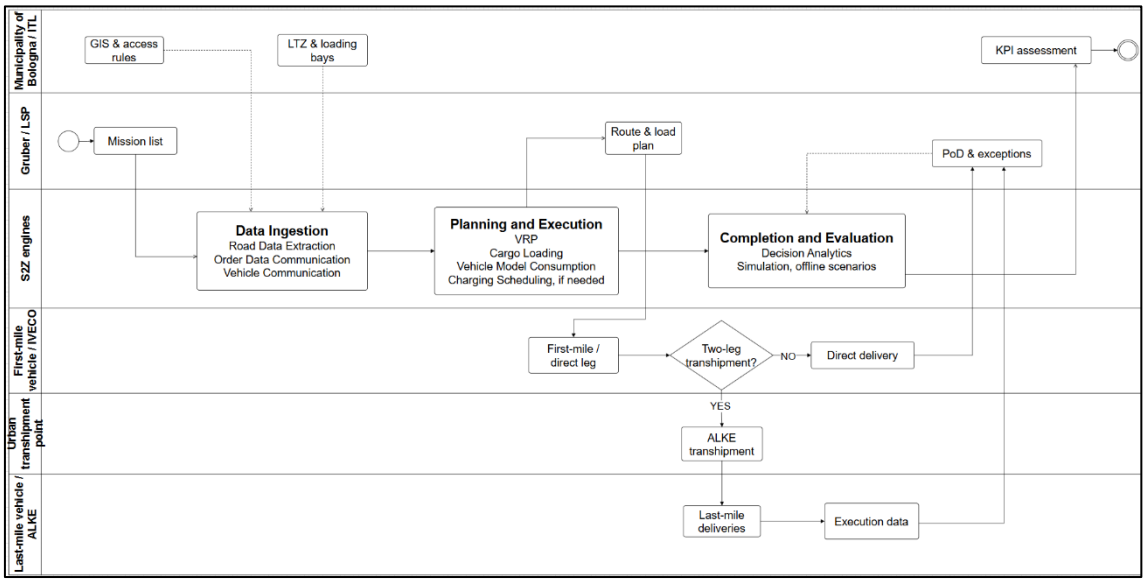



*Figure 6. Bologna BPM with S2Z engine layer*

### Actors

The main operational input is the daily mission list provided by **Gruber**. This dataset contains the information required to build the demand layer for planning, including delivery ID, address, weight, volume, service type, time constraints, delivery priority and operational constraints. The expected exchange mode is a structured machine-readable export, in CSV format, from Gruber's TMS environment.

Municipal data define the urban and regulatory context of the pilot. The **Municipality of Bologna** and ITL provide GIS layers, in shapefiles format, describing access rules, speed limits, loading bay information and other access regulation data. These datasets feed the data ingestion layer used by the platform to prepare the ground for subsequent planning and execution elaborations. Lockers installed in a previous research project, URBANE[1], remain a possible complementary infrastructure for small non-refrigerated goods, subject to confirmation of availability, software access, costs and operational usability of the surrounding areas.

The S2Z vehicle data involves **IVECO** and **ALKE** vehicles. Vehicle data support monitoring, energy assessment, KPI calculation, Total Cost of Ownership (TCO) comparison and simulation. Vehicles' data will be made available through API, using a JSON structure describing vehicle identifier, timestamp, operating status, Battery Discharge Indicator, kilometres, working hours, speed, motor and controller parameters, current, cabin temperature, heater status and GPS information. Gruber may also provide ex post fleet or telematics data for comparison vehicles, if needed.

### Available and expected data exchanges

[1] Micro-hubs network tested in the URBANE project in Bologna: https://urbane-horizoneurope.eu/demonstration-cities/lighthouse-living-labs/bologna-italy/

*Table 10. Bologna - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Daily mission and operational constraints** | Gruber | Structured export from TMS; CSV format; manual upload or API as possible transfer modes | Daily, before operations; same-day update only if urgent flows are included | Demand ingestion, route planning, loading support, energy assessment and analytics | Available. Structured export to be confirmed |
| **Road and access regulation** | Municipality of Bologna, ITL | Shapefiles, GIS-compatible layers, platform configuration | One-off, with updates when rules or infrastructure availability change | Road layer, routing constraints, geofencing, UVAR modelling, locker or micro-hub assessment | Available |
| **Vehicle** | IVECO, ALKE | ALKE JSON via PUSH or cloud API; IVECO data format to be confirmed | Real-time, near-real-time or ex post, depending on configuration | Vehicle monitoring, consumption assessment, charging feasibility | ALKE data structure available. IVECO format and access conditions to be finalised |
| **Execution and Proof of Delivery** | Gruber | Structured export, CSV | After route completion, ideally daily | Planned-versus-actual analysis, delivery status, failed deliveries and Decision Analytics | Available. Current PoD process is paper-based and scanned |
| **Evaluation and simulation** | ITL, Gruber, Municipality of Bologna | Aggregated and structured datasets derived from demand, GIS, vehicle, execution and PoD data | Pre-pilot, post-pilot and scenario-based | Different scenario analysis, What-if analysis | Scenario assumptions to be consolidated |

### Macroblock (engine)

The **Data Ingestion** macro-block connects the three main input layers of the Bologna pilot. The Order Data Communication function receives Gruber's structured mission data and harmonises it for downstream processing. The Road Data Extraction function uses municipal GIS and access regulation data to build the road and regulatory context for routing, geofencing and UVAR analysis. The Vehicle Communication function collects or receives vehicle-side data from S2Z vehicles and, where available, from Gruber comparison vehicles.

The **Planning and Execution** macro-block supports route planning, loading logic and feasibility checks. The VRP function uses mission data, delivery constraints, road data, vehicle type and possible transhipment logic to generate route outputs. The Cargo Loading function supports the allocation of freight between the first-mile and last-mile legs, especially where deliveries are pre-assigned to IVECO or ALKE before execution.

The Vehicle Model Consumption function estimates energy needs and range feasibility. The Charging Scheduling function is relevant where route length, battery status or operational duration make charging a constraint for the daily mission.

The **Completion and Evaluation** macro-block uses execution data to compare planned and actual operations. Structured PoD data, vehicle records, delivery outcomes and exception information feed Decision Analytics, KPI calculation and simulation. The Simulation function supports both pre-pilot and post-pilot analysis, including the current Gruber baseline, the S2Z transhipment configuration, an IVECO-only scenario and demand scaling in Bologna city centre.

## 7.2 Norway Pilots

### *7.2.1 Bergen*

The Bergen pilot is part of the Norway macro-pilot and focuses on the interaction between DHL Express urban delivery operations, Paxster right-sized electric vehicles, modular cargo units and geofenced urban access regulation. The operational configuration involves DHL Express as the logistics operator, Bergen Municipality in cooperation with Nivel[2] as providers of geofencing and access-rule data and Paxster as the provider of vehicle-side execution data. The BPM represents the sequence from goods preparation at the terminal to trunking transport towards a transfer point, cross-docking to Paxster vehicles, last-mile delivery within regulated or geofenced urban areas, geofence entry and exit, delivery execution, return to the transfer point and post-operation assessment.

[2] Nivel is a Norwegian mobility management platform, cooperating with the Bergen municipality, that allows cities and operators to exchange vehicle data and digital mobility policies: https://www.nivel.no/

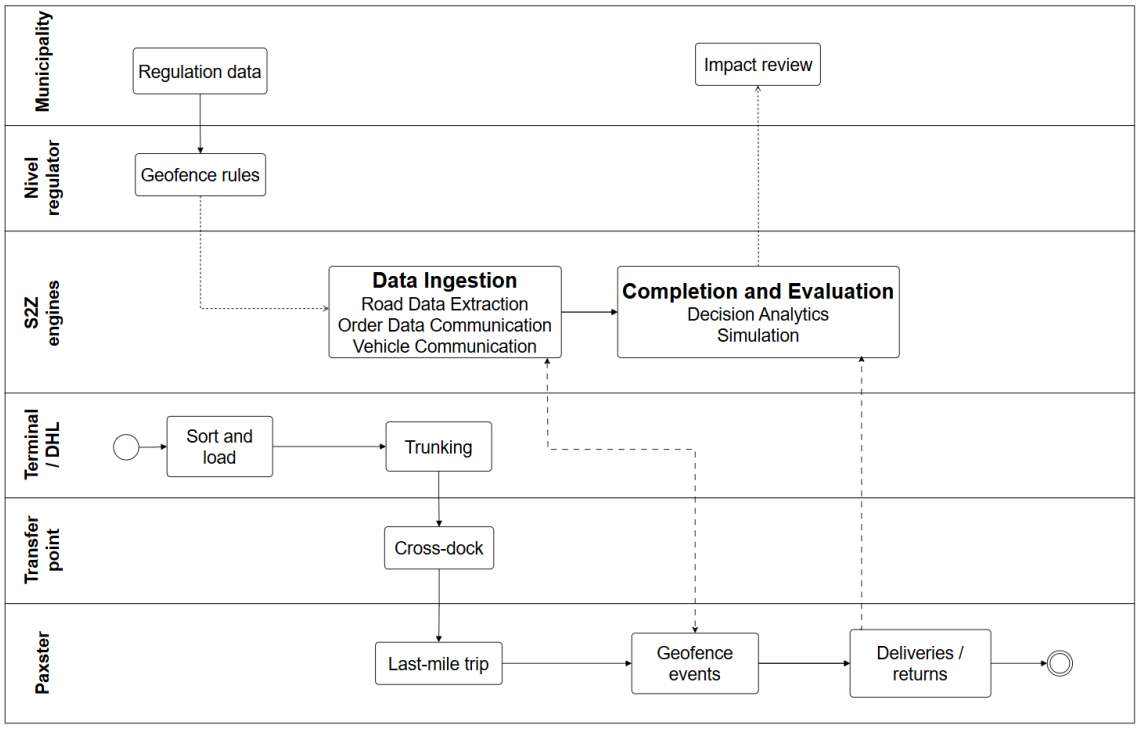



*Figure 7. Bergen BPM with S2Z engine layer*

### Actors

**DHL Express** is the logistics operator and the main provider of planned operational data. DHL Express performs routing internally and can provide post-routing stop or trip data for Bergen in CSV format. The expected dataset includes stop addresses, delivery weight, route identifiers, stop sequence, vehicle assignment, time windows and execution-related fields where available. Customer names are excluded before data sharing, while address-level sensitivity remains part of the governance assessment.

**Bergen Municipality** and the Nivel-related regulatory environment provide the urban regulation layer. Geofence zones, access rules, speed rules, time validity, allowed vehicle categories and possible curbside or parking rules are expected to be made available through MDS (Mobility Data Specification) which is an open API-based standard used to exchange operational mobility data and digital urban access rules between public authorities and mobility operators.

**Paxster** provides the vehicle execution layer. The relevant data include GPS traces, vehicle movement, speed profile, geofence entry and exit events, speed-reduction behaviour, kilometres driven, energy consumption and stop time. These data are not a trip plan. They describe actual execution and allow the S2Z platform to compare planned stops with vehicle behaviour during or after the route.

### Available and expected data exchanges

*Table 11. Bergen - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Daily mission and operational constraints** | DHL Express | CSV; manual upload to S2Z platform as initial option | Per operating day or pilot sample | Demand ingestion | Field layout pending |
| **Vehicle** | Paxster | CSV, telemetry export | During the trip; daily report where available | Reconstruct actual route, assess speed behaviour, energy use, stop time and geofence compliance | Available |
| **Road and access regulation** | Bergen Municipality, Nivel-related actors | MDS; shapefile as static supporting format | Dynamic or per rule update | Regulatory constraints, geofence compliance | Available but not complete |
| **Execution and PoD** | DHL Express | CSV | Per route or operating day | Close the loop between planned stops, completed deliveries and execution deviations | Availability and fields to be confirmed |
| **Evaluation and simulation** | DHL Express, Bergen Municipality | Aggregated and structured datasets derived from stop data, geofence events, vehicle telemetry | Pre-pilot and post-pilot | Assess geofenced access, fleet mix, walking distance, urban-space use and operational performance | Scenario definition pending |

**Macroblock (engine)**

The **Data Ingestion** macro-block connects the three core information layers of the Bergen pilot. The Order Data Communication engine harmonises DHL Express routing stop or trip data for monitoring and simulation. The Road Data Extraction engine processes MDS-based geofence rules, static geometries and road-context data into a regulatory layer. The Vehicle Communication engine receives Paxster execution data, including GPS traces, speed profile, geofence events, kilometres, energy use and stop time.

The **Planning and Execution** macro-block is not central to the Bergen pilot. Its engines can be activated in later phases only if specific analytical or scenario-testing needs are identified, for example to compare alternative routes, assess swap-box constraints, or evaluate energy and range feasibility under defined operating conditions.

The **Completion and Evaluation** macro-block is central for Bergen. Decision Analytics combines planned stops, execution data, geofence events, energy use, stop time and PoD information to generate monitoring outputs and KPIs. The Simulation function supports offline assessment of geofence extension or restriction, routing with and without access to regulated areas, fleet-mix scenarios, transfer-point configurations, walking distance from stop points to customers and use of urban space over time.

### 7.2.2 Oslo

The Oslo pilot is part of the Norway macro-pilot and focuses on the operational deployment of the modular swap-box logistics model. The operational configuration connects DHL Express distribution and city-hub operations, secondary sorting, last-mile vehicle loading, modular cargo-unit exchange, return logistics and the analytical use of S2Z platform outputs. Compared with Bergen, where the core focus is geofenced access regulation, Oslo concentrates more directly on modularity, standardised transhipment and the use of swap boxes to increase operational flexibility. The BPM represents a multi-stage distribution process in which trunking vehicles deliver consolidated freight to the city hub, where goods are sorted and loaded onto last-mile vehicles (9 electric vans and 6 Paxsters). Smaller vehicles such as Paxster have operational advantages in dense urban areas but have limited capacity for goods so they must return to the city hub to refill with goods during the day. The pilot will examine how swap boxes can extend the operational range of Paxster vehicles by either reducing transhipment time at DHL Express city hub, or by using micro depots to deposit swap boxes closer to the delivery area such that a Paxster does not need to return to the city hub to reload. Direct vehicle-to-vehicle transfer of swap boxes is also a potential scenario under consideration. Paxster then completes deliveries in areas where a larger vehicle is operationally less suitable.

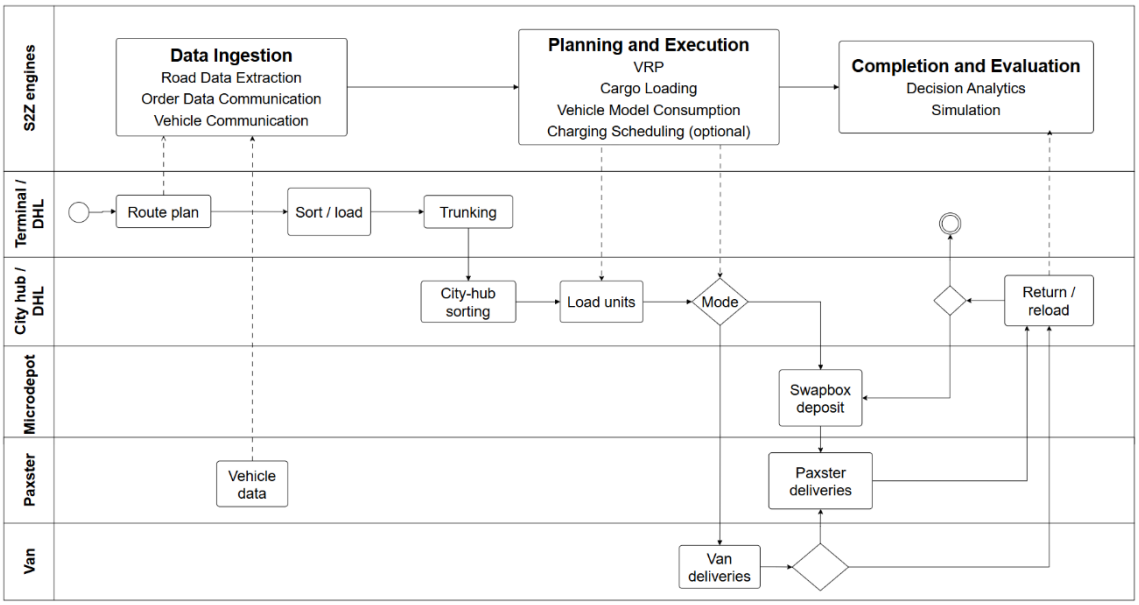



*Figure 8. Oslo BPM with S2Z engine layer*

#### Actors

**DHL Express** is the logistics operator and the main provider of planned operational data. DHL Express retains its internal routing process and can provide post-routing stop or trip data for Oslo in CSV format. The expected dataset includes stop addresses, delivery weight, route identifiers, stop sequence, vehicle assignment, time windows and execution-related fields where available. Customer names are excluded before data sharing.

The **City of Oslo**, the Norwegian Public Roads Authority and the wider regulatory environment provide the public-sector and urban context. For Oslo, regulatory data are less central than in Bergen, but access rules, curbside conditions, hub or micro-depot constraints and potential UVAR-related scenarios remain relevant for simulation activities.

**Paxster** and the relevant vehicle-side partners provide the execution and vehicle-status layer where smaller electric vehicles are included in the Oslo configuration. Vehicle data include GPS position, speed, kilometres driven, energy consumption, stop time and possible swap-box related identifiers. These data describe actual execution and support the comparison between planned operations, vehicle use and modular exchange patterns.

### Available and expected data exchanges

*Table 12. Oslo - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Daily mission and operational constraints** | DHL Express | CSV; manual upload to S2Z platform as initial option | Per operating day or pilot sample | Demand ingestion | Field layout pending |
| **Vehicle** | Paxster | CSV, telemetry export | During or after trips; daily report where available | Assess vehicle use, stop time, energy consumption, swap-box rotation and operational continuity | Schema and sample pending |
| **Road access and regulation** | City of Oslo, related actors | MDS where dynamic rules apply; shapefile or GIS layer for static context | One-off or per rule update | Access-rule context, curbside assessment | Available but not complete |
| **Execution and PoD** | DHL Express | CSV | Per route or operating day | Close the loop between planned stops, completed deliveries, failed deliveries and execution deviations | Availability and fields to be confirmed |
| **Evaluation and simulation** | DHL Express, City of Oslo | Aggregated and structured datasets derived from stops, swap-box use and vehicle execution data | Pre-pilot and post-pilot | Assess modularity, return logistics, fleet use, urban-space efficiency, walking distance and scalability | Scenario definition pending |

### Macroblock (engine)

The **Data Ingestion** macro-block connects DHL Express operational data, hub and swap-box configuration, vehicle-side execution data and the relevant urban-context datasets. The Order Data Communication Engine harmonises DHL Express routing and trip data and provides the structured operational input required by Cargo Loading engines, including delivery points and stop sequences. The Road Data Extraction engine

provides the road and access-context layer, with a stronger role where Oslo scenarios use UVAR, curbside or geofencing assumptions derived from the Norway macro-pilot. The Vehicle Communication engine receives vehicle execution data, including GPS, speed, distance, energy use, stop time and, where available, swap-box identifiers.

The **Planning and Execution** macro-block has a stronger operational relevance in Oslo than in Bergen, but it remains aligned with DHLExpress internal planning process. The VRP engine supports benchmarking and scenario comparison rather than direct replacement of DHL Express routing. The Cargo Loading engine is central because Oslo focuses on modular swap boxes, vehicle-to-vehicle exchange, hub-based exchange and return logistics. The Vehicle Model Consumption function supports energy and range assessment for different vehicle and load configurations. The Charging Scheduling engine is relevant where vehicle autonomy, charging windows or repeated distribution rounds affect operational feasibility.

The **Completion and Evaluation** macro-block is central for Oslo. Decision Analytics combines planned stops, executed routes, vehicle telemetry, stop times, swap-box movements and PoD information to produce monitoring outputs and KPIs. The Simulation engine supports analysis of hub and micro-depot configurations, fixed versus on-route exchange, fleet mix, swap-box rotation, return logistics, walking distance from stop points to customers, use of urban space over time and the scalability of the modular model across DHL Express Norwegian and European operations.

## 7.3 Thessaloniki pilot

The Thessaloniki pilot is structured as a two-tier urban logistics case connecting extra-urban logistics operations with right-sized electric distribution in the urban area. The operational configuration involves Diakinisis as logistics operator, the Municipality of Thessaloniki as provider of local regulatory and access-rule information, CERTH as technical partner managing the S2Z platform and engine environment and ALKE as vehicle provider for the right-sized eLCV. The BPM represents the integration sequence from regulation selection and geofencing rule definition to mission profile construction, route planning, route preparation, cross-docking to the ALKE vehicle, delivery execution, monitoring and post-execution assessment.

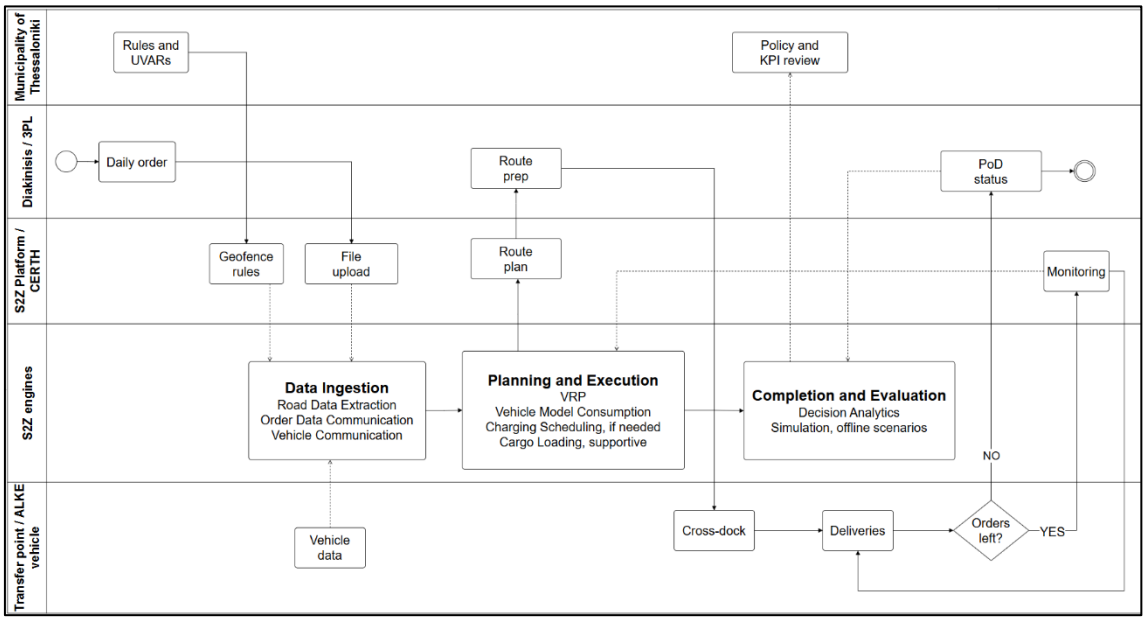



*Figure 9. Thessaloniki BPM with S2Z engine layer*

### Actors

The main operational input is the daily order or trip plan provided by **Diakinisis**. This dataset contains the information required to build the demand layer for route planning, including delivery points, order characteristics, time-related constraints, temperature requirements where relevant and operational priorities. The expected exchange mode is a structured CSV file extracted from Diakinisis' ERP environment and uploaded to the S2Z platform for next-day planning.

Municipal data define the regulatory context of the pilot. The **Municipality of Thessaloniki** provides or validates UVARs, geofencing zones, access restrictions, speed restrictions, vehicle eligibility rules, temporary restrictions and other local operational constraints. These data feed the road and regulatory layer used by the platform for planning, feasibility assessment, geofencing logic and simulation. The platform can support manual polygon definition and rule association. GIS upload remains a possible integration option subject to technical validation.

The **ALKE** vehicle data stream provides the execution and vehicle-status layer. ALKE data can be sent to an external platform through PUSH or made available on request through API access to the ALKE cloud. The available JSON structure includes timestamp, vehicle identification number, driving mode, Battery Discharge Indicator, operating status, total and partial kilometres, working hours, speed, controller temperature, controller voltage, current, cabin temperature, heater status and GPS information. These data support vehicle monitoring, route execution analysis, energy assessment, charging feasibility, KPI calculation and simulation.

### Available and expected data exchanges

*Table 13. Thessaloniki - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Daily mission and operational constraints** | Diakinisis | CSV | Daily, before planned operation | Demand ingestion | Pending |
| **Road and access regulation** | Municipality of Thessaloniki | Polygon drawing in S2Z platform or GIS-compatible upload | One-off, with updates when rules change | Regulatory constraints, geofencing compliance | Basic road layer available. Specific rules pending |
| **Vehicle** | ALKE | ALKE JSON via PUSH or cloud API | Real-time, near-real-time or ex post, depending on configuration | Vehicle monitoring, consumption assessment, charging feasibility | ALKE data structure available |
| **Execution and PoD** | Diakinisis | CSV | During execution or after route completion | Close the loop between planned stops, completed deliveries and execution deviations | Availability and fields to be confirmed |
| **Evaluation and simulation** | Diakinisis, Municipality of Thessaloniki | Aggregated and structured datasets derived from execution, vehicle and regulatory | Pre-pilot and post-pilot | Assessment of transhipment, fleet use, UVARs, geofencing, energy use, service reliability and scalability | Scenario definition pending |

### Macroblock (engine)

The **Data Ingestion** macro-block connects the three main inputs of the Thessaloniki pilot. The Order Data Communication engine receives the daily order or trip plan provided by Diakinisis and harmonises it into a structured demand dataset for downstream processing. The Road Data Extraction engine prepares the road and regulatory layer, including municipal road data, UVARs, geofencing zones, access restrictions, speed restrictions, vehicle eligibility rules and temporary constraints. The Vehicle Communication engine collects or receives ALKE vehicle data.

The **planning and execution** macro-block focus on route planning, energy feasibility and operational support. The VRP engine uses daily demand, road data, geofencing constraints, vehicle characteristics and transhipment information to generate an operational route plan or stop sequence. The Vehicle Model Consumption engine uses route, vehicle and telemetry data to estimate energy needs and range feasibility. The Charging Scheduling engine is relevant where battery status, route length or charging availability affect the feasibility of the daily mission. Cargo Loading has a supporting role in Thessaloniki. Its relevance increases where parcel dimensions, temperature constraints or modular loading units become operationally relevant, while current

evidence indicates that route duration, unloading time and parking constraints are more critical than vehicle space.

The **completion and evaluation** macro-block uses execution data to compare planned and executed operations. Proof-of-delivery information is required to validate delivery status, timestamps, failed deliveries and route or vehicle identifiers. These data feed monitoring, KPI calculation, Decision Analytics and Simulation engines.

## 7.4 Wroclaw pilot

The Wroclaw pilot is structured as a Polish use case for N1 eLCVs in urban and peri-urban logistics. The operational configuration connects DPD Polska's main logistics hubs, city hubs, eLCV last-mile operations, cargo-bike deliveries, swappable packaging and the potential Low Emission Zone in Wrocław. The pilot focuses on controlled-temperature deliveries, modular swappable cargo solutions, holistic energy management and bi-directional charging of e-bike batteries directly from eLCVs. The BPM represents the synthesised sequence from parcel sorting at the main hub to middle-leg transport towards city hubs or micro-hubs, route preparation, swappable box allocation, controlled-temperature last-mile deliveries, e-bike support, empty and full box rotation, execution monitoring and post-operation assessment.

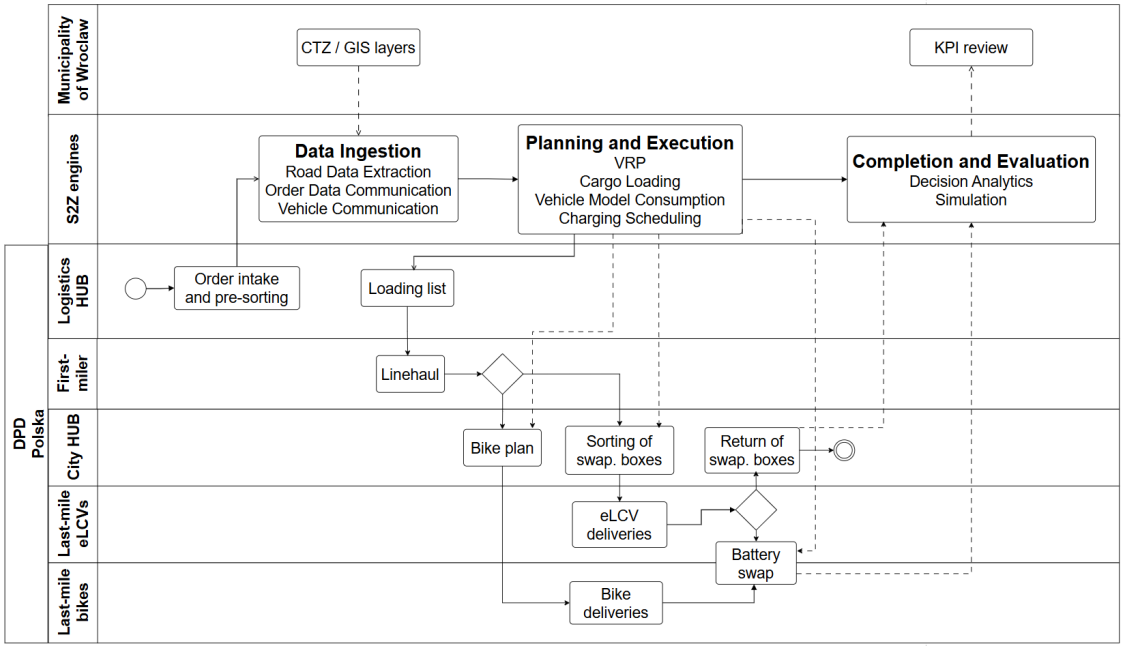



*Figure 10. Wroclaw BPM with S2Z engine layer*

### Actors

**DPD Polska** is the logistics operator and the main provider of operational data. Its role covers sorting at main logistics hubs, middle-leg transport to city hubs, last-mile execution with eLCVs and cargo bikes, and provision of basic delivery data.

The **Municipality of Wrocław** provides the urban and regulatory context. Its role covers traffic management, assessment of delivery methods from the perspective of the urban

space manager and definition of constraints linked to local regulations, climate-neutral city objectives and the potential Low Emission Zone. These data support road-layer preparation, access-rule modelling, geofencing, policy scenarios and municipal impact assessment.

**Łukasiewicz Research Network**, including Automotive Industry Institute (LPIM) and the Poznań Institute of Technology (LPIT), supports the technical and coordination layer. LPIM contributes to the development, implementation and testing of the bi-directional charger used to charge e-cargo-bike batteries from eLCVs. LPIT coordinates the pilot implementation and supports qualitative verification of data for impact assessment.

**IVECO** and **ALKE** provide the S2Z vehicle layer. ALKE data can be sent to an external platform through PUSH or made available through API access to the ALKE cloud. The available JSON structure includes timestamp, vehicle identifiers, driving mode, Battery Discharge Indicator, operating status, kilometres, working hours, speed, motor and controller parameters, current, cabin temperature, heater status and GPS information.

### Available and expected data exchanges

*Table 14. Wroclaw - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Daily mission and operational constraints** | DPD Polska | CSV; manual upload or API | Daily, likely before operations | Demand ingestion, routing | Field layout pending |
| **Road and access regulation** | Municipality of Wrocław | Shapefile | One-off, with updates when rules or infrastructure change | Regulatory constraints, geofencing simulation | Shapefile available |
| **Vehicle** | IVECO, ALKE | ALKE JSON via PUSH or cloud API; IVECO data format to be confirmed | Real-time, near-real-time or ex post, depending on configuration | Vehicle monitoring, consumption assessment, charging feasibility | ALKE data structure available. IVECO format and access conditions to be finalised |
| **Execution and PoD** | DPD Polska | Pending | After route completion, ideally daily | Planned-versus-actual analysis, delivery status, failed deliveries | PoD availability confirmed at high level |
| **Evaluation and simulation** | DPD Polska, Municipality of Wrocław | Aggregated and structured datasets derived from operational, vehicle, road, charging | Pre-pilot and post-pilot | Assessment of controlled-temperature deliveries, energy use and scalability | Scenario definition pending |

### Macroblock (engine)

The **Data Ingestion** macro-block connects DPD operational data, municipal regulation data and vehicle-side data. The Order Data Communication engine receives daily

delivery and collection information and harmonises it for routing, loading, analytics and simulation. The Road Data Extraction engine transforms municipal road, access, stopping and hub-location data into a computable planning layer. The Vehicle Communication engine receives telemetry from IVECO and ALKE vehicles and, where available, e-bike GPS, battery and charging-event data.

The **Planning and Execution** macro-block supports eLCV and e-bike operations. The VRP engine uses daily demand, hub locations, city-hub constraints, vehicle capacity, access rules and candidate transfer points to generate route outputs. The Cargo Loading engine is central for Wroclaw because the pilot includes modular swappable packaging, controlled-temperature cargo and parcel sorting by route or temperature category. The Vehicle Model Consumption engine estimates range and energy feasibility for controlled temperature eLCV operations. The Charging Scheduling engine is relevant for both vehicle charging and e-bike battery charging from eLCVs, including the assessment of battery replacement and route continuity.

The **Completion and Evaluation** macro-block uses execution data to assess operational and policy impacts. PoD, delivery status, timestamps, vehicle telemetry, charging events, e-bike data and emissions or energy indicators feed Decision Analytics engine, KPI calculation and municipal reporting. The Simulation engine supports scenario analysis for low-emission access rules, e-bike range extension, controlled-temperature delivery performance and the scalability of eLCV-based last-mile services in Wrocław.

## 7.5 Brussels pilot

The Brussels pilot is structured as a self-service electric van-sharing case for inhabitants and companies. The operational configuration connects the CLEM booking system and supervision platform, vehicle telematics, geofencing rules, charging infrastructure, local solar production and the S2Z platform. The service model is station-based: users book the vehicle through the CLEM app, select passenger or logistics mode, collect the vehicle from a fixed station and return it to the same station. The BPM represents the sequence from booking and use-mode selection to freight-box configuration, vehicle pick-up, monitoring and geolocation, geofencing notification, vehicle return, charging, extraction of travel data and UVAR identification. In this configuration, the S2Z platform acts as the interface through which vehicle, geofencing, charging and energy data are processed and made available as operational alerts, monitoring information, KPI inputs and simulation datasets.

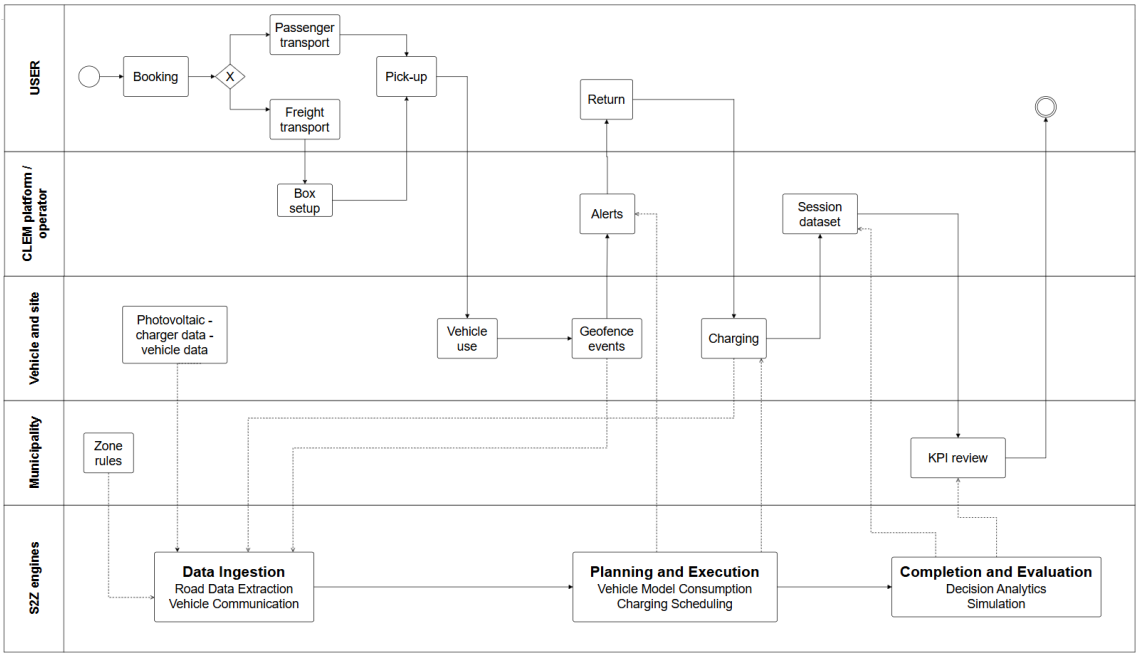



*Figure 11. Brussels BPM with S2Z engine layer*

### Actors

**CLEM** is the mobility and charging service operator. It manages the user app and relation management, the reservation and geolocation database, the supervision and charge point platform and the vehicle-side connection. CLEM can provide booking status, vehicle availability, State of Charge, location data, trip mode, alert events and charging-related data, solar production (given by EEBIC), subject to privacy and data-minimisation constraints. Detailed trip reconstruction is restricted, so location data are handled through aggregated, pseudonymised or event-based records.

The **Brussels authority** provides the regulatory and geofencing layer to feed S2Z platform and support for the installation of the station within a public area owned by Citydev (public real-estate and urban-development agency of the Brussels-Capital Region).

The vehicle and infrastructure layer includes pilot-specific vehicles and the **ALKE** eLCV with related onboard telematics.

### Available and expected data exchanges

*Table 15. Brussels - Available and expected data exchanges*

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Booking and trip-mode data** | CLEM / clem.mobi app | API or structured JSON/CSV export; TOMP-API | Per booking or near real-time; daily batch for analytics | Vehicle allocation, passenger/logistics mode, utilisation monitoring and simulation | Available. Schema, identifiers and privacy rules to be agreed |

| Data category | Provider | Expected format and transfer | Frequency | Main use | Status |
|---|---|---|---|---|---|
| **Vehicle** | CLEM / ALKE | CSV, telemetry export | Near real-time for operation; daily or post-trip for analytics | Availability, State of Charge, autonomy, Location data/geofence events and vehicle monitoring | Available. interface to be finalised |
| **Energy** | CLEM | OCPP/ API and MQTT | 15 min | V1G intelligently schedules EV charging around microgrid and user needs | API developed, Charging Station: integrated Solar production connection pending. |
| **Road and access regulation** | Brussels authority | GIS layer | One-off with versioned updates | UVAR logic | Specific rules pending |
| **Execution and PoD** | CLEM platform | structured log to be agreed | Per route or operating day | Zone entry/exit, insufficient energy, vehicle return, booking closure and exception analysis | Availability and fields to be confirmed |
| **Evaluation and simulation** | CLEM, Brussels pilot team | Aggregated and structured datasets to be confirmed | Pilot milestones and simulation cycles | User acceptance, box usability, logistics-only versus mixed-use model, fleet sizing and scale-up | Scenario definition pending |

**Macroblock (engine)**

The **Data Ingestion** macro-block is adapted to a shared-mobility service. The Order Data Communication function does not ingest a conventional delivery list; it harmonises booking, use-mode and vehicle-allocation data. The Road Data Extraction function processes geofencing and access-rule data into a computable regulatory layer. The Vehicle Communication function collects vehicle availability, State of Charge, privacy-preserving GPS or geofence events, alerts and vehicle-return information.

The **Planning and Execution** macro-block focuses on feasibility and configuration rather than professional multi-drop routing. The Charging Scheduling function is central because the pilot includes charging, solar-priority logic, off-peak fallback and readiness before the next booking. The Vehicle Model Consumption function supports autonomy and energy assessment using State of Charge, vehicle configuration, distance or event data and passenger/logistics mode.

The **Completion and Evaluation** macro-block uses booking closure, vehicle return, charging records, geofence events, alert history, modular-box outcomes and user feedback as the Brussels equivalent of execution evidence. Decision Analytics supports utilisation, energy, charging, geofence interaction, service reliability, user satisfaction and business-model assessment. The Simulation function tests logistics-only versus mixed-use operation, fleet and station capacity, geofencing policies, modular-box adoption and charging strategies.

# 8. Annex B - Detailed Data Exchange Requirements by S2Z Engine

This annex provides the detailed engine-level data exchange requirements supporting the connector architecture presented in Chapter 5. It translates the common architectural principles, connector layers and adoption pathway into practical information requirements for the individual S2Z engines.

The requirements are organised according to the three functional macro-blocks introduced in Chapter 2: Data Ingestion; Planning and Execution; and Completion and Evaluation. For each engine, the corresponding tables identify the required input data, expected providers, likely formats, exchange frequencies, possible transfer mechanisms, relevance across the S2Z pilots and implementation issues that remain to be resolved.

The same engine may perform different functions across the pilots. In some cases, it may support operational planning or execution. In others, it may be used for monitoring, benchmarking, KPI calculation, ex-post assessment or scenario simulation. The requirements should therefore be applied proportionally to the engines and platform usage modes selected for each pilot.

The annex provides a common technical baseline rather than imposing an identical integration configuration on all pilot sites. Final schemas, transfer frequencies, access arrangements and source-specific interfaces will be refined through representative data exchanges, connector testing and pilot preparation activities. Local adapters and mappings may evolve while remaining compatible with the common S2Z information model and engine interfaces.

## 8.1 Data Ingestion macro-block

The Data Ingestion macro-block provides the foundation for all downstream S2Z activities by collecting and harmonising data from pilot systems, municipalities, infrastructure providers and vehicles. The corresponding connectors transform heterogeneous external sources into structured datasets that can be consumed by the S2Z engines. Data exchange may range from periodic file-based transfers to automated API-based communication, depending on the maturity and availability of pilot systems.

*Table 16. Data Ingestion engines*

| | Road Data Extraction Engine | Order Data Communication Engine | Vehicle Communication Engine |
|---|---|---|---|
| **Required input** | Road network, GIS layers, LEZ, ZEZ, UVARs, geofencing zones, speed restrictions, access rules, loading bays, | Daily mission list | Vehicle position, speed, odometer, state of charge, battery data, energy consumption, vehicle status, geofence events |

| | Road Data Extraction Engine | Order Data Communication Engine | Vehicle Communication Engine |
|---|---|---|---|
| | stopping areas, road attributes | | |
| **Expected provider** | Municipalities | LSPs | OEMs, fleet management systems |
| **Expected format** | Shapefile, GIS layer, GeoJSON, OpenStreetMap-based layers | CSV or structured database export | CSV, API payload, telemetry export, CAN bus data |
| **Frequency** | One-off, with updates when rules change | Daily or per operating cycle. Same-day updates where needed | Real time, near-real time or ex post depending on pilot |
| **Possible transfer mechanism** | GIS upload, platform interface, structured file | Manual upload, API, structured file exchange | API, OEM data channel, telemetry connector |
| **Pilot relevance** | All pilots | All pilots | All pilots, with different intensity |
| **Open issue** | Completeness and update frequency of municipal layers remain pilot-specific | Structured export is not confirmed yet for all operators | Data ownership, frequency, granularity and access rights must be confirmed pilot by pilot |

Road and regulatory data are typically provided through municipal or external geospatial sources and require limited update frequency, except when temporary restrictions, access rules, or geofencing conditions change. Order and mission data represent the main operational input for logistics activities. Depending on the pilot context, these exchanges may support daily planning cycles or more dynamic updates during execution. Vehicle data exchange may involve different integration levels. While real-time telemetry enables advanced monitoring and adaptive decision-making, historical or ex-post data remain sufficient for KPI assessment, energy analysis, and model validation.

## 8.2 Planning and Execution macro-block

The Planning and Execution macro-block consumes harmonised datasets from the ingestion layer to support operational decisions, optimisation processes and feasibility assessments. The level of integration of each engine depends on the pilot objectives. Some deployments may use these engines as operational decision-support tools, while others may rely on them mainly for evaluation, comparison of alternatives or validation of innovative concepts.

The VRP Engine provides modular optimisation capabilities that can support route generation, comparison, feasibility analysis or scenario evaluation, without replacing existing routing solutions. The Cargo Loading Engine supports operations where loading

constraints, vehicle configuration, modular cargo units or parcel characteristics affect feasibility. Simplified loading approaches can be applied where detailed data are unavailable. The Charging Scheduling Engine supports cases in which charging availability, energy demand, or infrastructure constraints affect mission execution. Where charging is not an operational constraint, it can be used mainly for analytical purposes. The Vehicle Model Consumption Engine supports the assessment of operational plans against energy feasibility by estimating energy demand from route, vehicle, and operational characteristics, supporting both pre-operation assessment and post-operation validation.

*Table 17. Planning and execution engines*

| | VRP Engine | Cargo Loading Engine | Charging Scheduling Engine | Vehicle Model Consumption Engine |
|---|---|---|---|---|
| **Required input** | Orders, stops, depots, hubs, transhipment points, vehicle capacity, time windows, service times, road constraints, access rules, geofencing data | Parcel list, delivery sequence, parcel size, weight, volume, temperature class, swap-box data, vehicle loading space, unloading constraints | Planned routes, expected energy demand, state of charge, charging infrastructure, charger power, depot charging rules, return windows, tariffs where relevant | Route plan, distance, speed profile, road gradient, payload, vehicle specifications, battery parameters, auxiliary loads, energy data |
| **Expected provider** | LSPs, Data ingestion engines | LSPs, Data ingestion engines | LSPs, OEMs, fleet operators, Data ingestion engines | OEMs, LSPs, Data ingestion engines |
| **Expected format** | Structured dataset, GIS layer | Structured dataset | Telemetry export, API payload | Vehicle specification file, telemetry export, structured route dataset, TbC |
| **Frequency** | Daily or scenario-based | Daily or per loading plan | Daily, per route or ex post depending on use case | Scenario-based, planning phase or ex post |
| **Possible transfer mechanism** | Platform processing, structured file upload | Structured file upload | Platform interface, file exchange, API where available | Structured file, API, technical data exchange |
| **Pilot relevance** | Bologna, Thessaloniki, Wroclaw, Brussels. | Bologna, Wroclaw, partly Thessaloniki and Brussels | Relevant where charging is an operational constraint | All pilots for feasibility checks, KPI interpretation or simulation |

| | VRP Engine | Cargo Loading Engine | Charging Scheduling Engine | Vehicle Model Consumption Engine |
|---|---|---|---|---|
| | Benchmarking in Norway | | | |
| **Open issue** | Extent of operational use varies by pilot. Some operators may keep internal routing | Parcel dimensions, temperature attributes and loading constraints are not confirmed across all pilots | Charging needs are not confirmed as a priority for all pilots | Availability of payload, energy and vehicle calibration data remains uneven |

## 8.3 Completion and Evaluation macro-block

The Completion and Evaluation macro-block integrates planned and executed operational data to support KPI assessment, performance monitoring, and scenario analysis. Through the corresponding connectors, operational outcomes, vehicle observations and contextual information are transferred to the Decision Analytics and Simulation engines. These exchanges support validation of pilot results and refinement of models for future deployments.

*Table 18. Completion and evaluation engines*

| | Decision Analytics Engine | Simulation Engine |
|---|---|---|
| **Required input** | Planned routes, executed routes, PoD, energy use, geofence events, exceptions | Historical or representative demand, pilot order data, planned and executed routes, road network, regulatory scenarios, fleet configuration, vehicle specifications, hub or transhipment assumptions, KPI parameters |
| **Expected provider** | LSPs, OEMs, vehicle providers, Planning engines | LSPs, municipalities |
| **Expected format** | CSV, API payload | Structured datasets, scenario files, GIS layers, simulation input files |
| **Frequency** | Daily, per trip or ex post | Before pilot, after pilot or scenario-based |

The Decision Analytics Engine relies on structured records of planned routes, execution observations, and delivery outcomes. Paper-based or scanned proof-of-delivery documents should be transformed to structured fields before ingestion, as the engine operates on structured operational records rather than document formats. The Simulation Engine does not require real-time data but does require internally consistent baseline assumptions and comparable datasets across the scenarios under examination. Scenario configuration and input versioning are essential for results to be interpretable and replicable across pilots.

These exchanges maintain the same modular connector principle described throughout this chapter: pilot-specific adapters and mappings may evolve while preserving compatibility with the common S2Z data model and engine interfaces.