E-Laas

Energy optimal urban Logistics As A Service

Deliverable report

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1. Summary

Report D2.1 documents the work related to developing assumptions for survey research and simulation studies carried out within WP2. It directly builds on the work completed in WP0, in particular the results presented in reports D0.2 and D0.3. D0.2 defined the structure for describing reference cases and scenarios, while D0.3 identified scenarios of urban logistics systems for the RC1 reference case, i.e. the GZM Metropolis. D2.1 transfers these findings to the level of assumptions concerning data, survey research, and further simulation modelling.

The main purpose of report D2.1 is to define the data needs required for the analysis of energy-efficient urban logistics flows, and to indicate how these data can be collected, organised, and used in the next stages of the project. The report includes a classification of data sources, assumptions for survey research, a description of respondent groups and questionnaires, and general assumptions for simulation studies. The document is therefore methodological and preparatory in nature, supporting further analysis of user preferences and simulation experiments.

In the part concerning data sources, the report organises information relevant to the description of urban freight flows. It includes data on the transport network, transport zones, locations of senders and recipients, cargo categories, means of transport, costs, energy, emissions, and factors generating demand for deliveries. The report identifies data that cannot be reliably obtained only from administrative, spatial, or industry sources. This applies in particular to the behaviour of delivery providers, recipient preferences, service times, operational problems, infrastructure limitations, and acceptance of selected organisational solutions.

In the survey part, the report defines the assumptions for research conducted among participants of the urban logistics system. These studies cover drivers, couriers and delivery providers, representatives of municipalities and districts, service recipients, and logistics operators. The scope of the surveys was linked to the needs of further project analyses, including microsimulation modelling, optimisation of logistics operations, energy analysis, assessment of social aspects, and formulation of assumptions for urban policies. The surveys complement spatial and transport data, as they provide information on the behaviours and preferences of participants in urban delivery systems. The report also presents assumptions for carrying out the surveys, including the sample size, the structure of research groups, and the method of data transfer. The survey results form the basis for further analyses in D2.2, while selected survey data may be used to parameterise the models and experiments planned in D2.3.

In the part concerning the assumptions for simulation studies, the report discusses general assumptions for the use of modelling environments and tools, in particular QGIS, PTV Visum, FlexSim, and additionally Simantics System Dynamics. It defines the link between the macroscopic and microscopic levels of the research. The macroscopic model may provide data on the study area, TAZ zones, traffic conditions, and travel impedance, while the microscopic model may be used to represent selected last-mile delivery processes in detail and to determine KPI indicators.

Further work within WP2 will focus mainly on the scenarios identified in D0.3 as key for the project, namely ready-made food delivery, boxed meal delivery, and parcel delivery with home and parcel locker channels, including channel split and drone-based variants. This report

integrates the scenarios defined in WP0 with the next stages of work in WP2. The next report, D2.2, will concern synthesised knowledge about the needs and preferences of potential E-Laas users, while D2.3 will include the simulation model and indicators for assessing the energy performance of distribution systems. The final result of the task will be M2, which will include synthesised research results on sustainable urban logistics policies and the identification of the main barriers to achieving energy optimality goals.

2. Introduction

The E-Laas project focuses on the analysis of urban logistics systems from the perspective of energy consumption, operational efficiency, environmental impact, and the behaviour of system participants. According to the main logic of the project, urban logistics flows should be analysed not only as classical transport processes, but also as processes in which energy, emissions, delivery system organisation, urban infrastructure, social acceptance, and the possibilities of implementing low- and zero-emission solutions are important. Work carried out in WP0 created the conceptual basis for these studies. D0.2 defined the structure for describing scenarios and reference cases, while D0.3 identified scenarios of urban logistics systems for the RC1 case. These scenarios make it possible to indicate which types of transport relations, groups of participants, means of transport, decision variables, and evaluation indicators should be considered in further project work. D2.1 develops these findings by indicating which data sources may be used to parameterise the defined scenarios and what assumptions should be adopted for survey research and simulation studies.

From the perspective of WP2, the combination of three groups of data is particularly important. The first group consists of spatial and transport data, including, among others, the road network, transport zones, locations of senders and recipients, logistics infrastructure, types of means of transport, demographic and functional data, and potential sources of delivery demand. The second group consists of survey data, needed to identify the preferences, behaviours, and limitations of system participants. The third group consists of data and assumptions necessary to build simulation models and later evaluate KPIs.

Report D2.1 is preparatory in nature and supports the next stages of the research. Detailed analyses related to the surveys will be presented in D2.2, while simulation experiments will be presented in D2.3. The main role of the report is to organise data sources, describe the assumptions for obtaining empirical data, and define the general logic for using data as well as macro- and microsimulation modelling.

3. Purpose and scope of the report

The purpose of report D2.1 is to define the assumptions for survey research and simulation studies carried out within WP2 of the E-Laas project. The report documents the transition from the scenarios and reference cases defined in WP0 to assumptions concerning data collection, survey design, research organisation, and preparation of further modelling analyses. Its role is to indicate what types of data are needed for further analysis of urban delivery systems, where these data may come from, which data can be obtained from administrative, spatial, and transport sources, and which require surveys or expert consultations. The document also defines how these data may support macroscopic modelling, microsimulation, KPI analysis, and the formulation of conclusions for sustainable urban logistics. The scope of the report includes:

- classification of data sources relevant to the study of freight flows in the city,
- identification of cargo categories, potential senders and recipients, and means of transport,
- definition of data needed to build simulation models,
- indication of data used to estimate transport demand,
- identification of missing data that require collection through surveys,
- development of assumptions for survey research,
- indication of respondent groups and the scope of questionnaires,
- description of the survey implementation method and sample size,
- indication of the role of workshops, panels, and expert consultations as complementary activities,
- definition of assumptions for the use of simulation environments and data analysis tools,
- description of the role of macrosimulation as a source of data on the study area, TAZ zones, the transport network, flows, and traffic conditions, as well as its use in the study of the urban logistics system,
- description of assumptions for microsimulation studies that allow a detailed and scenario-based analysis of freight delivery processes in the urban area,
- indication of the general logic for integrating the micro- and macrosimulation levels.

The assumptions developed in D2.1 are mainly directed towards further research in WP2. In this context, the report has the following functions:

- it organises input data for urban logistics analyses,
- it indicates which data can be used in macro- and microsimulation modelling,
- it justifies the scope of the survey research,
- it documents the logic linking survey questions with the analytical areas of the project,
- it prepares the basis for the analysis of user needs and preferences in D2.2,
- it prepares the basis for building the simulation model, scenario studies, and assessment of distribution processes in D2.3,
- it provides a framework of research areas and tools for the assessment and recommendations concerning sustainable urban logistics policies in M2.

4. Classification of data sources

Cargo transport in cities is a key element of modern logistics systems, playing a significant role in urban economies and the daily lives of residents. With the dynamic development of urbanization, increasing population density, and growing consumer demands, urban transport faces new challenges that require effective and sustainable solutions.

One of the biggest challenges is heavy urban traffic, leading to road congestion, extending delivery times, and increasing operational costs. Limited road space, especially in city centers, hinders both the accessibility and efficiency of cargo transport. To address these issues, it is necessary to develop traffic management strategies and optimize delivery routes.

Additionally, road transport is a significant source of CO_2 emissions and other pollutants, contributing to climate change and public health problems. This necessitates the implementation of solutions to increase fleet eco-friendliness, such as electric vehicles, and to promote alternative forms of transport, such as cargo bikes and delivery drones.

Many cities introduce regulations aimed at reducing heavy traffic in the center, including low-emission zones and delivery time restrictions. This requires logistics companies to adjust their operations to local laws and seek innovative solutions to maintain delivery efficiency while complying with regulations.

Last-mile deliveries are particularly problematic in densely populated urban areas. Customers expect fast and precise deliveries, posing a challenge for urban logistics in terms of efficiency and flexibility. Solutions may include local logistics centers and the use of smaller vehicles for distribution in the most congested areas.

The rise of e-commerce has significantly impacted the volume of direct-to-consumer deliveries, requiring logistics companies to increase the efficiency of delivery processes and manage returns. Modern technologies, such as advanced IT systems, allow for route optimization, real-time cargo monitoring, and increased operational efficiency.

A key factor in solving urban transport problems is cooperation between local authorities and businesses. Through joint initiatives, strategies can be developed that are beneficial for both city residents and businesses, promoting sustainable development and improving the quality of life in urban spaces.

Thus, cargo transport in cities requires an integrated approach that considers both business and social needs. Technological innovations, sustainable practices, and effective intersectoral cooperation are key to the future of urban cargo transport, enabling the creation of more efficient, safer, and eco-friendly logistics systems.

The realization of cargo deliveries is directly related to the types of cargo transported. They determine the nature of the transport and the means of transport used. Their categorization, along with the identification of potential senders and recipients of cargo and the types of transport used, is compiled in Table 1.

Table 1. List of loads with potential senders and recipients

Cargo category	Description	Potential senders	Potential recipients	Transport type
Food products	Fresh products, frozen foods, beverages, packaged products	Food producers, wholesalers, warehouses	Grocery stores, supermarkets, restaurants	Delivery vans, refrigerated vehicles, cargo bikes
Everyday consumer goods	Household products, electronics, clothing	Manufacturers, distributors, logistics centres	Retail stores, shopping centres	Delivery vans, light commercial vehicles, cargo bikes, freight trams
Construction materials	Bricks, cement, wood, fittings, tools	Production plants, construction wholesalers	Construction sites, construction supply stores	Trucks, vehicles with trailers, freight trams

Pharmaceuticals and chemicals	Medicines, medical equipment, chemicals	Pharmaceutical companies, laboratories	Pharmacies, hospitals, clinics, laboratories	Delivery vans, specialised vehicles
Documents and parcels	Documents, parcels, correspondence	Companies, institutions, private individuals	Companies, institutions, private individuals	Bicycle couriers, motorcycle couriers, drones
Electronics and components	Computers, smartphones, electronic components	Electronics manufacturers, distributors	Electronics stores, repair services, enterprises	Vans, drones, cargo bikes
Dangerous goods	Explosive, flammable, toxic, and radioactive materials	Chemical industry, refineries, laboratories	Petrol stations, industrial companies, hospitals	Specialised vehicles equipped with safety systems
Waste and recycling	Municipal waste, recyclable materials	Households, companies, institutions	Waste treatment plants, recycling centres	Waste collection vehicles, recycling trucks
Oversized goods	Furniture, household appliances, machinery	Household appliance and furniture manufacturers, stores	Households, companies, institutions	Trucks, flatbed vehicles
Luxury goods	Jewellery, works of art, watches	Producers and distributors of luxury goods	Luxury stores, galleries, auctions	Armoured vans, bicycle couriers, drones

Developing a simulation model for the transportation of the aforementioned cargo categories between their senders and recipients requires the preparation of a range of data, which can also be categorized. These data will relate to the transport infrastructure, its capacity, the means of transport used and their parameters, the locations of the senders and recipients of cargo, and the volume of transportation demand between the identified senders and recipients of cargo. In addition to senders and recipients, it will be important to indicate the locations of various types of concentration points.

Table 2. Summary of data for the simulation model and their sources

Data category	Data type	Data source
The road network in its existing condition	Network vertices and their locations	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Network sections with their location and parameters	Metropolitan Transport Authority (ZTM) GZM;

		Municipal administration of streets and bridges in Katowice
	Maximum permissible speed on sections of the network	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Average daily load on a network section	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Peak load on a network section	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Section capacity in the number of vehicles	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Average speed on a section resulting from traffic load	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
Emission data on episodes	Pollution with CO2, methane, benzene and others	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
Means of transport	Types and types of means of transport used	Metropolitan Transport Authority (ZTM) GZM; Municipal administration of streets and bridges in Katowice
	Load capacity of a means of transport of a given type and type	Vehicle manufacturer data / Technical specifications
	Load capacity of a means of transport of a given type and type	Vehicle manufacturer data / Technical specifications
	The speed of a given type of transport	Vehicle manufacturer data / Technical specifications
	Average loading/unloading time of the means of transport	Logistics companies / Operational reports (data obtained from surveys)
	Power source for a means of transport of a given type and type	Vehicle manufacturer data / Technical specifications
	Energy/fuel consumption of the means of transport	Vehicle manufacturer data / Technical specifications
	CO2 emissions by means of transport	Vehicle manufacturer data / Technical specifications
Charging and refueling places vehicles	Location of charging and refueling places	OpenStreetMaps
	Average loading/refueling time of the means of transport	Databases of charging/refueling companies (data obtained from surveys)

	Average waiting time for charging/refueling	Databases of charging/refueling companies (data obtained from surveys)
Transport cost data	Fuel prices	Gas stations / Price reports
	Energy prices	Energy operators / Price reports
Data about the location of senders, recipients	Location of POIs in the city	OpenStreetMaps
	Location of food wholesalers	Business Panorama
	Location of pharmaceutical wholesalers	Business Panorama
	Location of a wholesaler with household goods	Business Panorama

Determining the demand for transport services (the volume of transportation required between senders and recipients of cargo) in turn requires identifying the factors generating this demand. Therefore, the table below compiles data that determine the volume of freight transport between the identified senders and recipients of cargo.

Table 3. Data summary for determining transport demand - macroscopic model

Data category	Data type	Data source
Demographic and socio-economic data	Population	GZM
	Age structure of the population	GZM
	Number of households	GZM
Details of places of residence/accommodation	Area of single-family and multi-family residential buildings	GZM
	Number of single-family and multi-family residential buildings	GZM
	Area of hotels, accommodation buildings	GZM
	Number of hotels, accommodation buildings	GZM
	Office space	GZM
Data about catering facilities	Area of catering facilities	GZM
	Number of catering facilities	GZM
Data about health care facilities	Area of health care facilities	GZM
	Number of healthcare facilities	GZM
Data about commercial and service facilities	Area of service buildings	GZM
	Area of commercial buildings	GZM
	Area of production and warehouse buildings	GZM
	WOH area	GZM
	Number of service buildings	GZM
	Number of commercial buildings	GZM
	Number of production and warehouse buildings	GZM
	Number of WOH	GZM
Schools, universities	Number of places in primary schools	GZM
	Number of places in secondary schools	GZM
	Number of places at universities.	GZM
	Number of other educational facilities	GZM
	Area of primary schools	GZM

	Area of secondary schools	GZM
	Area of universities	GZM
	Area of other educational facilities	GZM
Workplaces	Number of jobs in the activity category agriculture, industry and construction	GZM
	Number of jobs in the other activity category	GZM
	Number of jobs in the wholesale trade activity category	GZM
	Number of jobs in the retail and repair business category	GZM
	Number of jobs in the transport and storage activity category	GZM
	Number of jobs in the activity category: tourism, culture, recreation, gastronomy	GZM
	Number of jobs in the office activity category	GZM
	Number of jobs in the public administration activity category	GZM
	Number of jobs in the science and education activity category	GZM
	Number of jobs in the health and social assistance activity category	GZM

Based on the data compiled in Table 3, it will be possible to estimate the demand for transportation services in the scope of cargo carriage between distinguished senders and receivers located in the city. The data identified in Table 3 will serve as explanatory variables for the development of cargo flow matrices in the sender-receiver distinguished scheme, which will then serve as input data for the simulation model of cargo flow within the city.

A portion of the data necessary for building simulation models in a variant approach is impossible to obtain from local governments, websites offering interactive maps, or transport management entities, especially in urban areas. These data will characterize the servicing of individual senders and receivers, their preferences regarding this service, as well as specific characteristics of loading and unloading processes of transportation means. Therefore, the table below presents those data, the acquisition of which will require conducting surveys among participants in the analyzed cargo transportation processes within the city (table 4).

Table 4. Data summary for determining demand (transport demand) - survey

Data category	Data type	Respondent type
Delivery details	Size of a single delivery lot	Sender/receiver
	Number of deliveries per day	Sender/receiver
	Delivery time window	Recipient
	Type and type of means of transport used for delivery	Recipient
	Average loading/unloading time of a delivery batch	Sender/receiver

Means of transport	Average loading time	Carrier/Vehicle manufacturer
	Average vehicle refueling time	Carrier/Vehicle manufacturer
	Average waiting time for vehicle charging	Carrier/Charging infrastructure manager
	Average waiting time to refuel the vehicle	Carrier/Refueling infrastructure manager
Respondents' preferences	Flexibility in terms of timely delivery	Recipient
	Flexibility in terms of the means of transport used for delivery	Recipient
	Flexibility to incur higher delivery costs due to the use of an ecological means of transport	Recipient
	Flexibility in terms of delivery method, including e.g. cargo concentration points, parcel lockers	Recipients

For the thematic scope of the survey presented in Table 4, regarding participants in last-mile logistics transportation processes, the following assumptions have been outlined in the subsequent chapter to facilitate the preparation of appropriate survey forms.

5. Survey research assumptions

5.1. General overview

The purpose of the survey research is to collect empirical data on the needs, behaviours, preferences, and limitations of participants in the urban logistics system in the GZM area. The research is intended to support WP2 by identifying information that cannot be obtained from available administrative, spatial, transport, or industry sources, but which is important for the further description and modelling of urban freight flows. The surveys will help identify the needs and behaviours of logistics system participants, as well as limitations and bottlenecks in the functioning of urban logistics.

The research aims to provide a useful set of empirical information needed to parameterise selected scenarios developed in WP2, in particular ready-made food delivery, boxed meal delivery, and parcel delivery with home and parcel locker channels. The adopted survey structure distinguishes parcel deliveries to parcel lockers and parcel deliveries to individual recipients as separate data-collection modules. In the scenario structure adopted in D0.3, however, these modules jointly represent the parcel delivery scenario BS/AS 1.3 and should be interpreted as its complementary delivery channels rather than as separate base scenarios.

The scope of the research should make it possible to collect information on delivery service parameters, such as delivery frequency, size of a single delivery, time windows, means of transport used, loading and unloading service time, as well as respondent preferences regarding delivery time, choice of transport mode, acceptance of ecological solutions, willingness to share higher delivery costs related to transformation and urban policy, and acceptance of alternative service forms, such as delivery consolidation points or parcel lockers. This type of information must be collected directly from the participants in delivery processes.

The results of the surveys will be used mainly to supplement the description of demand, identify the behaviours of recipients and operators, define selected input parameters for models, and interpret later results of simulation analyses. The research should therefore provide data that make it possible to link the perspective of users, logistics operators, and local authorities with the assessment of delivery organisation variants in terms of energy, emissions, time, cost, and service quality. This understanding of the purpose and scope of the work is directly related to the assumptions of the project and WP2, which include the classification of data sources, preparation of surveys, identification of user needs, development of the simulation model, KPI analysis, and preparation of conclusions for urban recommendations.

Conducting the survey research requires the adoption of basic assumptions concerning the structure of the research forms, the method of reaching respondents, and the later use of the collected data. These assumptions will help ensure the usefulness of the information for further analytical and simulation work, while also limiting the scope of the research to questions that are necessary from the point of view of the project. The survey forms should meet the following requirements:

- clear questions - the questions should be formulated in a clear, concise, and understandable way for respondents. Overly technical language, industry abbreviations, and terms that could be interpreted differently by different groups of respondents should be avoided.
- limited survey length - the form should be as short as possible and focused on the most important issues. A survey that is too extensive may reduce the response rate, increase the number of incomplete answers, and lower the quality of the collected data.
- link between questions and the research purpose - each question should be justified by the needs of the project, in particular by the need to describe the behaviour of urban logistics system participants, identify operational limitations, and collect input data for further analyses.
- accessibility of the form - the survey should be available in a form that is convenient for respondents, primarily in an electronic format.
- confidentiality and anonymity of responses - the form should be prepared in a way that ensures and clearly states that the collected data will be used only for research purposes and analysed in an aggregated and fully anonymous form.

Depending on the type of respondents and the scope of information to be collected, several basic methods of conducting survey research can be used:

- paper surveys - a traditional form of research based on distributing printed forms. This method may be useful for respondents who prefer direct contact, or when the survey is carried out during meetings, workshops, or industry events. Due to the greater workload related to collecting and coding data, this method should not be treated as the main one.
- online surveys - research conducted using electronic forms made available to respondents through online platforms. This is an organisationally efficient solution, relatively easy to distribute, and it allows data to be collected and initially organised quickly. This method is particularly useful in studies of individual recipients, company representatives, and other groups that can be reached electronically.

- telephone interviews - research conducted by interviewers according to a prepared set of questions. This method may be more time-consuming and costly, but it can increase the response rate among selected groups of respondents and help clarify answers to questions concerning the practical organisation of deliveries, operational limitations, infrastructure, or the specific nature of business activities. Because an interviewer is involved, questions can be explained and better-quality answers can be collected.
- face-to-face interviews - research conducted in the form of direct conversations with respondents. They make it possible to obtain more detailed information, but they require more organisational effort and time. For this reason, they may be used only as a supporting method, for example as part of expert consultations, workshops, or meetings with selected stakeholders.

For the purpose of identifying data on freight deliveries in the city, online surveys carried out in the CAWI (Computer-Assisted Web Interviewing) format, that is through electronic forms, were adopted as the main research method. They allow respondents to complete the form at a convenient time, reduce organisational costs, and make later analysis of the results easier. This is particularly important in studies covering recipient preferences, acceptance of different delivery forms, frequency of using logistics services, methods of collecting parcels, and assessment of selected sustainable urban logistics solutions. At the same time, the use of CATI (Computer-Assisted Telephone Interviewing) telephone interviews was also considered justified. The use of CATI may increase the response rate, especially where an online survey alone might not provide a sufficient number of responses.

In addition, information collection may be supported by expert consultations, workshops, and meetings with representatives of urban logistics system stakeholders. This applies to the administrative, business, consumer, and scientific sides. Such activities should not replace the actual survey research, but they may help verify research assumptions, interpret results, and identify practical limitations related to the functioning and development of urban logistics.

5.2. Surveys scope and surveyed groups

The scope of the survey research should be treated as modular and linked to the scenarios identified in D0.3. This means that not all scenarios need to be developed to the same extent in the further work of WP2. Priority should be given to those scenarios that are directly related to recipient preferences, user behaviour, the possibility of changing the modal split, and the parameterisation of simulation models. This applies in particular to three active scenario groups: ready-made food delivery, boxed meal delivery, and parcel delivery with home and parcel locker channels. In the survey design, parcel deliveries to parcel lockers and direct courier deliveries to individual recipients were separated into different respondent groups in order to collect more precise empirical data on these channels. In the scenario logic of D0.3, however, they jointly support BS/AS 1.3 - Parcel delivery with home and parcel locker channels. Scenarios concerning pharmaceutical deliveries and B2B transport are treated as a complementary empirical scope and as directions for further research.

Due to the diverse nature of the information required to describe the scenarios, the scope of the research should be organised both by types of delivery scenarios and by respondent groups.

Operational data should be obtained primarily from drivers, couriers, delivery providers, and logistics operators. Data concerning preferences, acceptance of solutions, and parcel collection methods should be obtained from users and service recipients. Data concerning organisational constraints, infrastructure, regulations, and possible urban policy measures should be obtained from representatives of local government units or local administration.

The scope of the survey research was defined with reference to the identified types of urban logistics processes and the stakeholder groups participating in these processes. It was assumed that the research should cover both operational data concerning the execution of deliveries and information on preferences, limitations, and organisational and infrastructural barriers. The scope of the survey forms was subordinated to the need to obtain data useful for further project analyses, in particular for the parameterisation of selected delivery scenarios, the interpretation of simulation research results, and the identification of conditions for implementing sustainable urban logistics solutions.

It should be emphasised that the respondent groups are data-collection categories and should not be interpreted as a one-to-one representation of D0.3 base scenarios. Some respondent groups correspond directly to active scenario groups, while others provide supplementary or cross-cutting information. In particular, groups 4 and 5 jointly provide data for parcel delivery scenario BS/AS 1.3, group 3 provides supplementary information on urban B2C grocery deliveries, groups 6 and 7 provide exploratory data for future research scenarios, and groups 8–10 provide cross-cutting information on policy, user behaviour and operator constraints.

Ten respondent groups were distinguished in the study. Groups 1-7 include drivers, couriers, and delivery providers carrying out different types of urban deliveries. Group 8 includes representatives of municipalities or districts responsible for managing urban space and road traffic. Group 9 includes users and recipients of delivery services, while Group 10 includes logistics operators, courier companies, and entities managing distribution processes. The characteristics of the surveyed groups are presented in Table 5.

Table 5. Subdivision of surveyed groups

No.	Surveyed group	Characteristics
1	On-demand ready-made food delivery to individual recipients	On-demand ready-made food delivery to individual recipients
2	Boxed meal delivery to individual recipients	Night-time deliveries by selected catering companies to individual recipients.
3	Grocery deliveries to individual customers	Grocery deliveries to individual customers
4	Parcel deliveries to parcel lockers and pick-up points	Parcel deliveries to parcel lockers and pick-up points
5	Parcel deliveries to individual customers	Parcel deliveries to individual customers
6	B2B goods deliveries	Transport of large material flows to collective consumption facilities, shops, car repair workshops,

		companies, restaurants, hospitals, schools, construction sites, etc., excluding individual customers and deliveries of medicines and pharmaceuticals.
7	Urban delivery of medicines and pharmaceuticals	Deliveries of medicines from wholesalers to pharmacies, and deliveries of medicines and pharmaceuticals from wholesalers to hospitals.
8	Survey for municipalities/districts	Municipalities or city districts, in particular persons responsible for managing urban space, road traffic, parking organisation, infrastructure accessibility, and regulations concerning deliveries.
9	Survey for users	Cargo recipients, customers, and parcel recipients within deliveries carried out by delivery providers in groups 1-7.
10	Survey for logistics operators	Courier companies, logistics operators, distribution centres, and other entities organising or managing urban delivery processes.

The basic scope of the form and the general purpose of data collection are schematically presented in Fig. 1. The scheme indicates that survey data should support four main areas of further analysis: microsimulation modelling, optimisation of logistics operations, assessment of social aspects, and formulation of assumptions for urban policies in the field of urban logistics.

Scope of surveys for groups 1-7: drivers, couriers, and delivery providers

For groups 1-7, a common scope of information was planned, adapted to the specific nature of individual delivery types. The survey for drivers, couriers, and delivery providers includes three main parts: the respondent and delivery process profile, the characteristics of an average working day, and preferences and assessments concerning possible organisational, infrastructural, and technological changes.

The profile section is intended to collect information enabling responses to be assigned to the appropriate respondent group and providing a general description of the delivery process. This scope includes:

- the respondent's affiliation with one of groups 1-7;
- the town or towns where work is performed or where recipients are located;
- the type of goods transported, e.g. parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, medicines and pharmaceuticals, deliveries to companies;
- the operating area, e.g. rural areas, suburbs, residential estates, city centres, industrial zones, office zones;
- postal codes of loading and unloading locations;
- means of transport used for delivery, including on-foot deliveries, public transport, bicycle, cargo bike, motorcycle/scooter, electric scooter, passenger car, delivery vehicle up to 3.5 t GVW, truck above 3.5 t GVW, truck with trailer, drone;

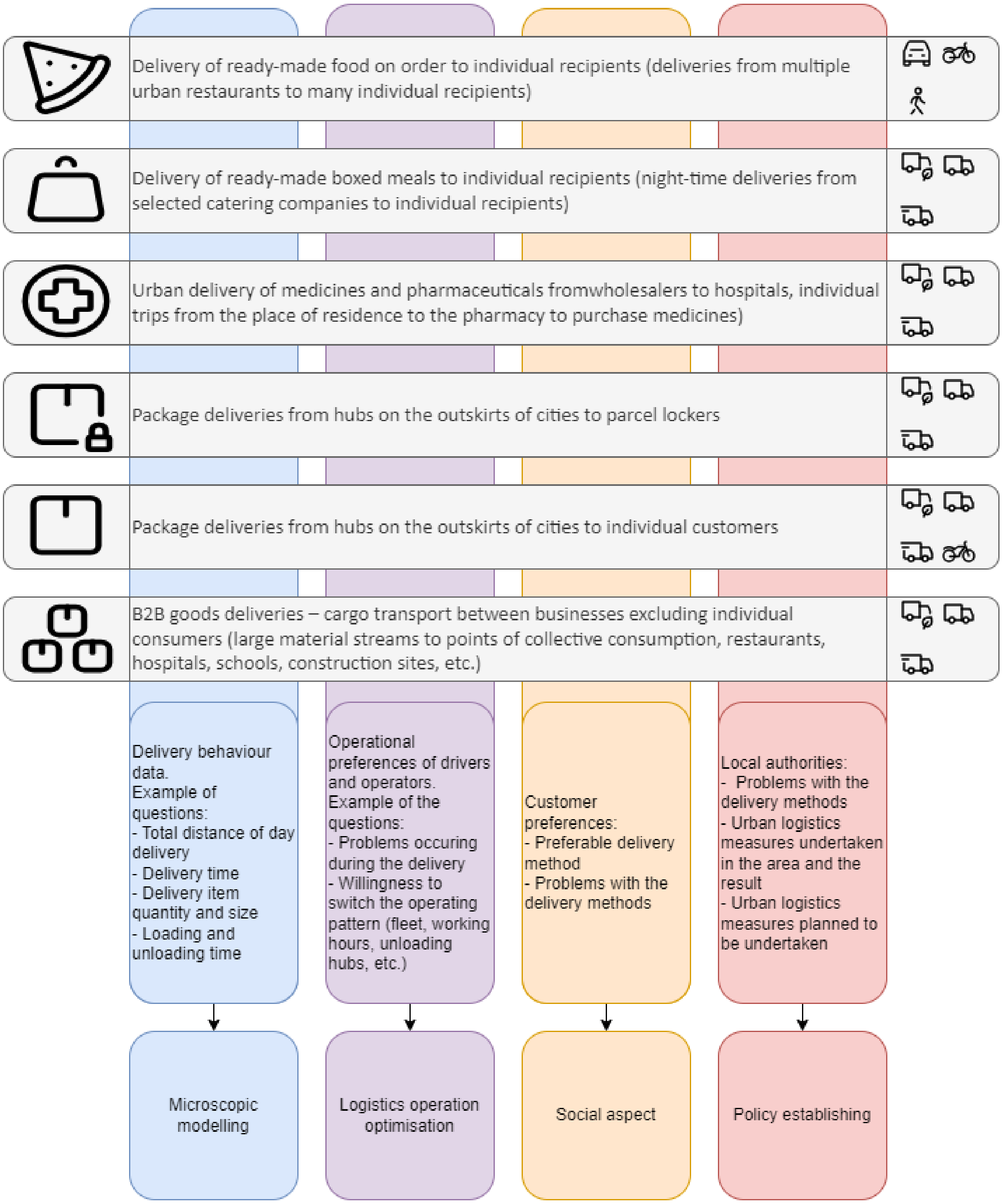

Fig. 1. Scheme of the data gathered in the questionnaire

- the possibility of transporting cargo sensitive to ambient temperature, e.g. using a refrigerated vehicle, insulated container, thermal bag, or other solutions;
- the type of drive or power source of the means of transport, e.g. no drive, petrol, diesel, LPG, CNG, LNG, electric drive, hybrid drive, or plug-in hybrid drive;
- the ownership model of the means of transport, including ownership, leasing, short- or long-term rental, rental from a logistics operator, carsharing, or rental from a settlement partner;

- the method of day-to-day vehicle operation and servicing, including refuelling, charging, charging during the delivery day, and responsibility for vehicle preparation;
- typical working days and work regularity;
- the type of mobile applications used, including company applications and publicly available applications used in the crowdsourcing model.

The second part of the questionnaire for groups 1-7 concerns an average working day. Its purpose is to obtain operational data describing the scale, time consumption, and organisation of the deliveries carried out. This scope includes:

- the number of kilometres travelled during a typical working day;
- the number of working hours per day;
- typical work start and end times;
- the number of loading addresses and the number of loading operations during the day;
- the number of delivery addresses during the day;
- the average number of parcels or delivery units per single delivery location;
- the average number of parcels or shipments handled during the day;
- the share of parcels by size, e.g. S, M, L, XL, larger shipments, and pallet units;
- the average distance between the loading point and the first delivery point;
- the average vehicle loading time;
- the average waiting time for loading;
- the average travel time between the loading point and the delivery point;
- the average unloading or delivery time in the vehicle-recipient-vehicle relation;
- the average time spent searching for a parking space or stopping place for unloading;
- the average daily idle time during working hours;
- the average daily time allocated to day-to-day vehicle operation and servicing, including refuelling or charging.

The form also includes additional questions specific to selected groups. For couriers carrying out parcel deliveries to individual customers, questions were included concerning situations in which the recipient is not present at the delivery address and the procedure followed in such cases. For B2B deliveries, the typical delivery locations were specified in more detail, such as shops, car repair workshops, construction sites, companies, offices, or restaurants. For selected deliveries carried out in an order-platform model, questions were also included concerning order selection, reasons for rejecting orders, the share of accepted orders, order cancellations, and the number of applications used in parallel.

The third part of the form for groups 1-7 concerns respondents' preferences and assessments. It includes questions on willingness to change the vehicle, change the type of drive, assess the usefulness of electric vehicles, the impact of urban infrastructure on the delivery process, the possibility of working outside peak hours or at night, parking problems, and stopping in prohibited places. Questions were also included on the most burdensome elements of the delivery process, the impact of weather conditions, seasonality, and the holiday period on efficiency and working time.

For respondents using electric vehicles, an additional module of questions was planned concerning the vehicle charging location, the need for charging during the day, assessment of the availability of charging infrastructure, sensitivity to energy prices, willingness to extend the trip to reach a cheaper charger, vehicle failure rates, and possible resignation from using an electric vehicle in winter. These data make it possible to assess the practical limitations of using electric vehicles in urban delivery processes.

Scope of the survey for group 8: municipalities and districts
The survey for municipalities and districts is primarily diagnostic and expert-oriented in nature. Its purpose is to obtain information on problems observed by administrative units and on possible measures in the field of urban logistics organisation. The form includes a basic profile identifying the town, municipality, or district, as well as open-ended questions concerning local conditions for deliveries.

The scope of the survey for municipalities and districts includes:
- identification of delivery-related problems observed in the municipality or district, such as blocking pavements, parking in prohibited places, excessive street load, reduced safety, or traffic obstruction;
- identification of solutions that the given unit could potentially introduce to improve urban logistics, e.g. dedicated parking spaces, chargers for electric vehicles, dynamic electricity pricing at chargers, dynamic pricing of parking spaces, transshipment centres, electric bicycles, subsidies or incentives for pro-environmental operators, delivery time windows, night-time deliveries, entry restrictions, or entry bans;
- assessment of the scope of cooperation with logistics operators, including in the area of parcel locker locations, parking or stopping spaces, chargers, or rules for entering restricted traffic zones;
- indication of urban logistics solutions that have already been introduced or tested;
- assessment of which of the existing solutions brought benefits and which caused negative effects.

The data obtained from municipalities and districts are intended to support the identification of infrastructural, spatial, and regulatory barriers, and to make it possible to relate the results of operational studies to the actual conditions of urban space management.

Scope of the survey for group 9: users and recipients of delivery services
The survey for users covers cargo recipients, customers, and parcel recipients within deliveries carried out by delivery providers from groups 1-7. Its purpose is to identify recipient preferences, ways of using delivery services, barriers related to parcel collection, and the importance of environmental aspects in choosing the form of delivery.

The profile section of the user survey includes:
- the town or towns related to the recipient's location;
- the postal code of the place of residence;
- the type of place of residence, e.g. rural area, suburb, residential estate, city centre;
- the respondent's gender and age;
- declared mobility modes, including the use of a car, public transport, and bicycle;
- indication of the types of deliveries used by the respondent, in accordance with groups 1-7.

For users using deliveries to individual recipients, questions were included concerning the preferred parcel collection method, e.g. parcel locker, courier, or pick-up point, as well as problems related to individual forms of delivery. Questions concerning problems with boxed meal delivery and food deliveries by couriers were also included, if the respondent uses such services.

An important element of the survey is the module concerning parcel collection and the use of parcel lockers or pick-up points. It includes, among others:
- the average number of parcels collected per week;
- the share of collected parcels by size;
- the maximum acceptable walking time or distance to a parcel locker without using a vehicle;
- the distance and walking time to the nearest parcel locker;
- the frequency of choosing a parcel locker or courier delivery when both forms are available;
- the method of parcel collection, e.g. on the way to or from work, while carrying out other activities, or as a dedicated trip;
- sending parcels and return shipments, including the share of individual sending methods;
- the frequency of sending parcels and the average number of parcels during a single sending operation;
- the importance of pollutant emissions related to parcel delivery and the willingness to choose companies offering deliveries by environmentally friendly vehicles.

For recipients related to B2B deliveries and deliveries of medicines and pharmaceuticals, a simplified module was planned concerning the number and frequency of deliveries, shipment sizes, sending return shipments, and the importance of pollutant emissions when choosing the delivery method.

Scope of the survey for group 10: logistics operators

The survey for operators is addressed to courier companies, logistics operators, distribution centres, and other entities organising urban delivery processes. Its purpose is to obtain information on the structure of the processes handled, the fleet, operating areas, barriers to implementing ecological solutions, and the potential acceptance of organisational changes.

The profile section of the operator survey includes:
- the town or towns related to the operating area or the company location;
- postal codes of loading points and unloading locations;
- the type of goods handled, e.g. parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, deliveries to pharmacies, deliveries to companies;
- the operating area, e.g. rural areas, suburbs, residential estates, city centres, industrial zones, or all of the above-mentioned types of areas;
- the vehicle fleet structure, including bicycles, cargo bikes, motorcycles/scooters, electric scooters, passenger cars, delivery vehicles up to 3.5 t GVW, trucks above 3.5 t GVW, trucks with trailers, and drones;

- the vehicle ownership model, including the share of vehicles owned by the company, vehicles owned by couriers, and vehicles owned by intermediaries;
- the use of vehicles for transporting cargo sensitive to ambient temperature;
- the share of vehicles by drive type, including combustion, electric, hybrid, and other vehicles.

The preference section of the survey includes an assessment of the possibility of shifting to more environmentally friendly means of transport, such as electric cars, cargo bikes, or smaller delivery vehicles. Questions were also included on incentives that could encourage operators to change their fleet and on the main barriers to implementing electric vehicles.

The survey for operators also includes questions concerning the impact of urban infrastructure on the delivery process, in particular parking areas, dedicated spaces for delivery providers, and spaces equipped with chargers. In addition, the difficulty of a potential change in the delivery method is examined through the use of transshipment points, microhubs, freight consolidation centres, or shared services. The preferred vehicle ownership model was also included.

A separate module concerns the impact of clean transport zones on operators' activities. This scope includes the assessment of potential changes in routes, types of vehicles assigned to route operation, the purchase of new vehicles, changes in time windows, and possible withdrawal from servicing selected areas. The survey also takes into account the impact of seasonality, including holidays, sales periods, and the summer holiday period, on the number of orders and the number of couriers involved.

The adopted scope of the survey research makes it possible to obtain data in four complementary areas. The first area covers operational data concerning delivery execution, such as the number of kilometres, working time, number of addresses, number of shipments, loading and unloading time, time spent searching for a stopping place, and vehicle service time. The second area covers the preferences and limitations of drivers, couriers, delivery providers, and operators, in particular those related to fleet changes, electromobility, charging infrastructure, work organisation, and the impact of external conditions. The third area concerns user preferences, including the choice of delivery forms, use of parcel lockers and pick-up points, parcel collection methods, and the importance of environmental aspects. The fourth area covers the perspective of municipalities and districts, including problems observed in urban space, measures already applied and planned, and possibilities for cooperation with logistics operators.

The scope of research defined in this way is intended to provide an organised set of data needed for further analyses in the project. These data may be used primarily to supplement scenario parameters, identify operational limitations, interpret the results of simulation studies, and formulate conclusions concerning the development of sustainable and energy-efficient urban logistics. Therefore, the aim is not to provide a full inventory of the urban logistics market, but to deliver detailed information necessary for further analyses in WP2.

5.3. Questionnaires

As part of the work in WP2, a set of survey questionnaires was prepared corresponding to the respondent groups defined in Section 5.2. The questionnaires were developed in such a way as to enable the collection of operational, preference-related, organisational, and institutional data concerning the functioning of urban logistics. The scope of the forms was adapted to the characteristics of individual respondent groups and to the type of information required for further project analyses.

Four basic types of questionnaires were adopted:

- a questionnaire for groups 1-7, i.e. drivers, couriers, and delivery providers carrying out different types of urban deliveries;
- a questionnaire for group 8, i.e. representatives of municipalities and districts;
- a questionnaire for group 9, i.e. recipients and users of delivery services;
- a questionnaire for group 10, i.e. logistics operators, courier companies, and distribution centres.

The scope of the questionnaires, in the format provided for the implementation of the research, is presented below.

5.3.1. Questionnaire for groups 1-7: drivers, couriers, and delivery providers

The questionnaire for groups 1-7 was intended for persons directly carrying out urban delivery processes. It includes the respondent profile, the characteristics of an average working day, additional questions for selected delivery groups, and a preference module concerning work organisation, vehicles, infrastructure, weather conditions, seasonality, and electromobility.

A. Respondent profile

- Affiliation with the surveyed group (1-7)
- Town/towns (work area/recipient location)
- Type of goods (parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, deliveries of medicines/pharmaceuticals; deliveries to companies)
- Operating area (rural areas, suburbs, residential estates, city centres, industrial zones, office zones)
- Postal codes of loading locations
- Postal codes of unloading locations
- Means of transport used for delivery (on foot, public transport, bicycle, cargo bike, motorcycle/scooter, electric scooter, passenger car, delivery vehicle up to 3.5 t GVW, truck above 3.5 t GVW, truck with trailer above 3.5 t GVW, drone)
- Do you use a vehicle that enables the transport of cargo sensitive to ambient temperature? (refrigerated vehicle, insulated container, thermal bag, other: …)
- Drive type (none, petrol, diesel, LPG, CNG, LNG, electric, hybrid, plug-in hybrid)
- Ownership model of the means of transport (own vehicle: cash purchase/leasing/short-term rental/long-term rental; rental from a logistics operator; pay-per-minute rental - carsharing; rental from a settlement partner)
- Vehicle operation and servicing (whether the vehicle is charged/refuelled during the delivery day, who is responsible for charging/refuelling, who is responsible for day-to-day vehicle preparation)
- Typical working days (weekdays/weekends)
- Work regularity (occasionally: a few days per month; daily: a few hours; daily: full-time)

- Type of mobile applications used: company application (dedicated to a given company, e.g. DPD, UPS), publicly available application (i.e. crowdsourcing - Glovo, Pyszne.pl, Uber Eats, other: …)

B. Average working day

- Total number of kilometres travelled during the day [km] (below 20, 20-50, 50-100, 100-150, 150-200, above 200)
- Number of working hours per day [h] (below 4, 4-6, 6-10, 10-12, above 12)
- Typical working hours [hh-hh] (typical start time, typical end time)
- Number of loading addresses during the day [pcs.] (number)
- Daily number of loading operations during the day [pcs.] (number)
- Number of delivery addresses during the day [pcs.] (number)
- Average number of parcels per single delivery location [pcs.] (1, 2-5, 5-10, above 10)
- Average number of parcels during the day [pcs.] (number)
- Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]
- Average distance between the loading point and the delivery point (first delivery location) [km] (0-5, 5-10, 10-20, above 20)
- Average vehicle loading time [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)
- Average waiting time for loading [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)
- Average travel time between the loading point and the delivery point [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)
- Average unloading time (delivery in the vehicle-recipient-vehicle relation) [min] (0-2, 2-5, 5-10, over 10 min)
- Average time spent searching for a parking space/stopping place for unloading [min] (0-2, 2-5, 5-10, over 10 min)
- Average daily idle time during working hours [min] (0-30, 30-60, 60-120, over 120 min)
- Average daily time allocated to day-to-day vehicle operation and servicing, including vehicle refuelling/charging [min] (0-15, 15-30, 30-60, over 60 min)

C. Additional questions for selected groups

For couriers from group 5 - parcel deliveries to individual customers:

- How often is the recipient absent from the delivery address? [%]
- Where do you most often leave the parcel when the recipient is absent? (neighbour, at the door/on the property, security desk, redirected to a pick-up point)

For couriers from group 6 - B2B:

- Delivery location (general store, large-format store, car repair workshops, construction sites, companies, offices, restaurants)

D. Preferences

- Would you replace your vehicle with another one? (larger/smaller car, bicycle, other)
- Would you switch to a vehicle with a different power source?
- How do you assess the usefulness of electric vehicles in your sector? (very high, high, medium, low, none)
- Would the development of urban infrastructure, such as parking areas, parking spaces dedicated to delivery providers, and parking spaces equipped with chargers, affect the delivery process, and how? (on a scale from 1 to 10)

- Would you change your working hours to night-time/off-peak hours in order to avoid losing time in traffic congestion? (yes/no)
- How often do you have problems finding a stopping place during delivery? (always, very often, often, rarely, very rarely)
- How often are you forced to stop in a prohibited place or in an active traffic lane? (always, very often, often, rarely, very rarely)
- What is the most annoying/burdensome element of the delivery process?
- To what extent does heavy rainfall reduce your efficiency? (does not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / makes work impossible, 100%)
- To what extent does heavy snowfall reduce your efficiency? (does not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / makes work impossible, 100%)
- To what extent do negative temperatures below -5°C reduce your efficiency? (do not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / make work impossible, 100%)
- To what extent do high temperatures above 30°C reduce your efficiency? (do not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / make work impossible, 100%)
- Do seasonal periods, e.g. holidays, extend your working day? (do not extend it, from 30 minutes to 1 h, from 1 h to 2 h, from 3 h to 5 h, 5 h or more)
- How does the summer holiday period affect your working time? (shortens it by more than 2 h, shortens it by 1-2 h, has no effect, extends it by 1-2 h, extends it by more than 2 h)

  If you use an electric vehicle:
    - Where do you most often charge your vehicle? (city/home/company base)
    - Where do you most often charge your vehicle during the day? (does not require charging during the day/company base/home/city-route)
    - Is the availability of chargers sufficient? (yes/no)
    - Do you think that the price of energy for vehicle charging should depend on the location and popularity of the charger? (yes/no)
    - Would you be willing to spend 10 minutes travelling to a charger in order to charge the battery more cheaply? (no / 10% cheaper / 25% cheaper / 50% cheaper)
    - Would you be willing to spend 20 minutes travelling to a charger in order to charge the battery more cheaply? (no / 10% cheaper / 25% cheaper / 50% cheaper)
    - How many working days per year do you lose due to vehicle failure? (number of days: …)
    - Do you give up using an electric vehicle in favour of a conventional or other vehicle during the winter season? (yes/no)

For couriers from groups 1 and 3 - selection of orders for execution:

- What has the greatest impact on rejecting an order? (max. 2 answers):
    - Distance/time
    - Weight/size
    - Remuneration

   - Too many orders (*appearing at the same time in the applications)
   - Fatigue
- What percentage of orders do you accept for execution? (0-100%)
- How often do you cancel an accepted order? (daily / once a week / once a month / less often / never)
- How many applications/services do you use simultaneously? (I do not use any / 1 / 2 / 3 or more)

5.3.2. Questionnaire for group 8: municipalities and districts

The questionnaire for group 8 was addressed to representatives of municipalities and districts. Its purpose was to obtain information on delivery-related problems observed from the perspective of local administration, possible measures to improve urban logistics, and previous experience in implementing solutions in this area.

A. Profile

- District/city/municipality:

B. Preferences - open-ended questions

- What delivery-related problems are observed in your municipality? (e.g. blocking pavements, parking in prohibited places, excessive street load, reduced safety, traffic obstruction)
- What solutions would your municipality be able to introduce in order to improve urban logistics? (e.g. dedicated parking spaces, chargers for electric vehicles, dynamic electricity pricing at chargers, dynamic pricing of parking spaces, transshipment centres, electric bicycles, subsidies/incentives for pro-environmental operators, delivery time windows, night-time deliveries, entry restrictions/bans)
- Do you cooperate with logistics operators in the organisation of delivery systems? (e.g. influence on the location of parcel lockers, joint development of concepts concerning the location of parking spaces or chargers, entry to restricted traffic zones)
- What solutions related to urban logistics have already been introduced/tested by your municipality?
- Which solutions brought benefits, and which had a negative impact?

5.3.3. Questionnaire for group 9: recipients

The questionnaire for group 9 was addressed to cargo recipients, customers, and users of delivery services. The form included a respondent profile and preference modules related to the use of different forms of delivery, parcel collection, parcel lockers, pick-up points, sending shipments, and the importance of environmental aspects.

A. Respondent profile

- Town/towns (recipient location)
- Postal code of the place of residence
- Place of residence (rural area, suburbs, residential estates, city centres)
- Gender (F/M/Other/I do not want to answer this question)
- Age (below 18, 18-25, 26-35, 36-50, 51 and over)
- Mobility modes (on a scale from 1 to 10, never-always): own car, public transport, bicycle

- Which types of deliveries do you use? (from groups 1-7) (multiple choice)

B. Preferences for groups 1-5

- What is your preferred and most frequently chosen parcel collection method? (parcel locker, courier, pick-up point)
- What problems are associated with the above delivery methods? (no delivery on the selected day, no precise time window, lost/damaged shipments)
- If you have used them, what problems occur with boxed meal delivery? (lack of punctuality, delays, omissions, missing deliveries, damaged packaging)
- If you have used them, what problems occur with food deliveries by couriers? (lack of punctuality, delays, omissions, missing deliveries, damaged packaging)
- Do you have any disability or limited ability? (no, mobility-related, hearing-related, sight-related)
- Average number of parcels collected per week [pcs.]
- Average share of collected parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]
- Characteristics of parcel collection from parcel lockers/pick-up points and their use:
    - ➢ Threshold walking time to a parcel locker - what is the maximum acceptable walking time/distance to a parcel locker without using a vehicle?
    - ➢ Distance to the nearest parcel locker [m] (0-200, 200-500, 500-1000, above 1000 m)
    - ➢ Walking time to the nearest parcel locker [min] (0-2, 2-5, 5-10, above 10 min)
    - ➢ Frequency of choosing a parcel locker/courier delivery, if both are available (0-10)
    - ➢ Collection method (on the way to/from work, while carrying out other activities, dedicated trip)
- If you send parcels, what is the percentage share of each method? (parcel locker/courier/drop-off point/post office)
- Do you hand over return shipments to the courier during delivery? [always-never]
- How often do you send parcels? [number of sending operations/month]
- How many parcels do you send on average during one sending operation? [pcs.]
- Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]
- Is the pollutant emission related to parcel delivery important to you, and do you choose companies that offer deliveries by environmentally friendly vehicles? (yes/no)

C. Preferences for groups 6-7

- Average number of parcels collected per week [pcs.]
- Average number of deliveries [more than once a day, daily, once a week, 2-3 times a week, 4-5 times a week]
- Average share of collected parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]
- If you send parcels, what is the percentage share of each method? (parcel locker/courier/drop-off point/post office)
- Do you hand over return shipments to the courier during delivery? [always-never]
- How often do you send parcels? [number of sending operations/month]
- How many parcels do you send on average during one sending operation? [pcs.]
- Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]

- Is the pollutant emission related to parcel delivery important to you, and do you choose companies that offer deliveries by environmentally friendly vehicles? (yes/no)

5.3.4. Questionnaire for group 10: logistics operators

The questionnaire for group 10 was addressed to logistics operators, courier companies, distribution centres, and other entities organising urban delivery processes. The form included a profile section concerning the operating area, the structure of goods handled, and the fleet, as well as questions concerning preferences, barriers, and potential organisational and technological changes.

A. Profile

- City/municipality (work area/company location):
    - Postal codes of loading points
    - Postal codes of unloading locations
- Type of goods (parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, deliveries to pharmacies, deliveries to companies)
- Operating area (rural areas, suburbs, residential estates, city centres, industrial zones, all of the above)
- Vehicle fleet (bicycle, cargo bike, motorcycle/scooter, electric scooter, passenger car, delivery vehicle up to 3.5 t GVW, truck above 3.5 t GVW, truck with trailer above 3.5 t GVW, drone)
- Current vehicle ownership model: percentage share of company-owned vehicles, courier-owned vehicles, and intermediary-owned vehicles
- Do you use vehicles for transporting cargo sensitive to ambient temperature? (refrigerated vehicle, insulated container, thermal bag, other: …)
- Drive type - percentage share (combustion, electric, hybrid, other)

B. Preferences

- What is the likelihood that you would replace vehicles in your fleet with environmentally friendly ones? (0-10)
    - Electric cars
    - Cargo bikes
    - Smaller delivery vehicles
    - Other: what kind?
- What incentives would convince you to change your fleet to a more environmentally friendly one?
- What are the main barriers to implementing electric vehicles in your fleet?
- Would the development of urban infrastructure, such as parking areas, parking spaces dedicated to delivery providers, and parking spaces equipped with chargers, affect the delivery process, and how? (on a scale from 1 to 10)
- To what extent would it be difficult for you to change the delivery method by using transshipment points, microhubs, freight consolidation centres, or shared services? (on a scale from 1 to 10)
- Preferred vehicle ownership model (company ownership, courier ownership, intermediary ownership)

- Does a clean transport zone affect your activity?
- What changes to your activity would result from the introduction of a clean transport zone?
    - Route modification (on a scale from 1 to 10)
    - Changes in the types of vehicles assigned to route operation (on a scale from 1 to 10)
    - Purchase of new vehicles (on a scale from 1 to 10)
    - Change of time windows (on a scale from 1 to 10)
    - Withdrawal from servicing areas within the clean transport zone (on a scale from 1 to 10)
- To what extent do seasonal periods, e.g. holidays or sales periods, affect the number of orders? (-100 to +100%)
- To what extent do seasonal periods, e.g. holidays or sales periods, affect the number of couriers involved? (-100 to +100%)
- To what extent does the summer holiday period affect the number of orders? (-100 to +100%)
- To what extent does the summer holiday period affect the number of couriers involved? (-100 to +100%)

5.4. Relationship between surveys and areas of data use

In order to organise the scope of the questionnaires and demonstrate the relationship between the survey questions and the further use of the information obtained, an assignment matrix was prepared linking the questions to the main analytical areas of the project. This summary is presented in Annex 1.

The assignment matrix has a supporting and documentation function. Its purpose is to indicate what types of data are obtained through individual questions and in which areas of further project work they may be used. The table includes six basic areas of information assignment:

- base data - basic data identifying the characteristics of respondents, location, type of delivery, type of goods transported, operating area, loading and unloading postal codes, type of vehicle or means of transport, and other information organising the research sample;
- microscopic modelling - data useful for microsimulation modelling, in particular parameters describing the course of deliveries, the number of kilometres, number of addresses, loading and unloading times, travel times, times spent searching for a stopping place, shipment sizes, and user behaviour related to parcel collection;
- logistics operation optimisation - data relating to the organisation of logistics operations, including the working model of delivery providers, the type of applications used, the vehicle ownership model, order selection, seasonality, fleet organisation, and the possibility of using microhubs, consolidation centres, and shared services;
- energy - data related to the type of drive, the use of electric vehicles, vehicle charging and charging during the day, availability of charging infrastructure, sensitivity to energy costs, and the potential shift of the fleet towards low-emission or zero-emission vehicles;

- social aspect - data concerning the preferences, behaviours, and limitations of participants in the urban logistics system, in particular the nuisance effects of the delivery process, problems with parcel collection, limited ability of recipients, the importance of pollutant emissions, the impact of weather conditions, and acceptance of organisational changes;
- policy formulation - data supporting the formulation of conclusions for urban policies, in particular concerning problems observed by municipalities and districts, possible measures by local administration, clean transport zones, organisation of delivery spaces, charging infrastructure, entry restrictions, night-time deliveries, and cooperation with logistics operators.

In the case of groups 1-7, covering drivers, couriers, and delivery providers, operational data used to describe the course of deliveries and for microsimulation modelling are of the greatest importance. This applies primarily to information on the number of kilometres, working time, number of loading and delivery addresses, loading time, waiting time, travel time, unloading time, and time spent searching for a stopping place. At the same time, preference-related questions in these groups make it possible to identify operational limitations, willingness to change the vehicle or drive type, infrastructural problems, and the impact of external conditions on delivery execution.

In the case of group 8, covering municipalities and districts, the questions were assigned primarily to the area of Policy formulation. Their purpose is to identify delivery-related problems observed from the perspective of local administration, measures that could be implemented, solutions tested so far, and experience concerning their effectiveness. These data may provide a basis for interpreting the results of operational studies in the context of local conditions for urban space management.

In the case of group 9, covering users and recipients of delivery services, data concerning parcel collection preferences, the use of parcel lockers and pick-up points, the frequency of collecting and sending parcels, the method of reaching a parcel locker, and the importance of environmental aspects are of particular significance. These data support both the modelling of recipient behaviour and the assessment of social and environmental aspects of different forms of delivery organisation.

In the case of group 10, covering logistics operators, the questions refer primarily to fleet organisation, the type of goods handled, operating area, vehicle ownership model, drive types, barriers to implementing electric vehicles, the impact of urban infrastructure, and the consequences of introducing clean transport zones. These data are important for assessing the possibilities of optimising logistics operations, conducting energy analyses, and identifying the conditions for implementing urban policies.

5.5. Carrying out of survey research

The implementation of the survey research requires defining the assumed number of responses for individual respondent groups and adopting rules for interpreting the results. Due to the diverse nature of the groups studied, the scope of the research included a set of several respondent groups corresponding to different types of participants in the urban logistics system, including drivers, couriers and delivery providers, representatives of municipalities and districts, users of delivery services, and logistics operators.

Based on the approaches presented in [1], [2], [1] for estimating the minimum sample size, the desired number of responses to be obtained was determined. In the classical approach, the minimum sample size can be determined on the basis of the assumed confidence level and the acceptable estimation error. When the structure of the variable under study is known and it is possible to adopt the mean value and variance from previous studies, the sample size may be determined from the following relationship:

$$n = \frac{u_\alpha^2 \cdot \sigma^2}{b_v^2}$$

where:

$$b_v = b \cdot \bar{x}$$

and:
n - minimum sample size,
u_α- value corresponding to the adopted confidence level of the normal distribution,
σ^2 - variance of the variable under study,
b - assumed relative error, e.g. 0,02 or 0,05,
$\bar{x}$ - mean value of the variable under study,
b_v - absolute error expressed in relation to the mean value.

This approach may be applied primarily in the case of quantitative variables, such as the number of kilometres, working time, the number of addresses served, loading time, unloading time, or the time spent searching for a stopping place, provided that reliable previous data are available for a given variable, making it possible to estimate its variance.

In a situation where the structure of the studied population is not known and the aim is to determine the minimum sample size for shares/proportions, a conservative approach is applied. It assumes the highest possible variability of responses ($p = 0{,}5$). In this case, the minimum sample size may be determined using the following formula:

$$n = \frac{u_\alpha^2}{4b^2}$$

where:
n - minimum sample size,
u_α- value corresponding to the adopted confidence level of the normal distribution,
b - assumed relative error, e.g. 0,02 or 0,05,

For a confidence level of 0.95, the value $u_\alpha = 1{,}96$ is adopted. With an acceptable estimation error of $b = 0{,}05$, the minimum sample size is

$$n = \frac{1{,}96^2}{4 \cdot 0{,}05^2} = 384{,}16$$

This means that, for an unknown population structure and a 5% error, the minimum sample size is, after rounding, 385 responses. In the study, however, it was assumed that this value would serve as a reference point for large respondent groups, primarily for users of delivery services. For the remaining groups, especially professional and industry groups that are more difficult to reach, a stratified and pragmatic approach was adopted, resulting from respondent availability, research costs, and the purpose of the project.

The survey research was commissioned to a subcontractor, who was responsible for organising the research process, recruiting respondents, carrying out the research using CATI and CAWI techniques, and anonymising the data. The project team received the data in a form enabling analysis, without identification of individual respondents. Responsibility for conducting the study in accordance with applicable regulations, including those concerning data protection and respondent anonymity, rested with the entity carrying out the research. The respondents' answers were provided by the contractor in .xlsx format and constitute part of the dataset for WP2.

Initially, an even distribution of questionnaires between respondent groups was assumed. This plan provided for obtaining a total of 2 400 questionnaires, with 240 questionnaires for each of the ten groups, divided into 120 CATI questionnaires and 120 CAWI questionnaires in each group. After consultations on the designed survey research, it was concluded that an even sample distribution did not correspond to the actual availability of individual respondent groups. Some groups, such as entities carrying out B2B deliveries or meal box delivery providers, are more difficult to recruit for survey research. This results from the limited number of such respondents, market dispersion, difficulties in unambiguously assigning respondents to a given group, and limited availability of contact databases.

At the same time, the group of users of delivery services is the largest and most accessible; therefore, increasing the number of questionnaires in this group was considered the most rational from the perspective of the research objective. In addition, the adjustment of the number of questionnaires resulted from the scenarios defined in D0.3, for which obtaining additional survey data had higher priority. As a result of these consultations, a modified sample size plan was adopted. Despite the fact that the research was carried out by a professional entity with access to a broad respondent database, it was not possible to fully complete the planned research. Ultimately, 2 427 questionnaires were obtained in the study (Table 6).

Table 6. Summary of completed questionnaires by survey type and delivery segment

Type of survey	General stakeholder surveys	Diet catering	Deliveries to companies	Deliveries of medicines/ pharmaceuticals	Grocery deliveries	Food from restaurants	Parcels to recipients	Parcels to parcel lockers	Total
On-demand ready-made food delivery to individual recipients		5			1	234			240
Boxed meal delivery to individual recipients		80							80
Grocery deliveries to individual customers					30				30
Parcel deliveries to individual customers							240		240
Parcel deliveries - parcel lockers and pick-up points								240	240

B2B goods deliveries			10						10
Urban delivery of medicines and pharmaceuticals				242					242
Survey for municipalities/districts	244								244
Survey for operators	238								238
Survey for users	863								863
Total	**1345**	**85**	**10**	**242**	**31**	**234**	**240**	**240**	**2427**

The total number of completed questionnaires was slightly higher than the number planned after consultations with the contractor. However, greater differences occurred in the distribution of questionnaires among individual groups. In particular, the number of user questionnaires was significantly increased, while the number of questionnaires in the B2B delivery group was lower than assumed. This resulted from difficulties in recruiting respondents meeting the criteria for this group and from the specific nature of the B2B delivery market. Differences between the planned and completed surveys, together with the indicative error for the completed sample, are presented in Table 7.

Table 7. Difference between completed surveys and indicative error

Respondent group	Plan after consultations	Number of completed questionnaires	Difference	Indicative maximum error at a confidence level of 0,95
On-demand ready-made food delivery to individual recipients	240	240	0	6,3%
Boxed meal delivery to individual recipients	80	80	0	11,0%
Grocery deliveries to individual customers	30	30	0	17,9%
Parcel deliveries - parcel lockers and pick-up points	240	240	0	6,3%
Parcel deliveries to individual customers	240	240	0	6,3%
B2B goods deliveries	60	10	-50	31,0%
Urban delivery of medicines and pharmaceuticals	240	242	2	6,3%
Survey for municipalities/districts	240	244	4	6,3%
Survey for users	798	863	65	3,3%
Survey for operators	240	238	-2	6,4%
Total	**2408**	**2427**	**19**	

The obtained sample sizes should be interpreted with regard to the purpose and nature of the study. For the largest group, i.e. users of delivery services, the number of 863 questionnaires provides stable material for analysing recipient preferences and behaviours. For most of the main operational groups, such as food deliveries from restaurants, parcel deliveries to recipients, deliveries to parcel lockers, deliveries of medicines and pharmaceuticals, municipalities/districts, and operators, sample sizes of 240 questionnaires make it possible to identify the main tendencies, typical parameters, and limitations. For smaller and more difficult-to-reach groups, such as B2B deliveries, the results should be treated as exploratory and complementary material.

It should also be emphasised that obtaining the full number of responses from one area only, i.e. exclusively from the Górnośląsko-Zagłębiowska Metropolis, was not possible within the adopted time and research budget. This resulted from the limited availability of respondent groups and the difficulty of obtaining sufficiently large samples in selected specialised segments of urban logistics. The number of questionnaires obtained was considered sufficient to support the data acquisition process and to serve as a source of information on general tendencies, behaviours, preferences, and operational parameters, which may then be adjusted to the size of the city, type of area, type of delivery, and the specific nature of the modelled scenario.

This approach is consistent with the purpose and scope of the research in the E-Laas project. The role of the surveys was to provide input data and reference points for further analyses. A detailed study of a selected delivery system in a specific area would require separate, more costly and time-consuming field research, conducted in close cooperation with local operators and municipal administration. For the purposes of the project, however, the adopted number of questionnaires is sufficient to identify the main relationships and tendencies and to use the results as support for further modelling work.

The survey research results will be subject to detailed analysis in subsequent WP2 reports, in particular in D2.2. Particular emphasis will be placed on the interpretation of data in the groups with the largest sample sizes and on the cautious use of results from smaller groups as a complementary source of knowledge about specific segments of urban logistics.

5.6. Additional activities supporting data collection, verification of assumptions, and research results

Survey research constitutes the primary method of obtaining additional information for the project from selected groups of participants in urban logistics processes. At the same time, due to the complexity of the problem addressed, it was considered justified to complement and verify the survey research through additional consultation-based activities during events related to the project, including workshops and conferences. These activities were aimed at verifying the research assumptions, gaining a better understanding of the perspectives of different last-mile logistics stakeholders, and enabling the adopted assumptions to be confronted with the opinions of representatives of the scientific community, public administration, logistics operators, and market practitioners. The additional activities included primarily:

- organisation of E-Laas project workshops;
- participation in and organisation of conference panels dedicated to the project;
- expert consultations with representatives of science, administration, logistics operators, and entities related to transport and urban logistics;
- consultations among consortium partners concerning modelling assumptions, input data, scenarios, stakeholder needs, and possible directions for the development of energy-efficient urban logistics.

These activities complemented the survey research. Their importance consisted primarily in enabling a broader view of the analysed problems, identifying potential implementation constraints, and verifying whether the scope of data obtained through the surveys corresponded to the actual needs of further project analyses. In this sense, workshops, consultations, and conference panels should be treated as an additional element of assumption verification and as a source of context for interpreting the survey research results.

6. Simulation research assumptions

In the E-Laas project, simulation research is intended to support the analysis of urban logistics by combining spatial, transport, operational, and survey data. The starting point for these studies is the scenarios defined in D0.3 for the RC1 reference case, i.e. the GZM Metropolis. These scenarios cover various segments of urban logistics, including ready-made food delivery, boxed meal delivery, and parcel delivery with home and parcel locker channels. In the simulation-oriented scope of WP2, parcel-locker delivery and direct home delivery are treated as delivery channels within BS/AS 1.3, rather than as separate base scenarios. Pharmaceutical delivery (BS/AS 1.4) and B2B urban freight deliveries (BS/AS 1.5) were indicated as valuable directions for further research, but they are not developed in full scope in the subsequent project reports.

The simulation research was subordinated to the main logic of the E-Laas project, i.e. the assessment of urban logistics systems from the perspective of energy consumption, operational efficiency, environmental impact, and user behaviour. This means that the modelled processes should be described not only by traditional transport measures, such as time, distance, the number of served points, or vehicle utilisation, but also by energy and emission indicators.

From the perspective of WP2, linking three levels of analysis is of particular importance. The first level covers assumptions for research scenarios and the classification of data sources, including data on the transport network, transport zones, locations of senders and recipients, demand structure, means of transport, as well as costs, energy, and emissions. The second level covers survey data, which supplement information on the behaviour of delivery providers, user preferences, service times, operational problems, and infrastructural barriers. The third level covers simulation modelling, in which these data may be used to represent delivery processes, compare organisational variants, and assess the effects of scenario changes.

It was assumed that the simulation research should be complementary in nature. The macroscopic model should be used to describe the entire urban or metropolitan area, identify main flows, and assess traffic volumes, travel times, emissions, and energy consumption at the network scale. The microscopic model, on the other hand, should enable a detailed representation of last-mile delivery processes in selected study areas, taking into account courier behaviour, order structure, methods of serving recipients, the use of different means of transport, and operational parameters obtained from the surveys. The concept of conducting the research and integrating analyses at the micro and macro scales is presented in Fig. 2.

The following part of the chapter presents assumptions concerning modelling environments, the role of macrosimulation in data acquisition, the general logic of last-mile delivery microsimulation, integration of the micro and macro levels, and the potential scaling of results to other urban areas. A detailed description of the simulation studies and the results of scenario experiments will be developed in the subsequent stages of the project work and presented in report D2.3 and M2.

6.1. Environments used for simulation research

Complementary modelling, data analysis, and simulation environments were used in the simulation research (Table 8). This results from the multi-level nature of urban logistics analyses, in which it is necessary to simultaneously take into account:

- spatial and location data;
- the structure of the transport network;
- freight flows at the district or city scale;
- the detailed course of last-mile delivery processes;
- the behaviour of users, delivery providers, and operators;
- energy, emission, and operational parameters;
- the potential effects of urban policies.

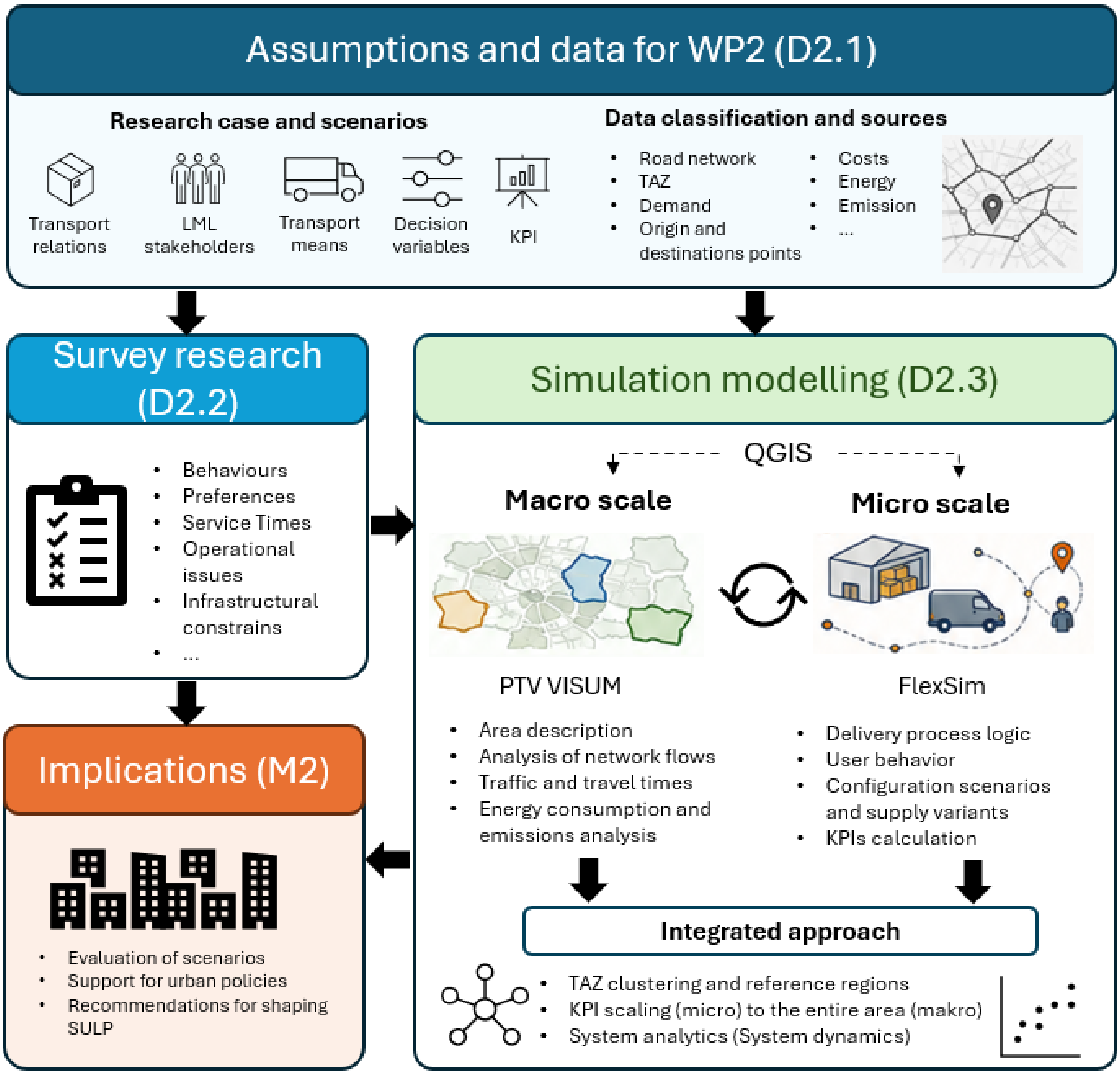

Fig. 2. Concept of the research in WP2 and simulation modelling for last-mile logistics

It was assumed that individual environments would be used in accordance with their intended purpose, and that the results obtained at one level of analysis could feed into subsequent stages of work. Therefore, a structure was adopted in which spatial data are prepared in the GIS environment, the macroscopic model is used to describe the entire area and traffic conditions, the microscopic model makes it possible to represent detailed delivery processes, while the System Dynamics approach may support the interpretation of system-level relationships at the highest level of abstraction.

QGIS serves as an environment for preparing and organising spatial data. It will be used to integrate data on transport zones, the road network, the distribution of senders and recipients, delivery concentration points, parcel lockers, pick-up points, service facilities, and other elements of urban infrastructure. These data are necessary both for work using the macroscopic model and for selecting and describing areas intended for microsimulation analyses, as well as for analyses using System Dynamics.

Table 8. Applied environments and their role in simulation research

Environment / tool	Application / scale	Assumed application	Example input data	Example results
QGIS [18]	spatial	preparation, integration, and visualisation of spatial data	locations of senders and recipients, transport zones, parcel lockers, service points, road network, urban planning data	spatial layers, characteristics of zones, data for macro and micro models
PTV Visum [17]	macroscopic	representation of the transport network and traffic conditions at the city/metropolitan scale	road network, transport zones, demand matrices, traffic volumes, travel times, network impedance	network flows, travel times, link loads, data for selecting microsimulation areas
FlexSim [7]	microscopic	detailed representation of last-mile delivery processes in selected areas	delivery points, order structure, vehicle types, loading and unloading times, courier behaviour, survey-based parameters	operational, energy, and emission KPIs for delivery scenarios
System Dynamics [20], [4]	system-level	analysis of general relationships and feedback loops between urban policies, users, operators, and infrastructure	scenario assumptions, demand trends, urban policies, infrastructural constraints, survey and simulation results	interpretation of long-term system-level relationships, support in formulating recommendations

PTV Visum is planned as the basic environment for macroscopic analyses. Its role is to represent the structure of the transport network, the division of the area into transport zones, spatial relations, travel times, network loads, and general traffic conditions. The macroscopic model makes it possible to define the context of urban logistics functioning at the scale of the entire city or metropolitan area. Results from this level may be used to:

- identify areas with different transport and spatial characteristics;
- select reference zones for microsimulation;
- determine travel times and travel impedance;
- analyse the impact of freight traffic on the network;
- prepare input data for detailed models;
- later scale the results obtained in microscopic models.

FlexSim, as a microsimulation environment, enables a detailed representation of last-mile delivery processes. At this level, the logic of order handling, vehicle movements, courier work, the use of different means of transport, loading and unloading times, recipient service, and changes in the configuration of the delivery system will be modelled. FlexSim makes it possible to analyse organisational variants, such as direct deliveries, deliveries to parcel lockers, the use of delivery concentration points, changes in vehicle type, or changes in the service structure. The results at this level should primarily include KPIs describing time, distance, vehicle utilisation, energy consumption, emissions, and service quality.

System Dynamics, implemented in Simantics or The Business Prototyping Toolkit for Python, will be used as a supporting environment for analysing system-level relationships at a higher level of abstraction. It will make it possible to interpret relationships between system elements, such as delivery demand, urban policies, user preferences, and environmental impacts. The System Dynamics approach may be particularly useful when formulating conclusions concerning the long-term consequences of urban measures and potential recommendations for SULP.

The adopted logic for using the environments assumes data flow between the levels of analysis:

I. QGIS - preparation and integration of spatial data.
II. PTV Visum (data source) - macroscopic analysis of the network, zones, and traffic conditions.
III. FlexSim - detailed microsimulation of selected delivery processes.
IV. PTV Visum (macroscopic analysis) - possible use of microsimulation results to interpret and scale effects to a larger area.
V. System Dynamics (macroscopic analysis) - potential support for interpreting system-level relationships and the consequences of urban policies.

The research will take into account a bidirectional link between the macro- and microsimulation levels. The macroscopic model provides input data for microsimulation, such as the characteristics of the area, the network structure, travel times, and traffic conditions. The microscopic model, in turn, makes it possible to determine detailed KPIs for selected delivery scenarios, which may then be interpreted or scaled in relation to larger urban areas.

Consequently, the indicated environments are treated as elements of a coherent research path. Their combined use will enable the transition from spatial and survey data, through macro- and microsimulation modelling, to KPI assessment and the formulation of conclusions concerning energy-efficient, sustainable, and socially acceptable urban logistics.

6.2. Macrosimulation for data collection

The macrosimulation model constitutes one of the main sources of contextual, spatial, and traffic-related data used to prepare further simulation studies of urban logistics. In the E-Laas project, it represents an analytical level that enables the description of the study area, the identification of traffic conditions, and the preparation of input data for more detailed analyses. The model used in the project was obtained in cooperation with GZM and is not included as an annex to the project dataset; however, it may be made available upon request.

In line with the logic adopted in D0.3, urban logistics scenarios are intended to provide the basis for further work in WP2, as well as in other tasks. They make it possible to define transport relations, groups of system participants, means of transport, decision variables, and potential assessment indicators. It is assumed that macroscopic data will be used primarily for:

- characterising the study area;
- describing the structure of the transport network;
- identifying TAZ transport zones;
- determining spatial relations between zones;
- obtaining information on traffic conditions and impedance on connections;
- indicating areas potentially representative for microsimulation;
- preparing the basis for scaling selected KPIs between zones.

In addition to describing the transport network, the macroscopic model makes it possible to link traffic information with the spatial, demographic, and functional characteristics of zones. This is particularly important for GZM, which has a polycentric structure, a diversified functional layout, and different types of urban, suburban, industrial, and service areas. At the same time, it constitutes a complex but representative research testbed.

For the purposes of further simulation research, it is assumed that different categories of data from the macroscopic level may be used (Table 9).

Table 9. Data categories obtained from the macrosimulation model

Data category	Example data scope	Application in further analyses
TAZ transport zones	zone boundaries, identifiers, area, location in relation to the network	basic spatial unit for describing, comparing, and grouping parts of the city
Zone characteristics	number of inhabitants, area functions, development type, workplaces, services, retail, education, healthcare	determining the potential for generating and attracting deliveries
Transport network	nodes, links, lengths, road classes, permitted speeds, capacities	representation of transport accessibility and basic conditions for carrying out deliveries
Spatial relations	connections between zones, hub-zone relations, zone-	preparation of assumptions for transport relations in scenarios

Data category	Example data scope	Application in further analyses
	recipient relations, zone-parcel locker relations	
Traffic conditions	traffic volumes, average speeds, link loads, potential congestion locations	determining the conditions under which urban deliveries may be carried out
Travel times and impedance	travel times between zones, connection impedance, OD relations	input data for route analyses, zone selection, and microsimulation parameterisation
Supporting data for energy and emission assessment	route lengths, speeds, network loads, traffic structure	basis for later estimation of energy consumption and emissions after linking with additional calculation models
Reference areas	selected base zones, similar zones, zone clusters	selection of city fragments for detailed microsimulation analyses

Traffic Analysis Zones (TAZs) are of particular importance in further work. These zones make it possible to organise the space of the city or metropolis into analytical units that can be compared in terms of selected characteristics. In the context of urban logistics research, these may include, among others:

- number of inhabitants;
- type and intensity of development;
- area function;
- number of workplaces;
- presence of services, retail, education, and healthcare;
- accessibility of the road network;
- distribution of parcel lockers and pick-up points;
- potential availability of hubs or delivery concentration points;
- traffic conditions and transport accessibility.

These data may support the identification of zones with similar characteristics. This is of significant importance later from the perspective of reducing the labour intensity of analyses. It was assumed that it would not be necessary to build a full microsimulation model for each zone, but rather to select a limited number of reference zones for which more detailed analyses could be carried out, and then relate the results to zones with similar characteristics.

On this basis, it was assumed that the macroscopic model may support the selection of reference areas based on criteria such as:

- functional diversity of the area;
- intensity of development;
- potential demand for deliveries;
- accessibility of the road network;
- typical traffic conditions;
- location in relation to hubs, parcel lockers, and pick-up points;
- representativeness in relation to other zones;
- possibility of obtaining or supplementing input data.

The selection of such areas will enable further microsimulation studies to be carried out for selected types of deliveries, primarily those indicated in D0.3 as active scenario groups for subsequent WP2 work, including ready-made food delivery, boxed meal delivery, and parcel delivery with home and parcel locker channels.

The macroscopic model will constitute the basic source of data for microsimulation by providing information on the spatial and transport context of the analysed zone. In addition, it will be supported by supplementary data from open sources such as OpenStreetMap [15] or the geoportal, i.e. the spatial data bank [8]. This applies primarily to:

- boundaries of the analysed zone;
- layout of the road network within the zone and its surroundings;
- availability of entry and exit points;
- travel times and impedance;
- relations between the zone and potential sending points or delivery concentration points;
- locations of recipients, parcel lockers, pick-up points, and facilities generating demand;
- typical traffic conditions;
- potential structure of demand for deliveries.

At the microsimulation level, these data will be supplemented with the results of survey research and expert consultations. They provide information such as loading and unloading times, time spent searching for a stopping place, number of shipments, typical courier behaviour, recipient preferences, operational problems, and infrastructure-related barriers.

In the first stage of the research, the macroscopic model, supported by GIS data, primarily serves as a data source and a spatial-traffic framework for further studies. The main task is to prepare the basis for selecting study areas, characterising zones, parameterising microsimulation models, and later interpreting the results at a scale larger than a single zone.

6.3. Microsimulation of last-mile logistics

This section of the report defines the methodological assumptions for microsimulation studies of last-mile logistics processes using the Discrete Event Simulation (DES) environment FlexSim. The objective of the microsimulation is to generate operational, energy and emission data for selected scenarios defined in D0.3, which subsequently serve for calibration and parametrisation of macroscopic models built in PTV Visum software.

The two-level approach - micro (FlexSim/DES) and macro (PTV Visum) - allows for mutual complementarity of both modelling methods. Microsimulation provides detailed data on the behaviour of individual vehicles, couriers and orders in a limited test area, accounting for process stochasticity, demand variability and operational constraints. Macro-simulation models operate at an aggregate level (traffic zones and flow streams) and require parametrisation with averaged characteristics. Microsimulation results serve as synthetic reference data for macro-model calibration.

The scope of this chapter covers the FlexSim model architecture, description of input data, scope of simulation experiments, KPI definitions, micro-model validation procedure and procedure for scaling results to the macro level. The chapter is directly linked to report D0.2

(definition of attributes for reference cases and scenarios) and report D0.3 (scenario catalogue for RC1 - GZM Metropolis).

6.3.1. FlexSim model architecture

The model in the FlexSim environment is built as a Discrete Event Simulation (DES) of last-mile logistics processes carried out in a selected test area. The test area corresponds to one or several traffic zones of RC1 - GZM Metropolis, for which network and demand data are available. The model represents transport network topology, locations of dispatch and delivery points, transport modes, and the logic of order assignment and execution.

The architecture of the microsimulation models consists of four interconnected functional layers: transport network, actors and logistics objects, process logic, and data collection and export. The layer scheme is presented in Table 10.

Table 10. Architecture layers of the FlexSim model

Model layer	Key elements	Function in simulation
Transport network	Nodes, links, speed and capacity attributes, permitted transport modes	Basis for route assignment; calculation of travel time, distance and energy consumption
Actors and logistics objects	Senders (restaurants, catering companies, hubs), individual receivers, parcel lockers, concentration points, vehicle and courier fleet	Order generation, cargo stream handling, operational logic
Process logic	Order generation rules, assignment and routing algorithms (TSP_VNS, A*), time windows, consolidation rules	Event flow control; execution of baseline and alternative scenarios
Data collection and export	Event counters, order registers, KPI calculators, export to CSV/Excel	Collection of simulation results for further analysis and macro-model calibration

The transport network is represented in the model as a directed graph $G = (V, E)$, where V denotes the set of nodes (intersections, access points to logistics objects) and E - the set of links (arcs). Each node is assigned an identifier, geographical coordinates and type (intersection, dispatch point, delivery point, parcel locker, concentration point). Each link is assigned: start node, end node, length, permitted speed, average speed accounting for traffic conditions, capacity, and the set of permitted transport modes. This attribute set corresponds to the minimum requirements specified in D0.2 for the transport_network_node and transport_network_link entities.

Network data for the test area are obtained from the GZM transport model or spatial data sources (OpenStreetMap), following verification and supplementation. The network is prepared as a link table (Edges) and associated with a node group (Group), in accordance with the format required by the routing algorithms implemented in the model.

In the microsimulation model, each type of actor or logistics object is represented as a separate class of objects. The main object classes are listed in Table 11. The listing corresponds to the entity attributes defined in the minimum attribute set of D0.2 (Table 8 of D0.2 report). Logistics objects are placed in the model according to their actual geographical coordinates and linked to the corresponding transport network nodes.

Table 11. Object classes in the FlexSim model and their counterparts in the D0.2 structure

Object class	D0.2/D0.3 counterpart	Key (selected) attributes in model
Sender	Restaurant, catering company, courier hub	node_id, operating_hours, dispatch_volume, dispatch_rate
Receiver	Individual receiver, destination point	node_id, demand_profile, time_window, pick_up_mode
ParcelLocker	Parcel locker / pick-up point	node_id, capacity, fill_level, service_area
ConcentrationPoint	Concentration point	node_id, capacity, consolidation_time, service_area
Vehicle	Transport mode / vehicle type	mode_id, propulsion, capacity, speed, energy_factor, emission_factor
DeliveryTask	Delivery task	task_id, sender_id, receiver_id, cargo_type, weight, volume, time_window

The process logic layer controls the event flow in the simulation. It encompasses: (1) generation of delivery orders according to the demand profile, (2) assignment of orders to vehicles (of different types) or couriers, (3) route determination and optimisation, (4) simulation of delivery execution with event logging, (5) handling of concentration points and parcel lockers.

The basic routing and optimisation algorithm in the model is TSP_VNS (Travelling Salesman Problem - Variable Neighbourhood Search), implemented as Custom Code in the FlexSim environment. The algorithm performs the following steps:

- Pre-processing of the distance matrix (preprocessed_paths) using the A* or Dijkstra shortest-path algorithm (parameter isDijkstra), determining minimum paths between all pairs of terminal nodes, including traffic parameters on links at specific times of day.
- Solution initialisation and preliminary local optimisation using the 2-opt method (_localsearch_order).
- Iterative VNS: random perturbations of the solution (shake, _ShakeOrder) with number of perturbations k = 1, …, k_max, followed by 2-opt local search and solution acceptance only in case of objective function improvement (best improvement strategy).
- Stop criterion: no improvement in consecutive noImproveMax iterations of the main loop.
- Full path reconstruction in graph G by joining optimally determined shortest paths between consecutive terminal nodes.

The implementation is based on the VNS algorithm as described by Hansen and Mladenovic (2001) [9]. For shortest-path determination, the A* algorithm (Hart, Nilsson, Raphael, 1968) [10] is applied, which in the deterministic variant (isDijkstra = 1) reduces to Dijkstra's algorithm [6]. The choice between A* and Dijkstra depends on graph density and simulation time requirements. The routing algorithm parametrisation for individual scenarios is compiled in Table 12.

Table 12. Routing algorithm parametrisation for D0.3 scenarios

Scenario (D0.3)	Route type	backToDepot	Transport modes	Notes
BS/AS 1.1 - Ready-made food delivery	Path with return	1	Vehicles, bicycles, e-scooters	Multiple receivers per route; return to restaurant/depot
BS/AS 1.2 - Boxed meal delivery	Cycle / path	1	Vehicles, bicycles, e-bikes	Planned multi-stop routes
BS/AS 1.3 - Parcel delivery with home and parcel locker channels	Cycle (hub → lockers)	1	Vehicles, EV, drones	Hub-locker segment; self-pickup modelled separately

In parcel delivery scenarios (BS/AS 1.3), the model handles the following sub-processes: (1) delivery of parcels from hubs to homes, (2) delivery of parcels from hubs to parcel lockers, (3) self-pick-up by users, and, in drone-based variants, delivery from parcel lockers to recipients in AS 1.3.4 or direct hub-to-home drone delivery in AS 1.3.10.

6.3.2. Microsimulation input data

The FlexSim model input data correspond to the minimum attributes defined in D0.2 (Table 8 of D0.2 report). They are divided into five thematic groups: network data, demand data, data on senders and logistics objects, data on transport modes, and energy and emission data. A summary of data groups with their sources and scope is provided in Table 13.

Table 13. FlexSim model input data groups, their attributes and sources

Data group	Attributes	Data source	Notes
Network data	node_id, coordinates, link_id, length, speed, capacity, permitted transport modes	GZM transport model, OpenStreetMap, road authority data	Topological verification; speed attributes supplemented from GPS data
Demand data	Number of orders, time distribution, spatial distribution, peak hours, demand growth (AS scenarios)	Logistics operators, surveys (D2.2), public data, literature	Stochastic data; distribution calibration from empirical or expert data
Senders and logistics objects	Location of restaurants, catering firms, hubs, parcel lockers, concentration points; operating hours, throughput	Project partner data, public data (geoportals, registers), OSM	Locations linked to network nodes
Transport modes	Type, propulsion, capacity, speed, loading/unloading time, range, access restrictions	Manufacturer technical data, industry literature, operator data	Parameterised separately per modal variant

Energy and emission data	Unit fuel consumption [l/100 km], electricity [kWh/km], CO_2 emission factor [g CO_2/km or g CO_2/kWh], unit costs	IPCC 2023 [11], KOBiZE [12], literature, operator data	CO_2 emission factor for electricity in Poland: ~700 g CO_2/kWh (KOBiZE, national grid data); subject to verification

Preparation of input data requires a preliminary data validation stage (see Section 5.5). Data for which empirical values are not available are replaced by expert assumptions or values from literature - each time with documentation of the source and uncertainty level, in accordance with D0.2 recommendations.

6.3.3. Scope of simulation experiments

The scope of simulation experiments at the micro level covers all scenarios designated in D0.3 as Core Scenarios (CS) and Supporting Scenarios (SS) for areas for which the required input data are available. Baseline scenarios (BS) are executed first as reference points for comparisons with alternative scenarios (AS). Scenarios designated in D0.3 as Future Research Proposals - i.e. BS/AS 1.4 (pharmaceutical deliveries) and BS/AS 1.5 (B2B) - are not covered by the current scope of microsimulation experiments.

Table 14. Scope of microsimulation experiments for D0.3 scenarios

Scenario	D0.3 status	Micro experiment type	Main active variables
BS 1.1 Ready-made food delivery	CS	Reference scenario	demand, restaurant and recipient locations, base modal split, order assignment
AS 1.1.1 Low-emission modal split in ready-made food delivery	SS	Comparative variant	modal split change, low-emission mode share
AS 1.1.2 Demand increase and high low-emission share in ready-made food delivery	SS	Scalability / fleet variant	demand multiplier, low-emission modal structure, vehicle utilisation
AS 1.1.3 Demand increase and zero-emission structure in ready-made food delivery	SS	Zero-emission feasibility variant	demand multiplier, zero-emission modal structure, resource utilisation
BS 1.2 Boxed meal delivery to homes and offices	CS	Reference scenario	demand, residential and office recipients, time windows, base vehicle structure

AS 1.2.1 Electric mix in boxed meal delivery	SS	Fleet electrification variant	electric vehicle share, vehicle capacity, vehicle assignment
AS 1.2.2 Demand increase and electric vans in boxed meal delivery	SS	Demand growth / fleet variant	demand multiplier, electric vans, vehicle utilisation
AS 1.2.3 Demand increase and zero-emission boxed meal delivery	SS	Zero-emission feasibility variant	demand multiplier, zero-emission vehicle structure, route structure
BS 1.3 Parcel delivery with home and parcel locker channels	CS	Reference scenario	common parcel demand, home/locker channel split, parcel eligibility
AS 1.3.1 Low-emission moderate parcel delivery	SS	Operator fleet transition	moderate low-emission structure for hub-to-home and hub-to-locker relations
AS 1.3.2 Low-emission high parcel delivery	SS	Operator fleet transition	high low-emission structure, vehicle assignment
AS 1.3.3 Zero-emission parcel delivery	SS	Zero-emission operator fleet variant	zero-emission structure for operator relations
AS 1.3.4 Drone delivery from parcel lockers	SS	Drone-based variant	parcel-locker-to-home by drone, drone eligibility, drone range and capacity
AS 1.3.5 Parcel locker only channel	SS	Channel split variant	100% parcel locker channel for eligible parcels
AS 1.3.6 Major parcel locker share	SS	Channel split variant	75% parcel locker / 25% home delivery
AS 1.3.7 Equal home and parcel locker share	SS	Channel split variant	50% parcel locker / 50% home delivery
AS 1.3.8 Minor parcel locker share	SS	Channel split variant	25% parcel locker / 75% home delivery
AS 1.3.9 Direct home parcel delivery only	SS	Channel split variant	100% home delivery / 0% parcel locker
AS 1.3.10 Drone-only direct parcel delivery	SS	Experimental drone variant	direct hub-to-home drone delivery, drone eligibility and operational constraints

Microsimulation experiments are carried out for selected test areas within RC1 - GZM Metropolis. Selection of test areas accounts for: availability of network and demand data at the required level of detail, morphological diversity (inner-city, peripheral and polycentric areas), representativeness for the broader GZM context, and the possibility of result validation against external data.

Selection of test areas results from application of a clustering model developed as an intermediate layer between microsimulation models and the macroscopic model.

The basic simulation horizon covers one full working day (8-24 h) with event granularity at the second level. For scenarios requiring assessment of daily variability (e.g. AS 1.1.2), multi-day series or multiple runs (replications) with different random generator seeds are performed, in accordance with statistical verification methodology for DES results [14].

For each baseline scenario (BS), an experiment design is developed specifying: the set of constant background parameters (fixed/background attributes per D0.2), the set of active scenario variables (active attributes), the range of values tested for each active variable, and the number of replications necessary to obtain statistically significant results.

The minimum number of replications per parameter configuration is 10, allowing estimation of confidence intervals for KPIs assuming a normal distribution of results. For scenarios with high stochastic variability (e.g. AS 1.1.2, AS 1.2.2), the number of replications may be increased to 30, in accordance with the guidelines of Law and Kelton [14].

6.3.4. KPI definitions

KPIs recorded in the model correspond to the KPI set defined in D0.3 (Table 3 of D0.3 report) and their micro-level elaboration in D0.2 (Table 10 of D0.2 report). Table 15 contains formal definitions of KPIs calculated in the model, their units, aggregation level and link to subsequent macro-simulation analysis.

Table 15. FlexSim microsimulation KPI definitions

KPI	Formal definition	Unit	Aggregation	Link to macro model
Total distance (TD)	Sum of all link lengths covered by all vehicles: TD = Σ d_ij	km	Scenario / vehicle / order	Scaling to distances in macro zones
Average delivery time (ADT)	Mean time from order generation to delivery: ADT = (1/N) Σ (t_del,i - t_gen,i)	min	Scenario / segment	Service time parameter in macro model
Total energy consumption (TE)	TE = Σ_v Σ_ij d_ij · e_v, where e_v - unit energy consumption of vehicle v [kWh/km]	kWh	Scenario / mode / order	Energy intensity factor for macro model
Total fuel consumption (TF)	TF = Σ_v Σ_ij d_ij · f_v, for combustion vehicles, where f_v [l/km]	l	Scenario / vehicle	Emission and cost indicator for macro model

CO2eq emissions (TCO2)	TCO2 = TF · EF_fuel + TE_el · EF_el	kg CO2eq	Scenario / mode	Environmental indicator for SULP analyses
Orders served (NS)	Number of orders delivered within time window: NS = |{i : t_del,i ≤ t_win,i}|	pcs.	Scenario	System efficiency indicator
On-time rate (P)	P = NS / N_total · 100%	%	Scenario	Service quality indicator
Vehicle utilisation (VU)	VU = (vehicle active time) / (total simulation time) · 100%	%	Vehicle / fleet	Fleet efficiency parameter for macro model
Consolidation level (CL)	CL = (shipments per route) / (number of routes)	pcs./route	Scenario	Consolidation efficiency for model variants involving consolidation or concentration points, if analysed as supplementary or future extensions.
Energy per order (EPO)	EPO = TE / N_total	kWh/order	Scenario	Key coefficient for macro model calibration
Distance per order (DPO)	DPO = TD / N_total	km/order	Scenario	Key coefficient for macro model calibration

The EPO (energy per order) and DPO (distance per order) indicators are of particular importance in the process of scaling results to the macro model, as they constitute unit coefficients characterising the operational and energy efficiency of a specific scenario variant. They are calculated as the result of each replication and exported to the consolidated results spreadsheet.

6.3.5. Microsimulation model validation procedure

Validation of the microsimulation model is carried out in accordance with the methodology recommended for DES models by Sargent (2013) [19], encompassing: verification of implementation correctness (verification), conceptual validation (face validity), and operational validation (operational validity). The objective of validation is to confirm that the model reproduces real-life logistics processes in the test area with sufficient accuracy and that the simulation results are reliable as input data for macro-model calibration.

Verification includes checking the correctness of the model's process logic, the functioning of routing algorithms (TSP_VNS, A*/Dijkstra), energy converters, result aggregators and visualisers, and the correctness of KPI calculations. Methods applied:

- unit tests of routing algorithms on simplified graphs with known optimal solutions;
- order mass balance verification: the number of generated orders must equal the sum of served and unserved orders;

- consistency verification of energy results: TE calculation based on the sum of distances and unit coefficients must yield results consistent with the consumption recorded at individual vehicle level;
- visual inspection of simulation animation for selected test scenarios.

Conceptual validation consists of assessment by industry experts and project partners of whether the model's behaviour is consistent with expectations arising from knowledge of real urban logistics processes. Assessment covers: general route patterns, delivery times, KPI levels for baseline scenarios and the model's response to changes in input parameters. Conceptual validation is conducted in workshop mode with participation of project partners (WUT, Metropolis GZM).

Data for conceptual validation are also constructed from surveys conducted among project stakeholders. Operational validation consists of comparing baseline scenario (BS) results with available empirical data or benchmarks from literature. The following approaches are applied depending on data availability:

- comparison of average delivery times with data from logistics operators operating in the GZM area (if available);
- comparison of estimated distances and energy consumption with published benchmarks for European last-mile logistics systems [3], [16];
- sensitivity analysis: assessment of the impact of ±20% changes in key input parameters (demand, speed, unit energy consumption) on KPI values - expected monotonic and proportional model response.

Acceptance criteria for operational validation are as follows: deviation of simulation results from reference values for operational KPIs (ADT, DPO) must not exceed ±20%, and for energy KPIs (EPO, TCO2) - ±25%, which is the accepted standard for DES models used in urban logistics research [16].

6.4. Micro- and macroscale integration for last-mile logistics research

The integration of the micro- and macrosimulation levels constitutes one of the key and, at the same time, novel methodological elements of further research carried out in WP2. It results from the need to combine two perspectives of urban logistics analysis. On the one hand, it is necessary to represent the entire urban or metropolitan area, its spatial structure, transport zones, road network, and traffic conditions. On the other hand, detailed last-mile delivery processes, including order handling, courier behaviour, loading and unloading times, the choice of means of transport, and the quality of recipient service, require modelling at the microscopic level. This approach is consistent with the micro-macro model integration methodology applied in urban logistics research [3], [5] in which microsimulation results serve as characteristic coefficients calibrating the parameters of higher-level models.

It was therefore assumed that the macroscopic and microscopic levels would be treated as mutually linked analytical layers. The macroscopic model provides data on the structure of the area and traffic conditions, while the microscopic model enables a detailed assessment of selected delivery processes and the determination of KPI indicators for specific organisational scenarios. The basic assumption of the integration is that:

- the macro level provides input data, spatial context, and interpretative framework for microsimulation, as described in Section 6.2;
- the micro level provides detailed operational, energy, and emission indicators, which may then be interpreted at a broader scale;
- the integration level enables selected results to be scaled from test zones to similar zones or to larger parts of the city;
- the system level may support the interpretation of long-term relationships between demand, user behaviour, urban policies, and infrastructure.

D2.1 defines the methodological assumptions and the logic of data flow that may be used in further work, in particular in D2.3 and in the formulation of conclusions for M2.

6.4.1. Data flow from the micro level to the macro level

The microsimulation model may provide detailed results describing the functioning of the selected delivery system. These results may constitute reference data for further interpretation and scaling. This applies primarily to KPI indicators determined for selected delivery scenarios (Table 16).

Table 16. Use of micro-level data at the macro scale

Micro-level results	Use at the macro level
Delivery execution time	Assessment of service quality and comparison of organisational variants
Length of delivery routes	Estimation of transport load in similar zones
Number of served points	Assessment of the operational efficiency of the delivery system
Loading and unloading time	Adjustment of operational parameters in larger-scale analyses
Time spent searching for a stopping place	Identification of infrastructural and spatial barriers
Vehicle utilisation	Assessment of fleet demand and potential modal shifts
Energy consumption	Estimation of the energy effects of delivery scenarios
Emissions	Environmental assessment of delivery organisation variants
Sensitivity to changes in demand or means of transport	Analysis of the effects of alternative scenarios
Level of recipient service	Interpretation of the social and quality-related effects of changes in the system

These results may then be related to zones with similar spatial, transport, and demand characteristics. This approach makes it possible to reduce the labour intensity of building microsimulation models, as it does not require detailed modelling of every city zone. Instead, it is possible to use a limited number of reference zones and estimate selected KPIs for similar zones.

Moreover, data from the macroscopic level may provide a basis for further estimation of energy consumption and emissions. This applies in particular to information such as route lengths, travel times, speeds, link loads, and traffic structure. Macroscopic data alone are not sufficient for a full energy assessment of last-mile delivery processes. They need to be linked with vehicle parameters, fleet structure, cargo data, the method of delivery service, and additional calculation models.

6.4.2. Scaling KPIs from the micro level to the macro level

In micro-macro integration, an important element of the research is the assessment of the possibility of using microsimulation results to estimate selected KPIs at a larger spatial scale. This scaling is understood as a procedure aimed at transferring information from a zone studied in detail in the microsimulation model to other zones with similar characteristics. A simplified research scheme is presented in Fig. 3.

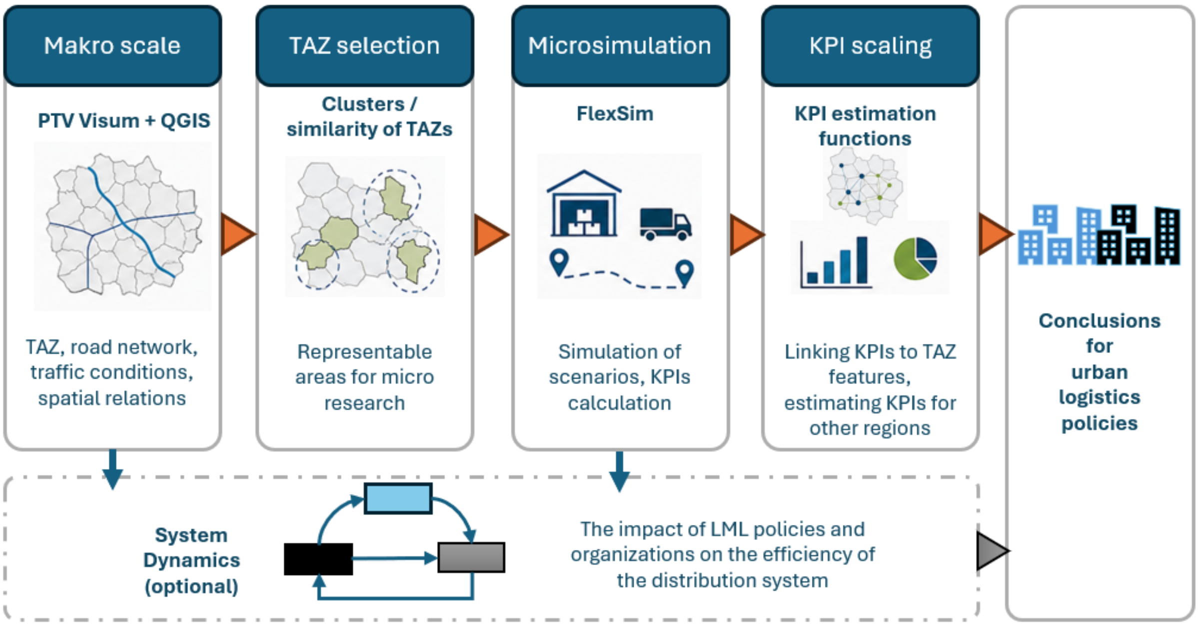

Fig. 3. KPI scaling procedure for complex urban analysis

In this approach, the scaling procedure may include the following elements:

- characterisation of TAZ zones based on GIS data, data from the macroscopic model, and demographic, functional, and infrastructural data;
- selection of a reference zone or reference zones for which it is possible to prepare a detailed microsimulation model;
- carrying out microsimulation for selected delivery scenarios and calculating KPIs;
- identification of zones similar to the reference zone based on selected characteristics, e.g. development type, number of inhabitants, length of the road network, number of parcel lockers, demand structure, or traffic conditions;
- estimation of selected KPIs for similar zones using the results obtained in the reference zone;
- verification of the interpretation, including assessment of whether the result may be treated as an approximation or only as an indicator of tendencies;

- aggregation of results to the level of a larger area, e.g. a city, a group of zones, or a selected demand segment.

The indicators that may potentially be subject to such interpretation include the assessment measures defined in Section 6.3.4 of this report. Due to the diversity of urban logistics, KPI scaling should be carried out carefully and preferably by demand segments or types of delivery processes. Results obtained for one type of delivery should not be directly transferred to all other segments. Ready-made food delivery, boxed meal delivery, and parcel delivery differ in their operational characteristics. Within parcel delivery, home delivery, parcel-locker delivery, self-pick-up and drone-based variants should be interpreted as alternative channels or relations within the same parcel-demand framework. Therefore, it was assumed that micro-macro integration may be carried out in two variants:

- segment-based integration - microsimulation results are related to a specific type of delivery, e.g. parcels to recipients or deliveries to parcel lockers; this is the most justified approach for WP2;
- aggregated integration - results from several segments are combined into a broader assessment of the urban logistics system; this is possible only after taking into account the demand structure and data limitations.

In D2.1, the main importance lies in indicating the logic of this process, while detailed calculations and comparisons of variants will be presented in subsequent stages, primarily in D2.3 and M2.

It should also be noted that scaling results to other cities may potentially be possible; however, this should be treated only as a potential direction for further research and not as the scope of analyses carried out directly in this report. In the E-Laas project, the main reference area for WUT work is the Górnośląsko-Zagłębiowska Metropolis, while the developed logic of integrating micro- and macrosimulation models may provide a basis for later examining the possibility of transferring selected results to other urban areas.

From a methodological perspective, this means the possibility of constructing a description of a city from representative fragments that differ in size, function, development density, road network structure, availability of logistics infrastructure, and potential demand for deliveries. Results obtained for selected reference zones could then be used as a reference point for similar zones and, in the longer term, also for cities with a similar spatial and functional structure. This approach is consistent with the concept developed in the project of using the similarity of TAZ zones to approximate microsimulation results and reduce the labour intensity of research in large urban areas.

However, it should be emphasised that transferring results to other cities would require separate validation. Differences in urban structure, user behaviour, availability of parcel lockers and pick-up points, traffic organisation, parking policy, charging infrastructure, and local regulations may significantly affect the obtained KPIs. Therefore, at the current stage, scaling to other cities should be understood only as methodological potential and a direction for further research, not as a ready-to-implement procedure.

In future work, it would be possible to use this logic to compare cities of different sizes and characteristics, e.g. monocentric, polycentric, densely urbanised, dispersed, industrial, or service-oriented cities. On this basis, more differentiated suggestions concerning the shaping of urban policies could be formulated.

6.4.3. System Dynamics in the research methodology of last-mile logistics

In addition, at the highest level of abstraction, the use of the System Dynamics approach may be considered, for example in the Simantics System Dynamics environment or as a Python library, BPTK-Py. This approach may support the interpretation of system-level relationships that are not always directly visible in network or process models.

System Dynamics may be particularly useful for describing feedback loops between:

- increasing demand for deliveries;
- the availability of charging infrastructure;
- operators' willingness to change their fleet;
- the level of user acceptance of different delivery forms;
- urban policies concerning delivery zones, parcel lockers, microhubs, or clean transport zones;
- changes in costs, service time, energy consumption, and emissions;
- the level of quality of life and the nuisance effects of urban logistics.

For the purposes of D2.1, System Dynamics should be treated as a potential supporting tool for interpreting the effects of urban policies and long-term system-level relationships. Its role may primarily consist in supporting the synthesis of results from D2.2 and D2.3 and preparing analyses for M2.

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8. Annex 1. Questionnaires and assignment of information to analytical areas

The annex presents a summary of the questions used in the survey questionnaires, together with the assignment of each question to the areas of data use in the project. The "x" mark indicates that the answer to a given question may constitute a source of information for a specific analytical area. One question may be assigned to more than one area, as some data may be used in parallel, e.g. in microsimulation modelling, optimisation of logistics operations, energy analysis, and the assessment of social aspects or urban policies.

Groups	Type of question	Question	Base data	Microscopic Modelling	Logistics operation optimisation	Energy	Social aspect	Policy formulation
1 to 7	Respondent profile	Town/towns (work area/recipient location)	x					
		Type of goods (parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, deliveries of medicines/pharmaceuticals; deliveries to companies)	x					
		Operating area (rural areas, suburbs, residential estates, city centres, industrial zones, office zones)	x					
		Postal codes of loading locations	x					
		Postal codes of unloading locations	x					
		Means of transport used for delivery (on foot, public transport, bicycle, cargo bike, motorcycle/scooter, electric scooter, passenger car, delivery vehicle up to 3.5 t GVW, truck above 3.5 t GVW, truck with trailer above 3.5 t GVW, drone, other)		x		x		
		Do you use a vehicle that enables the transport of cargo sensitive to ambient temperature? (refrigerated vehicle, insulated container, thermal bag, other body types: …)				x	x	
		Drive type (none, petrol, diesel, LPG, CNG, LNG, electric, hybrid, plug-in hybrid, other)		x		x		
		Ownership model of the means of transport (own vehicle: cash purchase/leasing/short-term rental/long-term rental; rental from a logistics operator; pay-per-minute rental - carsharing; rental from a settlement partner)			x			
		Vehicle operation and servicing (whether the vehicle is charged/refuelled during the delivery day, who is responsible for charging/refuelling, who is responsible for day-to-day vehicle preparation)			x	x		
		Typical working days (weekdays/weekends)		x				
		Work regularity (occasionally: a few days per month; daily: a few hours; daily: full-time)		x				
		Type of mobile applications used: company application (dedicated to a given company, e.g. DPD, UPS), publicly available application (i.e. crowdsourcing - Glovo, Pyszne.pl, Uber Eats, other: …)			x			
	Average working day	Total number of kilometres travelled during the day [km] (below 20, 20-50, 50-100, 100-150, 150-200, above 200)		x		x		

		Number of working hours per day [h] (below 4, 4-6, 6-10, 10-12, above 12)		x				
		Typical working hours [hh-hh] (typical start time, typical end time)		x				
		Number of loading addresses during the day [pcs.] (number)		x				
		Daily number of loading operations during the day [pcs.] (number)		x				
		Number of delivery addresses during the day [pcs.] (number)		x				
		Average number of parcels per single delivery location [pcs.] (1, 2-5, 5-10, above 10)		x				
		Average number of parcels during the day [pcs.] (number)		x				
		Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit, container, swap body]		x				
		Average distance between the loading point and the delivery point (first delivery location) [km] (0-5, 5-10, 10-20, above 20)		x				
		Average vehicle loading time [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)		x				
		Average waiting time for loading [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)		x				
		Average travel time between the loading point and the delivery point [min] (0-5, 5-10, 10-15, 15-30, 30-60, over 60 min)		x				
		Average unloading time (delivery in the vehicle-recipient-vehicle relation) [min] (0-2, 2-5, 5-10, over 10 min)		x				
		Average time spent searching for a parking space/stopping place for unloading [min] (0-2, 2-5, 5-10, over 10 min)		x				
		Average daily idle time during working hours [min] (0-30, 30-60, 60-120, over 120 min)		x				
		Average daily time allocated to day-to-day vehicle operation and servicing, including vehicle refuelling/charging [min] (0-15, 15-30, 30-60, over 60 min)		x				
5	Average working day	How often is the recipient absent from the delivery address? [%]		x			x	
		Where do you most often leave the parcel when the recipient is absent? (neighbour, at the door/on the property, security desk, redirected to a pick-up point)		x			x	
6		Delivery location (general store, large-format store, car repair workshops, construction sites, companies, offices, restaurants)	x	x				
1 to 7	Preferences	Would you replace your vehicle with another one? (larger/smaller car, bicycle, other)			x	x	x	
		Would you switch to a vehicle with a different power source?			x	x	x	
		How do you assess the usefulness of electric vehicles in your sector? (very high, high, medium, low, none)			x	x		
		Would the development of urban infrastructure, such as parking areas, parking spaces dedicated to delivery providers, and parking spaces equipped with chargers, affect the delivery process, and how? (on a scale from 1 to 10)			x			x
		Would you change your working hours to night-time/off-peak hours in order to avoid losing time in traffic congestion? (yes/no)		x	x		x	x
		How often do you have problems finding a stopping place during delivery? (always, very often, often, rarely, very rarely)			x		x	x

		How often are you forced to stop in a prohibited place or in an active traffic lane? (always, very often, often, rarely, very rarely)		x	x		x	x
		What is the most annoying/burdensome element of the delivery process?			x		x	x
		To what extent does heavy rainfall reduce your efficiency? (does not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / makes work impossible, 100%)		x			x	
		To what extent does heavy snowfall reduce your efficiency? (does not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / makes work impossible, 100%)		x			x	
		To what extent do negative temperatures below -5°C reduce your efficiency? (do not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / make work impossible, 100%)		x			x	
		To what extent do high temperatures above 30°C reduce your efficiency? (do not reduce it / to a small extent, up to 20% / to a medium extent, up to 50% / significantly, up to 75% / make work impossible, 100%)		x			x	
		Do seasonal periods, e.g. holidays, extend your working day? (do not extend it, from 30 minutes to 1 h, from 1 h to 2 h, from 3 h to 5 h, 5 h or more)		x	x		x	
		How does the summer holiday period affect your working time? (shortens it by more than 2 h, shortens it by 1-2 h, has no effect, extends it by 1-2 h, extends it by more than 2 h)		x	x		x	
		If you use an electric vehicle:						
		Where do you most often charge your vehicle? (city/home/company base)		x	x	x		
		Where do you most often charge your vehicle during the day? (does not require charging during the day/company base/home/city-route)		x	x	x		
		Is the availability of chargers sufficient? (yes/no)				x		
		Do you think that the price of energy for vehicle charging should depend on the location and popularity of the charger? (yes/no)				x		x
		Would you be willing to spend 10 minutes travelling to a charger in order to charge the battery more cheaply? (no / 10% cheaper / 25% cheaper / 50% cheaper)				x		
		Would you be willing to spend 20 minutes travelling to a charger in order to charge the battery more cheaply? (no / 10% cheaper / 25% cheaper / 50% cheaper)				x		
		How many working days per year do you lose due to vehicle failure? (number of days: …)			x		x	
		Do you give up using an electric vehicle in favour of a conventional or other vehicle during the winter season? (yes/no)			x			
1 to 3	Selection of orders for delivery	What has the greatest impact on rejecting an order? (max. 2 answers):						
		Distance/time			x			
		Weight/size			x			
		Remuneration			x			
		Too many orders (*appearing at the same time in the applications)			x			
		Fatigue			x			

		What percentage of orders do you accept for execution? (0-100%)			x			
		How often do you cancel an accepted order? (daily / once a week / once a month / less often / never)			x			
		How many applications/services do you use simultaneously? (I do not use any / 1 / 2 / 3 or more)			x			
8	Profile	Town/towns/municipality	x					
	Preferences - open-ended questions	What delivery-related problems are observed in your municipality? (e.g. blocking pavements, parking in prohibited places, excessive street load, reduced safety, traffic obstruction)						x
		What solutions would your municipality be able to introduce in order to improve urban logistics? (e.g. dedicated parking spaces, chargers for electric vehicles, dynamic electricity pricing at chargers, dynamic pricing of parking spaces, transshipment centres, electric bicycles, subsidies/incentives for pro-environmental operators, delivery time windows, night-time deliveries, entry restrictions/bans, other)						x
		Do you cooperate with logistics operators in the organisation of delivery systems? (e.g. influence on the location of parcel lockers, joint development of concepts concerning the location of parking spaces or chargers, entry to restricted traffic zones)						x
		What solutions related to urban logistics have already been introduced/tested by your municipality?						x
		Which solutions brought benefits, and which had a negative impact?						x
9	Respondent profile	Town/towns (recipient location)	x					
		Postal code of the place of residence	x					
		Place of residence (rural area, suburbs, residential estates on the outskirts, residential estates close to the city centre, city centres)	x					
		Gender (F/M/Other/I do not want to answer this question)	x					
		Age (below 18, 18-25, 26-35, 36-50, 51 and over)	x					
		Mobility modes (on a scale from 1 to 10, never-always): own car, public transport, bicycle, other	x					
		Which types of deliveries do you use? (from groups 1-7) (multiple choice)	x					
Recipients in groups 1 to 5	Preferences	What is your preferred and most frequently chosen parcel collection method? (parcel locker, courier, pick-up point)		x			x	
		What problems are associated with the above delivery methods? (no delivery on the selected day, no precise time window, lost/damaged shipments)					x	
		If you have used them, what problems occur with boxed meal delivery? (lack of punctuality, delays, omissions, missing deliveries, damaged packaging, other)					x	
		If you have used them, what problems occur with food deliveries by couriers? (lack of punctuality, delays, omissions, missing deliveries, damaged packaging, other)					x	
		Do you have any disability or limited ability? (no, mobility-related, hearing-related, sight-related)					x	
		Average number of parcels collected per week [pcs.]		x			x	
		Average share of collected parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]		x			x	
		Characteristics of parcel collection from parcel lockers/pick-up points and their use:		x			x	

		Threshold walking time to a parcel locker - what is the maximum acceptable walking time/distance to a parcel locker without using a vehicle?		x			x	
		Distance to the nearest parcel locker [m] (0-200, 200-500, 500-1000, above 1000 m)		x			x	
		Walking time to the nearest parcel locker [min] (0-2, 2-5, 5-10, above 10 min)		x			x	
		Frequency of choosing a parcel locker/courier delivery, if both are available (0 - always parcel locker; 10 - always courier)		x			x	
		Collection method (on the way to/from work, while carrying out other activities, dedicated trip)		x			x	
		If you send parcels, what is the percentage share of each method? (parcel locker/courier/drop-off point/post office)		x			x	
		Do you hand over return shipments to the courier during delivery? [always-never]		x			x	
		How often do you send parcels? [number of sending operations/month]		x			x	
		How many parcels do you send on average during one sending operation? [pcs.]		x			x	
		Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]		x			x	
		Is the pollutant emission related to parcel delivery important to you, and do you choose companies that offer deliveries by environmentally friendly vehicles? (yes/no)				x	x	
Recipients in groups 6 to 7	Preferences	Average number of parcels collected per week [pcs.]		x			x	
		Average number of deliveries [more than once a day, daily, once a week, 2-3 times a week, 4-5 times a week]		x			x	
		Average share of collected parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]		x			x	
		If you send parcels, what is the percentage share of each method? (parcel locker/courier/drop-off point/post office)		x			x	
		Do you hand over return shipments to the courier during delivery? [always-never]		x			x	
		How often do you send parcels? [number of sending operations/month]		x			x	
		How many parcels do you send on average during one sending operation? [pcs.]		x			x	
		Average share of parcels by size [%S, %M, %L, %XL, %larger, %pallet unit]		x			x	
		Is the pollutant emission related to parcel delivery important to you, and do you choose companies that offer deliveries by environmentally friendly vehicles? (yes/no)		x			x	
10	Respondent profile	City/cities (work area/company location)						
		Postal codes of loading points	x					
		Postal codes of unloading locations	x					
		Type of goods (parcels to recipients, parcels to parcel lockers, food from restaurants, diet catering, grocery deliveries, deliveries to pharmacies, deliveries to companies)	x					
		Operating area (rural areas, suburbs, residential estates, city centres, industrial zones, all of the above)	x					
		Vehicle fleet (bicycle, cargo bike, motorcycle/scooter, electric scooter, passenger car, delivery vehicle up to 3.5 t GVW, truck above 3.5 t GVW, truck with trailer above 3.5 t GVW, drone, other)	x	x	x			
		Current vehicle ownership model: percentage share of company-owned vehicles, courier-owned vehicles, and intermediary-owned vehicles			x			

		Do you use vehicles for transporting cargo sensitive to ambient temperature? (refrigerated vehicle, insulated container, thermal bag, other: …)			x			
		Drive type - percentage share (combustion, electric, hybrid, other)			x	x		
	Preferences	What is the likelihood that you would replace vehicles in your fleet with environmentally friendly ones? (0-10)						
		Electric cars						x
		Cargo bikes						x
		Smaller delivery vehicles						x
		Other: what kind?						x
		What incentives would convince you to change your fleet to a more environmentally friendly one?						x
		What are the main barriers to implementing electric vehicles in your fleet?						x
		Would the development of urban infrastructure, such as parking areas, parking spaces dedicated to delivery providers, and parking spaces equipped with chargers, affect the delivery process, and how? (on a scale from 1 to 10)						x
		To what extent would it be difficult for you to change the delivery method by using transshipment points, microhubs, freight consolidation centres, or shared services? (on a scale from 1 to 10)						x
		Preferred vehicle ownership model (company ownership, courier ownership, intermediary ownership)						x
		Does a clean transport zone affect your activity?						x
		What changes to your activity would result from the introduction of a clean transport zone?						x
		Route modification (on a scale from 1 to 10)						x
		Changes in the types of vehicles assigned to route operation (on a scale from 1 to 10)						x
		Purchase of new vehicles (on a scale from 1 to 10)						x
		Change of time windows (on a scale from 1 to 10)						x
		Withdrawal from servicing areas within the clean transport zone (on a scale from 1 to 10)						x
		To what extent do seasonal periods, e.g. holidays or sales periods, affect the number of orders? (-100 to +100%)			x			
		To what extent do seasonal periods, e.g. holidays or sales periods, affect the number of couriers involved? (-100 to +100%)			x			
		To what extent does the summer holiday period affect the number of orders? (-100 to +100%)			x			
		To what extent does the summer holiday period affect the number of couriers involved? (-100 to +100%)			x			