D2.5: Thessaloniki Demonstrator

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Authoring, Revision & QA Information

Deliverable Contributors	
Contributor	Organisation (Acronym)
Georgia Ayfantopoulou	CERTH
Dimos Touloumidis	CERTH
Elpida Xenou	CERTH
Panagiotis Kanellopoulos	ACS
Konstantina Bessa	RCM
Alice Benini	ITL

Deliverable Contributors				
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Executive summary

This report presents the findings and outcomes of the Thessaloniki Demonstrator under the URBANE Project, which aims to enhance green urban logistics through multi-actor collaboration and PI-inspired last-mile delivery solutions. The primary purpose of this deliverable (D2.5) is to document the integration and assessment of innovative logistics solutions within the urban environment of Thessaloniki, Greece, aligning with the city's ambition to become a zero-emission city by 2030. The project conducted extensive data collection and analysis, encompassing operational data from local logistics partners and socioeconomic data from the Region of Central Macedonia. The work involved demonstrating two key use cases: the installation of micro-hubs in public spaces and the simulation of Physical Internet (PI)-inspired green last-mile solutions utilizing digital twin (DT) technology. These efforts were evaluated based on various key performance indicators, including transportation costs, labor, CO2 emissions, and user preferences. Key innovations introduced include a collaborative macro and micro consolidation delivery model, the use of digital twins for real-time optimization of logistics operations, the integration of blockchain technology for enhanced parcel tracking, and the development of user-centric logistics solutions. The findings show that these innovative approaches significantly improve delivery efficiency and reduce environmental impacts, supporting the city's decarbonization goals. The report concludes that strategic placement of micro-hubs, digital twin technology, and blockchain integration, combined with stakeholder engagement and adaptive business models, offer effective pathways to sustainable urban logistics and provide a replicable model for other cities aiming for similar sustainability targets.

Table of contents

List of Figures

List of Tables

List of Abbreviations

ACRONYM	DESCRIPTION
ACS	Associated Courier Services
AI	Artificial Intelligence
AMB	Agent-Based Modeling
BPMN	Business Process Model and Notation
B2C	Business to Consumer
CO2	Carbon Dioxide
DT	Digital Twin
eLCV	Electric Light Commercial Vehicle
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FL	Facility Location
GA	Grant Agreement
GIS	Geographic Information System
HORECA	Hotels, Restaurants, and Catering
ICT	Information and Communication Technology
IoT	Internet of Things
KPI	Key Performance Indicator
LL	Living Lab
MoT	Municipality of Thessaloniki
PI	Physical Internet
RCM	Region of Central Macedonia
SLA	Service Level Agreement
SULP	Sustainable Urban Logistics Planning
TEN-T	Trans-European Transport Network
TSN	Time-Sensitive Networking
UCC	Urban Consolidation Center

1. Introduction

The **URBANE** project, formally known as "Upscaling Innovative Green Urban Logistics Solutions Through Multi-Actor Collaboration and PI-inspired Last Mile Deliveries," is committed to driving the transition towards sustainable, efficient, and resilient urban logistics. Work Package 2 (WP2) of URBANE focuses on the implementation and demonstration of innovative logistics solutions across four Lighthouse Living Labs (LLs), with Thessaloniki, Greece, serving as one of the key testbeds.

This deliverable, D2.5, specifically addresses the Thessaloniki Demonstrator, which is a pivotal component of WP2. The objective of this deliverable is to document the efforts embarked on to integrate and assess green last-mile logistics solutions within the Thessaloniki urban environment and to demonstrate a collaborative macro and micro consolidation delivery system by integrating hub and spoke principles and digital as a service delivery models. These solutions are designed to support the city's ambition to become a zero-emission city by 2030, aligning with its participation in the European Mission for 100 Climate Neutral and Smart Cities as well as enriching the ongoing regional SULP for the region of Central Macedonia.

The document outlines the methodologies adopted for data collection and analysis, including the utilization of extensive last-mile logistics data, socioeconomic Geographic Information System (GIS)-based data, and survey-based public perception feedback. These data-driven approaches are critical for evaluating the sustainability impact of the logistics innovations implemented in Thessaloniki, such as the installation of micro-hubs (parcel lockers) and the simulation of Physical Internet (PI)-inspired green last-mile solutions.

The deliverable also explores the LL setup in Thessaloniki, detailing the local context, the existing logistics infrastructure, and the key stakeholders involved. The Thessaloniki Living Lab aims to demonstrate a collaborative macro and micro consolidation delivery system, integrating hub-and-spoke principles with digital as-a-service delivery models. By leveraging the existing ACS (Courier Company -industry partner of Thessaloniki LL) infrastructure and expanding it with innovative solutions, the project seeks to enhance the efficiency of urban logistics while minimizing environmental impacts.

Key objectives of this deliverable include:

1. Mapping stakeholders and analyzing their roles and perspectives on the logistics innovations implemented in Thessaloniki.
2. Assessing the effectiveness, sustainability impact, and transferability potential of the URBANE LL innovations within the Thessaloniki context but also generalizing to generate transferable results.
3. Identifying potential barriers and enablers to the adoption of these innovations, providing actionable insights for scaling and replication in other urban environments.

The deliverable is structured to provide a detailed account of the planning, execution, and evaluation of the Thessaloniki LL activities, aligning with the overall goals of WP2. By documenting these efforts, this report not only contributes to the URBANE project's objectives but also offers a replicable model for other cities aiming to achieve sustainable urban logistics. Moreover, the document presents the details of the holistic methodology followed by Thessaloniki LL in order to design, implement and evaluate the green logistics solutions provided by the URBANE project.

1.1 URBANE Outputs Mapping to GA Commitments

TABLE 1: DELIVERABLE ADHERENCE TO GRANT AGREEMENT DELIVERABLE AND WORK DESCRIPTION

URBANE GA ITEM	URBANE GA ITEM DESCRIPTION	DOCUMENT CHAPTER(S)	JUSTIFICATION
		DELIVERABLE	
D2.5 Thessaloniki Demonstrator	*Demonstrator and report on user acceptance/lessons learned. D2.5 will describe the operation of a Hub and Spoke delivery model supported by Digital Twins. The LL will demonstrate the installation of micro-hubs/micro-consolidation lockers and the application of AI-enabled dynamic routing and fleet management. The deliverable will document the specifications for efficient operations, fleet and infrastructure details, user stories involving all stakeholders, the LL DT models, a detailed implementation plan, measurements during operation in real life settings and lessons learned to be considered in replication of Hub and Spoke delivery model.*	1-11	*This deliverable meets the GA requirements by outlining the deployment of the Hub and Spoke delivery model, supported by Digital Twin technology in Thessaloniki's Living Lab. It covers the setup of micro-hubs and lockers, along with the use of AI-driven dynamic routing and fleet management systems. The document provides details on operational efficiency, fleet and infrastructure specifics, and stakeholder experiences. Additionally, it presents an implementation strategy, captures operational data from real-world settings, and highlights key lessons learned for potential replication in other urban environments.*
		TASK	
Task 2.5 Thessaloniki Living Lab Implementation	*[Extract from the formal Task/subtask description in the GA.]*	[Respective chapters and section numbers within this document addressing the GA described task/subtask.]	[Explain how this deliverable's chapters/sections address the requirements set by the GA task/subtask described.]
Task 2.5 Thessaloniki Living Lab Implementation	*The goal of Thessaloniki's site is to demonstrate a collaborative macro and micro consolidation delivery system by integrating hub and spoke principles and digital as a service delivery models*	4.1 (use case – 1 Locker alliance network)	During the course of URBANE ACS expanded significantly their network of locker by X%. Moreover, at a single network Thessaloniki LL tested a blockchain system integration to a shared locker.
Task 2.5 Thessaloniki Living Lab Implementation	*The main requirements of the micro-consolidation hubs (lockers) and the different business use cases to be tested will be defined and implemented.*	3.1.3, 3.2.3, 5	During the pilot demonstration different business scenarios tested including normal locker network expansion, alliance locker network, and UCC with lockers scenario.

Task 2.5 Thessaloniki Living Lab Implementation	*The ThessM@LL DT infrastructure and data will be used for assessing jointly the impact of innovative services and delivery methods with variable scenarios of micro-consolidation network locations, business models and intelligent operations solutions*	4.1-4.2 (USE CASE -1&2)	During the UC-2 Thessaloniki LL demonstrated the potential of joint operations with UCC and shared micro hub network with the use and extension of Thessaloniki Urban Logistics DT along with the traffic aware dynamic routing algorithm adaptation through the project.
Task 2.5 Thessaloniki Living Lab Implementation	*The innovative business model will be demonstrated in a real operational environment*	7.1-7.2, 8.3, 10	The locker alliance network was demonstrated on real environment as one of the ACS lockers tested to be accessible from other 3rd party providers while the large-scale impact was evaluated via the Agent Based model and Thessaloniki DT
Task 2.5 Thessaloniki Living Lab Implementation	*The holistic innovation approach implemented will include the provision of "last mile delivery marketplace" which will offer two categories of services to all actors of city logistics industry of the agglomeration: (1) services enabling innovative last mile operations, and (2) services for supporting facility location optimum planning*	4.1-4.2, 7.1-7.2, 8.3.3, 10	The blockchain solution serves as a ground base paradigm for exchanging events and tracking information for a future marketplace that all lockers are available to all users. The existing network as well as future expansions will be based on the facility location model of the UTP and the Agent-based model results. Moreover, the implementation demonstrates the usage the traffic aware dynamic routing algorithm.

1.2 Deliverable overview and Report Structure

The deliverable follows a clear and systematic structure to ensure a comprehensive understanding of the Thessaloniki LL and its outcomes:

- **Section 2** presents a detailed overview of the data collected and utilized to demonstrate and quantify the logistics solutions implemented in the Thessaloniki LL. This section is crucial for establishing the empirical basis for the project's evaluations and findings.
- **Section 3** sets the context for the Thessaloniki LL, providing insights into the region's characteristics, vision, and challenges. This is followed by **Section 4**, which delves into the specific use cases implemented in Thessaloniki, focusing on innovative urban logistics solutions aimed at achieving decarbonization.
- **Sections 5 and 6** focus on the stakeholders involved in the Thessaloniki LL and provide an analysis of the governance framework that guided the actions within the Living Lab throughout the implementation period. These sections emphasize the importance of stakeholder engagement and regulatory alignment in achieving project goals.

- **Section 7** describes the actual implementation of the pilot projects, building on the groundwork laid by the previous sections. It details the step-by-step process followed to bring logistics solutions to life within the Thessaloniki LL.
- **Section 8** outlines the existing infrastructure that was leveraged during the Thessaloniki LL, as well as the new models and technologies that were integrated as part of the URBANE project. This section highlights the role of infrastructure in supporting innovative logistics solutions.
- **Sections 9, 10, 11 &12** provide an in-depth analysis of the measurable results, comparing the "As-is" situation with the outcomes observed during the pilot implementations. Based on these results and the overall experience gained, the final sections offer lessons learned and recommendations for future projects.

2. Data collection and analysis

Data collection is the process of gathering information for research or analysis. In URBANE WP2, the purposes are i) to perform a mapping of stakeholders in the different LLs, generating an overview of their perspectives on the LL innovations, ii) to assess the effectiveness and the sustainability impact of the URBANE LL innovations, iii) to identify the potential or actual barriers and enablers to uptake, and iv) to assess the transferability potential of the last mile solutions. For these purposes, different methods of data collection were used in URBANE, depending on the resources available to each LL. They included desk research, qualitative governance analysis, interest mapping through interviews, and survey-based public perception feedback data. This data was collected in each LL scoping document – demonstrator (*D2.2, D2.3, D2.4, D2.5*) and then assessed and validated in *D2.1 Validation Report*.

The adopted methods in this document are the following:

- **Stakeholder mapping:** the process of identifying and categorizing individuals or organizations impacted by or interested in a project. This involves creating an overview that lists relevant entities and groups them accordingly.
- **Desk research:** collecting information from existing sources such as the LL's own databases, books, articles, reports, and online resources, including SULPs. As most of these documents were in the LL's native language, each Living Lab contributed to this process by providing English translations of their findings.
- **Qualitative governance analysis:** examination of how decisions are made, and power is distributed within an organization or community.
- **Survey-based public perception feedback data:** gathering information about people's perceptions, attitudes, and opinions on a specific topic. While some Living Labs (LLs) have incorporated regular surveys into their operations, others chose to conduct surveys specifically for the URBANE project.
- **T3.2 Structured Datasheets** (spreadsheet. format): template and guidelines for selection and calculation of Key Performance Indicators (KPIs), accompanied by general guidelines on the use of sheets and by descriptions, units of measurement, target group, and calculation methodology for each KPI.
- **BPMN diagram of the AS-IS and TO-BE situation:** description of the process as it occurs before the implementation of the solution and during pilot execution.

Data collection was performed under the coordination of ITL with the assistance of NORCE and FIT Consulting (WP3 leader), who developed the methods and followed and guided LLs in the implementation. The same methodology will be transferred to the Wave 2 LLs.

2.1 Data collection for impact assessment during pilot activities

Before the initiation of data collection for last mile logistics, a diverse set of data points is to be compiled from various sources. This includes operational metrics from logistics partners, customer feedback, and real-time tracking information. Comprehensive data will be gathered to help in the evaluation and optimization of the efficiency and sustainability of last mile delivery operations.

2.1.1 Last-Mile Logistics Data

The primary datasets utilized in this analysis is sourced from the URBANE local industry partner, ACS, and predominantly comprise operations data. This dataset is vital for evaluating the sustainability impacts of logistics operations across Thessaloniki. Data collection is structured into three distinct aggregation levels: Route Aggregated Data, Shipping Details Data, and Delivery Data. Route Aggregated Data encapsulates each logistic route through metrics such as total distance, delivery time, and number of stops, offering insights into the efficiency and sustainability of various routes. Shipping Details Data is more granular, focusing on individual parcel attributes like weight, dimensions, and delivery specifics, which are essential for assessing shipment characteristics and their influence on logistics performance. Meanwhile, Delivery Data tracks each parcel's journey, including all intermediate stops from the depot to the destination, providing detailed operational data such as timestamps, geographical coordinates, and status updates.

This dataset covers a full-year cycle, capturing seasonal fluctuations, peak periods, and other temporal dynamics within the Thessaloniki region. Such comprehensive temporal and spatial coverage enable robust analyses of delivery methods and routes, crucial for sustainability assessments. For instance, by evaluating the Route Aggregated Data, it was possible to identify the most efficient routes in terms of resource usage and emissions, thereby pinpointing opportunities to minimize environmental impact. The Shipping Details Data allows for an analysis of how parcel characteristics affect delivery efficiency, informing potential improvements in packaging and shipping methods. Additionally, the detailed Delivery Data offers insights into the operational aspects of each delivery, highlighting inefficiencies and areas for process optimization.

In summary, the extensive datasets provided by ACS are instrumental in conducting a thorough sustainability impact analysis. They not only furnish the necessary detail and breadth to assess the environmental footprint of logistics operations in Thessaloniki but also facilitate targeted interventions aimed at enhancing sustainability across various levels of the logistics network.

The following Table 2 provides a comprehensive overview of each delivery route, capturing essential details that are crucial for analyzing the efficiency and sustainability of logistics operations. Each route is uniquely identified by a “Batchid”, ensuring distinct tracking and analysis. The type of vehicle used, whether a van or a motorbike, is specified in the “Routing_Vehicle” field, which is vital for understanding variations in fuel consumption and emissions across different vehicle types. The “Routing_Station_Id” field indicates the starting depot of each route, allowing for an analysis of geographical distribution and depot efficiency.

Furthermore, the “Routing_Courier_id” identifies the courier responsible for the route, facilitating performance assessments and identifying potential areas for operational improvement. The “Routing_Stops_Cnt” field provides an estimate of the number of stops or unique deliveries per route, which is key to understanding the workload and efficiency. The "RouteTotalDistance" records the total distance traveled, a crucial metric for calculating fuel consumption and emissions.

The dataset also includes fields for "RouteDeliveryTotalTime" and "RouteTravelTotalTime", capturing the total time spent on deliveries and the total time the vehicle is on the road, respectively. These metrics are critical for identifying time-intensive segments and assessing overall route efficiency. The "RouteTotalTime" is the sum of these times, providing a complete picture of the route duration.

Additionally, the "RouteStartTime" and "RouteEndTime" fields record the exact start and end times of the routes, offering insights into scheduling efficiency and peak delivery periods. Overall, this dataset is invaluable for conducting a detailed analysis of delivery operations, enabling optimization of route planning, reduction of fuel consumption, and minimization of emissions, thereby improving the sustainability of logistics operations in Thessaloniki. The dataset provided with a confidentiality agreement to CERTH in order to generate the results of impact assessment.

TABLE 2 ROUTING MASTER DATA.

Field	Values	Description
Batchid	uuid string	The unique id of a single route
Routing_Vehicle	Van, Motorbike	Vehicle
Routing_Station_Id	String	Depot of the route start
Routing_Courier_id	String	Courier id (refer to person)
Routing_Stops_Cnt	Integer	Estimation of number of stops in the route (number of unique deliveries)
RouteTotalDistance	Integer	Total distance travelled in the route
RouteDeliveryTotalTime	Integer	Total time of the route spend on delivery the parcel
RouteTravelTotalTime	Integer	Total travel time (vehicle is on the road)
RouteTotalTime	Integer	Total route time (is the sum of RouteDeliveryTotalTime and RouteTravelTotalTime)
RouteStartTime	Datetime YY-MM-DD-HH-MM-SS	The datetime that the route starts
RouteEndTime	Datetime YY-MM-DD-HH-MM-SS	The datetime that the route ends (vehicle back to the depot)

Table 3 offers a detailed view of each parcel's journey, providing key information necessary for analyzing and optimizing delivery operations. Each parcel is associated with a "Station_Id", indicating the depot from which it originates, and a "Courier_id", identifying the courier responsible for its delivery. The dataset includes the "Estimated time that the route starts" and "Estimated time that the route ends", capturing the expected start and end times of the route in which the parcel is delivered. This temporal data is critical for scheduling and operational efficiency.

Each parcel is uniquely identified by a "Parcel Id", a 10-digit number ensuring distinct tracking. The dataset records the "Estimated time of Arrival (ETA)" and "Estimated time of Departure (ETD)", which are essential for planning and meeting delivery commitments. The “ArrivalTime” field logs the actual arrival time of the parcel, allowing for performance comparison against the estimated times.

Geographical coordinates of the parcel's destination are provided by the “diak_latitude” and “diak_longitude” fields, enabling precise routing and geographical analysis. The “master_id” links the parcel to the specific route, facilitating comprehensive route analysis.

The “ETA_DEVIATION” field measures the deviation in minutes from the estimated delivery time, highlighting areas where delivery times differ from expectations. This is crucial for identifying bottlenecks and improving delivery accuracy. The “Routing_order” and “Final_Routing_order” fields indicate the planned and actual delivery order of the parcel within the route, respectively, helping to evaluate and optimize delivery sequences.

Finally, the “Type” field categorizes the delivery type as either home delivery (1), home pickup (2), or locker delivery (3), providing insights into the variety of delivery methods and their operational impacts. This dataset is essential for a granular analysis of delivery operations, enabling the optimization of routes, improvement of delivery accuracy, and enhancement of overall logistical efficiency in Thessaloniki.

TABLE 3 ROUTING DETAIL DATA.

Field	Values	Description
Station_Id	String	Depot of the related parcel
Courier_id	String	Courier id (refer to person)
Estimated time that the route starts	Datetime YY-MM-DD-HH-MM-SS	The datetime that the route expected to start
Estimated time that the route ends	Datetime YY-MM-DD-HH-MM-SS	The datetime that the route expected to end
Parcel Id*	10-digit number	The unique number of each parcel. Each row contains a unique parcel
ETA	Datetime YY-MM-DD-HH-MM-SS	Estimated time of Arrival
ETD	Datetime YY-MM-DD-HH-MM-SS	Estimated time of Departure
ArrivalTime	Datetime YY-MM-DD-HH-MM-SS	Actual time of arrival
diak_latitude	Float	The Latitude of parcel destination
diak_longitude	Float	The Longitude of parcel destination
master_id	uuid	The ID of the route that this parcel belongs
ETA_DEVIATION	Int	The deviation in minutes that the delivery actually took place
Routing_order	Int	The scheduled order in the route that this parcel planned to be delivered

Field	Values	Description
Final_Routing_order	Int	The actual order in the route that this parcel actually delivered
Type	Int (1,2,3)	1: Home delivery, 2: Home pickup, 3: Locker Delivery

Table 4 provides detailed information on each parcel's final journey, capturing essential metrics that are crucial for evaluating and optimizing last-mile logistics operations. The "diak_timeparad" field records the actual time of delivery, offering precise temporal data for performance analysis. The "station_id_dest" indicates the origin depot for the last mile, which is vital for tracking the logistics flow and depot efficiency.

The "delivery_courier" field identifies the courier responsible for the final delivery, enabling assessments of courier performance and identification of potential areas for operational improvements. The weight of each parcel is captured in the "Varos" field, which is crucial for analyzing load distribution and vehicle utilization.

Geographical coordinates of the parcel's destination are provided by the "delivery_address_lat" and "delivery_address_long" fields, ensuring accurate mapping and route planning. The "Type_of_delivery" field categorizes the delivery type into home delivery (1), home pickup (2), or locker delivery (3), providing insights into the variety of delivery methods and their operational impacts.

The dimensions of each parcel are detailed in the "zyg_length", "zyg_height", and "zyg_width" fields. These measurements are important for understanding space utilization and optimizing packing strategies. Finally, the "no_pod" field contains the parcel ID, matching with the Parcel Id from the shipping details data table, ensuring consistency and traceability across datasets.

Overall, this dataset is essential for a granular analysis of last-mile delivery operations, facilitating the optimization of delivery routes, enhancement of courier performance, and improvement of logistical efficiency in Thessaloniki.

TABLE 4 SHIPMENT DETAIL DATA.

Field	Values	Description
diak_timeparad	Datetime YY-MM-DD-HH-MM-SS	Time of actual delivery
station_id_dest	String	The origin depot for last mile
delivery_courier	String	The ID of the courier
Varos	Float	The weight of the parcel
delivery_address_lat	Float	The Latitude of parcel destination
delivery_address_long	Float	The Longitude of parcel destination
Type_of_delivery	Int (1,2,3)	1: Home delivery, 2: Home pickup, 3: Locker Delivery
zyg_length	Float	The length of the parcel
zyg_height	Float	The height of the parcel
zyg_width	Float	The width of the parcel
no_pod	Int	The parcel ID (matches with **Parcel Id* from Table 3**

The processed data provides valuable insights into the operational efficiency of ACS. The histograms below illustrate key metrics derived from the raw data, highlighting the distribution of stops per route, total distance per route, and total duration per route.

1. **Histogram of Stops per Route:** This histogram shows the frequency of routes based on the total number of stops. The data reveals that most routes have between 20 and 50 stops, with a mean of 34.82 stops per route. The group of trips with less than 20 parcels refer to the motorbike trips that have less capacity. This indicates that routes are generally optimized to handle a moderate number of deliveries, balancing efficiency and workload for the couriers. Further utilization of the cargo area could be achieved by using parcel lockers or better optimized routes as it allows to serve more parcels on a single stop.
2. **Histogram of Total Distance per Route**: The histogram depicting the total distance traveled per route shows a highly skewed distribution. Most routes cover a distance of up to 20,000 meters, with a mean distance of 13,702.33 meters. The long tail in the histogram suggests that a few routes cover significantly longer distances, potentially indicating areas for further optimization in route planning to reduce travel distance and associated costs.
3. **3. Histogram of Total Duration per Route:** The histogram of the total duration per route indicates the frequency of routes based on the total time spent. The mean duration is 166.16 minutes, with most routes falling between 0 and 200 minutes. This distribution suggests that while many routes are completed efficiently within a shorter duration, there are some routes that require more time, likely due to longer travel distances or a higher number of stops.

In summary, these histograms provide a comprehensive view of the operational patterns in ACS's delivery network. By analyzing the number of stops, total distance, and duration of routes, we can identify potential inefficiencies and opportunities for optimization. For instance, routes with significantly higher distances or durations may benefit from re-routing or better scheduling to enhance overall efficiency and reduce costs.

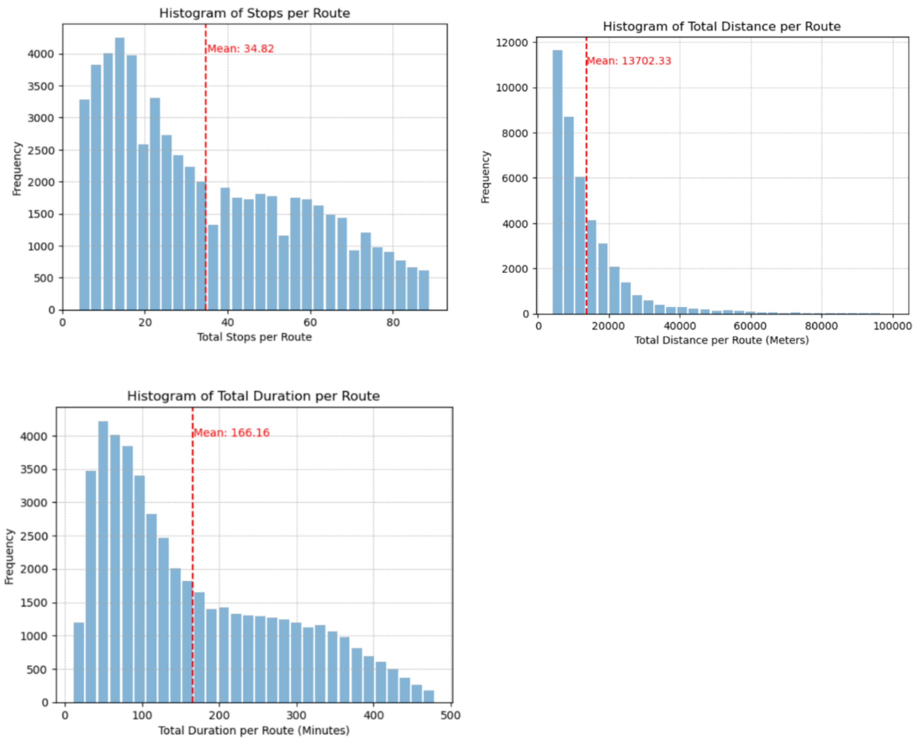


FIGURE 1: DESCRIPTIVE STATISTICS OF ACS OPERATIONAL DATA INCLUDING STOPS PER ROUTE, DISTANCE PER ROUTE, AND DURATION PER ROUTE

The first image presents a 3D plot illustrating the average daily demand for deliveries across different areas in the municipality of Thessaloniki. In this visualization, darker red regions indicate higher demand. The tallest columns, representing the highest demand, are prominently concentrated in the central and eastern parts of Thessaloniki, reflecting dense urban areas with significant commercial activity. These areas likely contain a high concentration of residential and business addresses, leading to increased delivery requests.

This spatial representation is invaluable for logistics planning, as it highlights the regions where delivery resources should be concentrated. It can also aid in the strategic placement of micro-consolidation hubs or lockers to better serve high-demand areas, ultimately improving delivery efficiency and reducing travel times.

FIGURE 2: 3D DENSITY PLOT OF AVERAGE DAILY DEMAND OF ACS DELIVERIES

The second image depicts the monthly delivery volumes in Thessaloniki from November 2022 to August 2023. This bar chart reveals distinct patterns in delivery demand, influenced by seasonal and economic factors:

- **November 2022**: The highest delivery volume is observed in November, with 226,000 deliveries. This peak can be attributed to Black Friday sales, a major shopping event that significantly boosts online orders and deliveries.
- **December 2022**: The delivery volume slightly decreases to 210,000 in December, still high due to the Christmas shopping season. This period typically sees an increase in gift purchases and festive shopping, sustaining a high demand for deliveries.
- **January 2023**: A noticeable drop in deliveries to 184,000 is seen in January, likely due to the post-holiday season slowdown, where consumer spending typically decreases after the festive period.
- **February to March 2023**: The demand starts to rise again in February (157,000) and peaks in March (198,000), possibly driven by winter sales and the end of the fiscal year for some businesses.
- **April 2023**: Deliveries decline to 177,000 in April, reflecting a typical post-sales season dip.
- **May to June 2023**: A significant increase in deliveries is observed in May (225,000) and June (224,000), correlating with summer sales, particularly in the fashion industry, as consumers prepare for the summer season.

- **July to August 2023**: The volume of deliveries decreases to 174,000 in July and further to 146,000 in August, which can be attributed to the holiday season when many residents are on vacation, leading to a reduction in online shopping and deliveries.

These patterns underscore the importance of understanding seasonal fluctuations in delivery demand. Logistics companies can leverage this information to optimize resource allocation, manage workforce scheduling, and enhance overall service efficiency by anticipating periods of high and low demand. This data-driven approach ensures that the logistics network can effectively handle peak times while maintaining operational efficiency throughout the year.

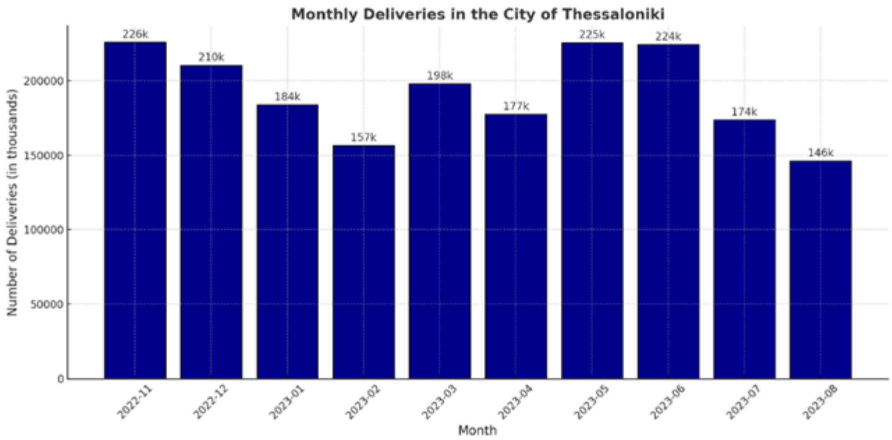


FIGURE 3: TOTAL MONTHLY DELIVERIES IN THE MUNICIPALITY OF THESSALONIKI (19.7 SQ.M., 300.000 CITIZENS)

During the period from September 2022 to August 2023, parcel locker data reveals significant insights into the number of orders completed, retention times, and daily demand served by each locker. For illustrative purposes, we present the status of this period for five selected lockers. At that time, ACS had a sparse network of parcel lockers. The data shows diverse usage patterns across different locations, with variations in daily demand and retention times.

Through the URBANE project, and based on the facility location model developed, ACS had the opportunity to expand its network quantitatively using sophisticated methods. This strategic expansion aimed to optimize locker placements in high-demand areas, enhancing delivery efficiency and reducing operational costs. The following chapters will present both the methodology employed to utilize the available data and the implementation of the proposed innovations, highlighting the importance of data-driven decision-making in improving urban logistics solutions.

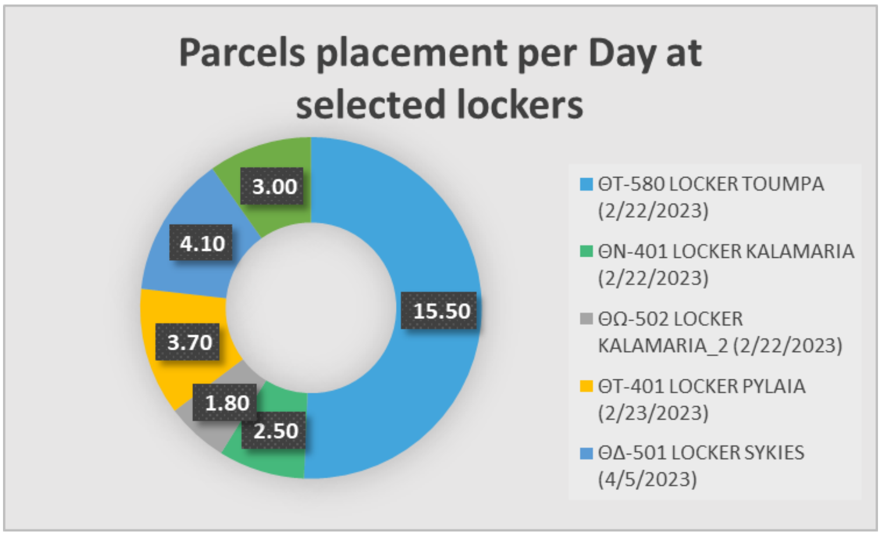


FIGURE 4: PARCEL PLACEMENT PER DAY UP TO SEPEMBER 2023 FOR SELECTED ACS LOCKERS

One of the critical factors that Thessaloniki pilot treats carefully is the retention time of the parcel in the locker by the time it placed up to the pickup time. For the selected lockers, which all share the same feature as part of dense urban areas, this metric ranges from 17 to 24 hours. The aim is to study, understand and evaluate measures that minimize this KPI to maximize utilization of parcel locker networks.

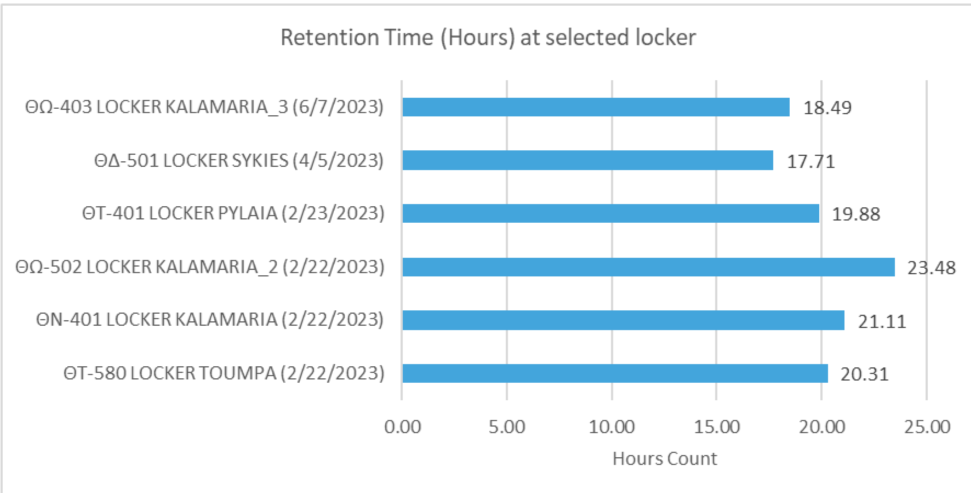


FIGURE 5: AVERAGE RETENTION TIME ON SELECTED LOCKERS OF ACS IN THESSALONIKI (HOURS)

To comprehensively assess the sustainability and efficiency of logistics operations in Thessaloniki, it is imperative to consider the existing logistics infrastructure, particularly the parcel locker networks, and the operating depots maintained by ACS and other prominent logistics companies throughout the city.

FIGURE 6: THE CURRENT ACS INFRASTRUCTURE/PARCEL LOCKERS WITHIN THESSALONIKI

Thessaloniki's logistics infrastructure, specifically concerning locker and depot networks, is characterized by a relatively dense distribution of lockers (https://www.eett.gr/online-efarmoges/efarmoges-gia-katanalotes/tachydromika-katastimata/). With a total of 525 lockers across the agglomeration (density of 26.25 lockers/km^2), including 92 operated by ACS (density of 4.6 lockers/km^2), citizens have reasonable access to these self-service points. The average proximity to any locker is estimated at 250-300 meters, facilitating convenient parcel retrieval. ACS, a major player in the sector, operates approximately 34 depots, supporting locker operations and broader logistics functions. However, while the overall locker density is satisfactory, access to ACS lockers specifically is slightly more limited, with an average distance of 550 meters for citizens. This indicates potential disparities in service coverage depending on the provider and geographic location within the city.

2.1.2 Socioeconomic GIS based Data

The second data layer essential for our analysis encompasses socioeconomic data provided by the Region of Central Macedonia (RCM) and their GIS URBANLAB, accessible via their portal (https://urbanlab.pkm.gov.gr/portal/apps/sites/#/home). This dataset includes the average household income for the year 2012. To adjust these figures to reflect the economic conditions of 2023, we employed the GDP growth rate of Greece, allowing us to project the 2012 income data to current values. This approach ensures that our socioeconomic analysis is grounded in up-to-date financial contexts, offering a realistic depiction of household income distributions across Thessaloniki.

In addition to income data, the RCM URBANLAB also provided population estimates for each region, enabling us to map demographic distributions accurately. These population estimates are crucial for understanding the density and distribution of residents, which directly impacts logistics and delivery operations within urban environments.

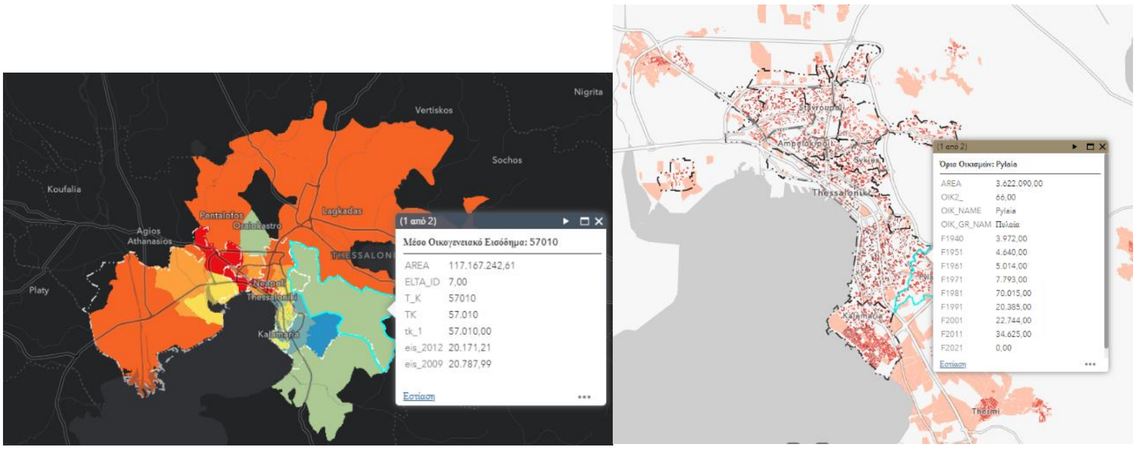


FIGURE 7: POPULATION AND INCOME GIS MAPS FROM RCM URBAN LAB DATABASES

For data points not available through any accessible GIS systems in Thessaloniki's Living Lab (LL), we relied on statistics from the Hellenic Statistical Authority. This additional data source included detailed demographics such as sex and age group distributions and household compositions for the year 2021 (https://www.statistics.gr/en/2021-census-res-pop-results). By integrating these diverse datasets, we can comprehensively analyze the socioeconomic landscape of Thessaloniki, providing a robust foundation for evaluating and optimizing logistics operations in relation to demographic and economic factors.

This comprehensive socioeconomic GIS-based dataset not only enhances the accuracy of our sustainability assessments but also supports strategic planning and decision-making processes aimed at improving urban logistics efficiency. By understanding the interplay between socioeconomic conditions and logistics operations, we can identify targeted interventions to better serve the city's diverse population while promoting sustainable growth.

TABLE 5 : HOUSEHOLD COMPOSITION ON REGION OF CENTRAL MACEDONIA

Number of households	Number of members	Size of household
735,827	**1,762,904**	**RCM**
230,934	230,934	1
211,758	423,516	2
133,757	401,271	3
112,231	448,924	4
47,147	258,259	5+

The table above presents a detailed breakdown of household sizes within a specific population, highlighting the number of households, total members, and average household size. It reveals that the majority of households, totaling 735,827, consist of just one member, accounting for a total of 1,762,904 individuals. Two-member households are also significant, with 230,934 households encompassing 230,934 members. Three-member households' number 211,758, housing a total of 423,516 members, while four-member households include 133,757 households with 401,271 members. Households with five members are fewer, totaling 112,231, but account for 448,924 individuals, indicating a higher average household size. Finally, households with six or more members are the least common, comprising 47,147 households and 258,259 members.

TABLE 6 LL SEX AND AGE GROUPS ON REGION OF CENTRAL MACEDONIA

Total	Sex		Age groups
	Males	Females	
1,795,669	867,180	928,489	
147,159	75,361	71,798	0-9
190,795	97,605	93,190	10-19
189,447	95,703	93,744	20-29
203,058	100,682	102,376	30-39

Finally, Table 6 provides a comprehensive demographic overview, segmented by total population, sex, and specific age groups. The total population amounts to 1,795,669 individuals, with a nearly balanced gender distribution: 867,180 males and 928,489 females. Breaking down by age groups, the data indicates 147,159 individuals aged 0-9 years, with 75,361 males and 71,798 females. The 10-19 years age group includes 190,795 individuals, comprising 97,605 males and 93,190 females. In the 20-29 years age group, there are 189,447 individuals, with a nearly even split of 95,703 males and 93,744 females. Lastly, the 30-39 years age group consists of 203,058 individuals, with 100,682 males and 102,376 females. This detailed breakdown is essential for understanding the population structure, aiding in targeted service provision, resource allocation, and policy development to address the specific needs of different age and gender groups within the community.

2.1.3 User choice for parcel locker and home delivery

To collect information regarding the variables that affect users' choice for parcel locker against home delivery, a survey was conducted. The survey hosted on the European Commission's EU Survey platform and consisted of various types of questions including single-choice, multiple-choice, and free-text responses to obtain detailed feedback from the users. Through the question, it assesses demographic information such as age, gender, and location, alongside usage patterns like the frequency of use, types of goods collected, and reasons for using the lockers. It gauges user satisfaction with factors such as the location, accessibility, and security of the lockers. The survey also delves into behavioral insights, examining preferences for locker locations, times of use, and any issues encountered. Additionally, it seeks feedback on future expectations and desired improvements for parcel locker services.

With a focus on understanding users' choice for parcel locker against home delivery, 8 scenarios were delineated. To streamline the design of stated preference surveys and ensure that the scenarios presented to participants effectively capture their preferences without overwhelming them with excessive combinations, a preliminary survey was conducted. This initial survey targeted a smaller sample of 10-20 individuals to identify which attributes and levels most significantly influenced their choices between home delivery and parcel locker options. By focusing on identifying the most controversial or decision-influencing factors, such as cost implications (e.g., the preference for €1 over €3 delivery charges), this approach allowed for the refinement of scenario variables. Consequently, this strategy not only facilitated a reduction in the total number of potential scenario combinations—from a cumbersome 84 to a more manageable set—but also ensured that the final scenarios included in the main survey were both relevant and impactful in assessing user preferences. This method of using a pilot survey to prune and prioritize scenario variables enhances the efficiency and effectiveness of the research design, making it more targeted and less burdensome for participants.

Each scenario described different variables for each type of delivery (home delivery and parcel locker). Specifically, two variables were selected for home delivery; the first one is the time window within the parcel expected at home (1h/3h) and the second one is cost of home delivery (1€/3€). On the other hand, three variables were selected for parcel locker delivery; one is distance from locker on foot (5mins/10mins/15mins), the second is the maximum retention time of the parcel to the locker (24h/48h) and the last is the cost for parcel locker delivery (0€/1€/3€).

In more detail, for Scenario 1, the first option for delivery is a home delivery service with a one-hour time window and a cost of €1. The alternative is to pick up the package from a smart locker located within a five-minute walking distance, available within 24 hours from the moment it is ready for pickup, also for a cost of €1. In Scenario 2, the first option is again a home delivery with a one-hour time window, priced at €1. The second option is to retrieve the package from a smart locker situated a 15-minute walk away, available within 24 hours from the moment it becomes ready for collection, with a cost of €3. Scenario 3 offers a home delivery option with a three-hour time window and a cost of €1. Alternatively, the package can be picked up from a smart locker located 15 minutes away on foot, available within 48 hours from the time it is ready for pickup, for a cost of €3. In Scenario 4, the home delivery service is available with a three-hour time window at a cost of €3. The other option is to collect the package from a smart locker, located 15 minutes away by foot, available within 24 hours from the moment it is ready for pickup, and this service is free of charge. Scenario 5 presents a home delivery option with a one-hour time window for a fee of €3. Alternatively, the package can be picked up from a smart locker 15 minutes away on foot, available within 48 hours from the moment it is ready, at no cost. For Scenario 6, there is a home delivery service with a three-hour time window costing €3. The second option is to collect the package from a smart locker located five minutes away on foot, available within 48 hours from the time it is ready, at no cost. In Scenario 7, the home delivery option comes with a three-hour time window and a cost of €1. Alternatively, the package can be retrieved from a smart locker located a 10-minute walk away, available within 24 hours from the moment it is ready for pickup, for a cost of €1. Lastly, Scenario 8 offers a home delivery service with a three-hour time window at a cost of €1. The other option is to pick up the package from a smart locker situated five minutes away on foot, available within 48 hours from the time it is ready for pickup, at a cost of €1.

In total, 202 responses from participants within the Region of Central Macedonia (RCM) and the Municipality of Thessaloniki (MoT) were collected through the EU survey.

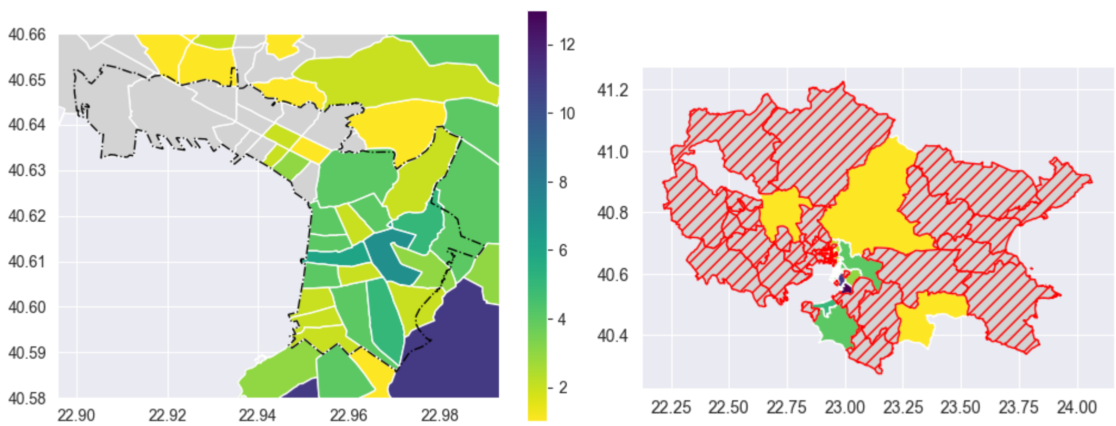


FIGURE 8: THE SURVEY RESULTS SPATIAL DISTRIBUTION ACROSS THE MUNICIPALITY AND THE REGION OF THESSALONIKI

A preliminary analysis revealed that the locker delivery was the most preferred method in the most cases while the cost was considered to play a key role to this selection.

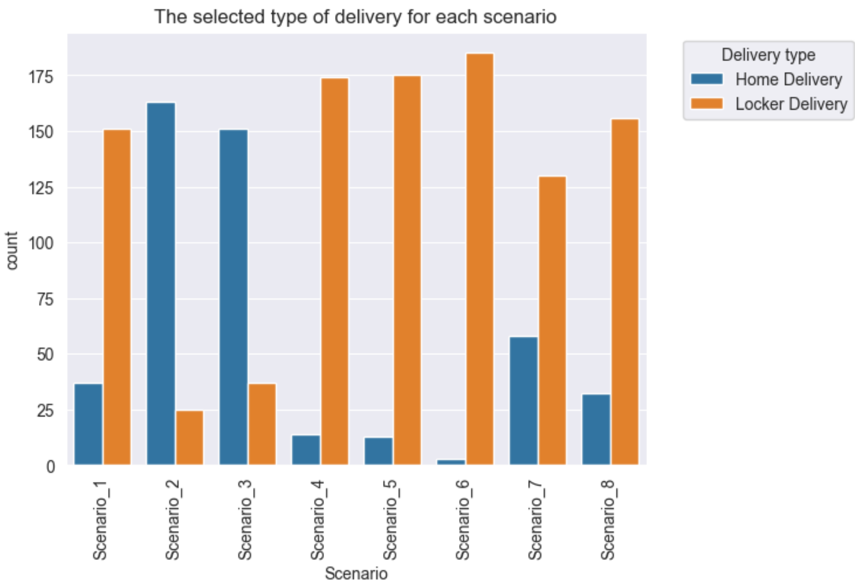


FIGURE 9: THE PREFERENCE OF HOME AND PARCEL LOCKER DELIVERY FOR EACH SCENARIO

Firstly, cost emerges as a predominant factor influencing delivery method selection. In scenarios where locker delivery was offered free of charge, respondents overwhelmingly preferred this option despite potential inconveniences such as longer walking distances or extended availability windows. This trend was particularly evident in Scenarios 4, 5, and 6, where free locker delivery options consistently attracted the majority of respondents. This suggests a high price sensitivity among consumers, indicating that reducing or eliminating delivery costs can significantly sway preferences toward locker delivery solutions. Secondly, the convenience of home delivery, particularly in terms of shorter time windows, appears to be a critical factor for consumers. In scenarios where home delivery was available with a one-hour time window, there was a notable preference for this option, even when the locker delivery alternative was priced competitively. Scenarios 1 and 2 exemplify this trend, where respondents chose home delivery despite the locker option being either cost-equivalent or slightly higher in cost. This indicates that for many consumers, the immediacy and convenience of a shorter delivery window outweigh the benefits of lower costs associated with locker delivery. Moreover, the data suggests that walking distance to locker locations significantly impacts consumer choice. When the walking distance was minimal (e.g., five minutes in Scenario 1), the locker delivery option saw considerable preference. However, as the walking distance increased (e.g., 15 minutes in Scenarios 2, 3, and 5), the attractiveness of locker delivery decreased, even when cost advantages were present. This highlights the importance of strategically locating locker delivery points within a short walking distance to enhance their appeal to consumers. Another notable insight is the balancing act between cost and convenience. In scenarios where both cost and convenience were reasonably balanced, such as Scenario 7, there was a more varied distribution of preferences, indicating that when consumers do not perceive a significant disadvantage in either option, their choices become more evenly split. This underscores the necessity for delivery service providers to carefully consider the interplay between cost, time window, and convenience in their service offerings. Finally, the analysis also reveals an underlying preference for home delivery when costs are not prohibitive, and time windows are reasonably short. This suggests that while locker delivery can be attractive due to cost benefits, the inherent convenience of home delivery—where consumers do not need to leave their homes—remains a strong influencing factor. For delivery services aiming to increase locker usage, it would be beneficial to further reduce costs or enhance convenience, such as by decreasing walking distances or offering additional incentives.

To understand how the distance from the closest locker and the maximum retention time of a parcel in the locker affect the choice of a user for parcel locker delivery, we used a logistic regression model. This model is suitable for binary outcome variables, such as the decision to use parcel locker delivery or not. Logistic regression models the probability of a user choosing parcel locker delivery based on the independent variables, which in this case are the distance to the nearest locker and the maximum retention time of the parcel in the locker. The main results of the logistic regression fit include the estimated coefficients for the predictor variables. A positive coefficient for the distance variable would suggest that as the distance to the nearest locker increases, the likelihood of choosing parcel locker delivery also increases. Conversely, a negative coefficient would indicate that users are less likely to choose parcel locker delivery as the distance increases. For the maximum retention time, a positive coefficient would mean that longer retention times make users more likely to opt for parcel locker delivery, while a negative coefficient would imply the opposite. To evaluate the model's performance, we look at metrics such as the Akaike Information Criterion (AIC) and the area under the Receiver Operating Characteristic (ROC) curve (AUC). A lower AIC value indicates a better fit, and a higher AUC value indicates better discriminative ability of the model. Additionally, p-values for the coefficients help determine the statistical significance of the predictors. If the p-values are low (typically less than 0.05), it means that the corresponding predictor variable significantly affects the choice of parcel locker delivery.

The model used to understand how the distance from the closest locker and the maximum retention time of a parcel in the locker affect the choice of a user for parcel locker delivery is likely a logistic regression model. This type of model is appropriate for binary outcome variables, such as whether or not a user chooses parcel locker delivery.

```
Optimization terminated successfully.
         Current function value: 0.562822
         Iterations 6
                           Logit Regression Results
==============================================================================
Dep. Variable:          Delivery Type   No. Observations:                 1504
Model:                          Logit   Df Residuals:                     1501
Method:                           MLE   Df Model:                            2
Date:                Wed, 31 Jul 2024   Pseudo R-squ.:                 0.09457
Time:                        15:26:27   Log-Likelihood:                -846.48
converged:                       True   LL-Null:                       -934.90
Covariance Type:            nonrobust   LLR p-value:                 3.992e-39
=================================================================================
                    coef    std err          z      P>|z|      [0.025      0.975]
---------------------------------------------------------------------------------
const             2.1944      0.253      8.670      0.000       1.698       2.691
dist_locker      -0.1678      0.014    -11.766      0.000      -0.196      -0.140
window_locker     0.0140      0.005      2.841      0.004       0.004       0.024
=================================================================================
```

FIGURE 10: THE LOGISTIC REGRESSION RESULTS

The logistic regression model was employed to understand how the distance from the closest locker and the maximum retention time of a parcel in the locker affect a user's choice of parcel locker delivery. This model predicts the probability of a user opting for parcel locker delivery based on these two variables.

The results indicate the following:

- **Intercept (Constant):** The baseline log-odds of choosing parcel locker delivery is 2.1944, which is statistically significant ($p < 0.001$).
- **Distance to Locker (dist_locker):** The coefficient is -0.1678 ($p < 0.001$), indicating that for each unit increase in distance, the log-odds of choosing parcel locker delivery decrease by 0.1678. This suggests that users are less likely to choose parcel locker delivery as the distance to the locker increases.
- **Maximum Retention Time (window_locker):** The coefficient is 0.0140 ($p = 0.004$), indicating that for each unit increase in retention time, the log-odds of choosing parcel locker delivery increase by 0.0140. This suggests that users are more likely to choose parcel locker delivery with longer retention times.

The model explains about 9.46% of the variability in the choice of parcel locker delivery (Pseudo R-squared = 0.09457), and all the predictors are statistically significant, highlighting their meaningful impact on the user's delivery choice.

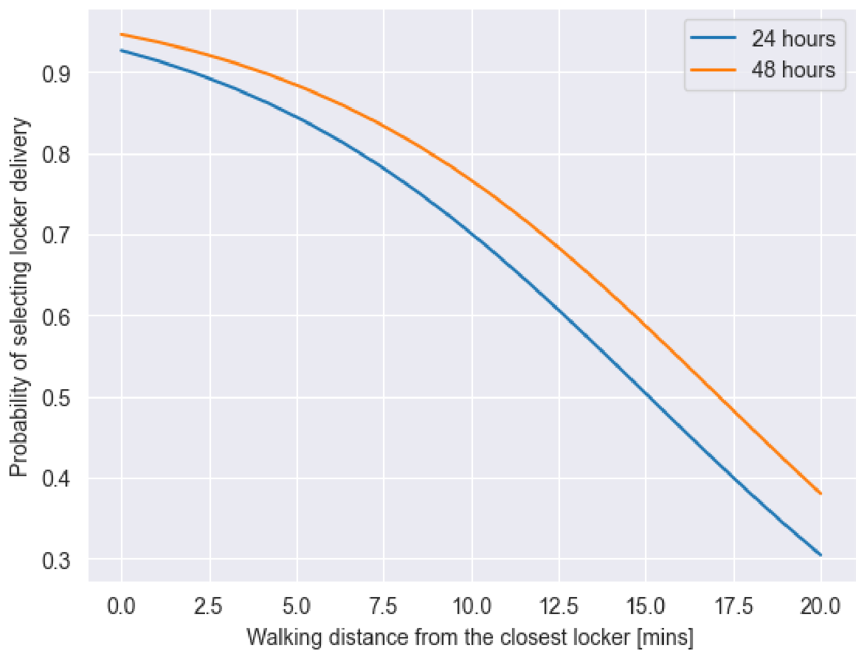


FIGURE 11: THE SIGMOID CURVE REGARDING THE RETENTION TIME OF PARCEL TO THE LOCKER AND THE WALKING DISTANCE FROM THE CLOSEST LOCKER

The plot illustrates the relationship between the walking distance from the closest locker and the probability of selecting locker delivery, considering two different scenarios for the maximum retention time of the parcel in the locker: 24 hours and 48 hours. The x-axis represents the walking distance in minutes, ranging from 0 to 20 minutes, while the y-axis shows the predicted probability of choosing locker delivery, ranging from 0.3 to 1.0. The blue curve, which corresponds to a 24-hour retention time, indicates that as walking distance increases, the probability of selecting locker delivery decreases, starting at approximately 0.92 at 0 minutes and declining to around 0.35 at 20 minutes. The orange curve, representing a 48-hour retention time, follows a similar trend but remains higher across all distances, starting slightly above 0.95 at 0 minutes and dropping to about 0.42 at 20 minutes. This demonstrates an inverse relationship between walking distance and the likelihood of choosing locker delivery, with longer retention times mitigating the effect of increased distance. For instance, at a 10-minute walking distance, the probability is about 0.65 for a 24-hour retention time and approximately 0.75 for a 48-hour retention time. These findings highlight that both proximity to lockers and extended retention times significantly influence user decisions, suggesting that logistics companies can enhance locker delivery adoption by optimizing locker locations and extending retention periods.

3. Living Lab setup

3.1 Context – Local plans – Key initiatives

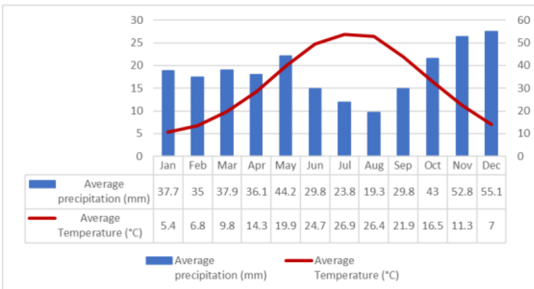
3.1.1 The city of Thessaloniki

3.1.1.1 Location and characteristics

Thessaloniki agglomeration, located in the northern part of Greece, is the second largest city in the country, with a population of 1.106.730 in its greater area. The city centre, also known as the municipality of Thessaloniki, covers an area of 19.3 km2 and has a population of 325.182. The minimum elevation of the city is the sea level (0 m), and the highest is 250 m and the average one is 126 m.

3.1.1.2 Climate and weather conditions

When it comes to the climate, the dominant climate of the area is “Mediterranean”, which is characterized by mild wet winters and warm to hot, dry summers. As it can be seen in the following figure, in average, the mean monthly temperature is between 5.4 and 26.9 oC while the maximum precipitation is met during December and doesn’t exceed 55 mm. The heating degree days (HDD) were found to be from 10 to 20 oC and the cooling degree days (CDD) were found from 20 to 27.5 °C (Papakostas, K., & Kyriakis, N. 2005).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average precipitation (mm)	37.7	35	37.9	36.1	44.2	29.8	23.8	19.3	29.8	43	52.8	55.1
Average Temperature (°C)	5.4	6.8	9.8	14.3	19.9	24.7	26.9	26.4	21.9	16.5	11.3	7

FIGURE 12: REGION OF CENTRAL MACEDONIA AND CLIMATE PROFILE

3.1.1.3 The land uses and the ecommerce

The city centre is highly populated, with limited public spaces and a concentration of different land uses such as residential, educational, commercial, business/services, and leisure activities. The urban fabric of the city centre, which reflects its historical continuity, is not designed to efficiently support these land uses and could lead to a significant environmental burden. This is particularly relevant to the intense commercial activity that generates significant passenger and urban freight flows, as well as the growth of e-commerce and last-mile deliveries.

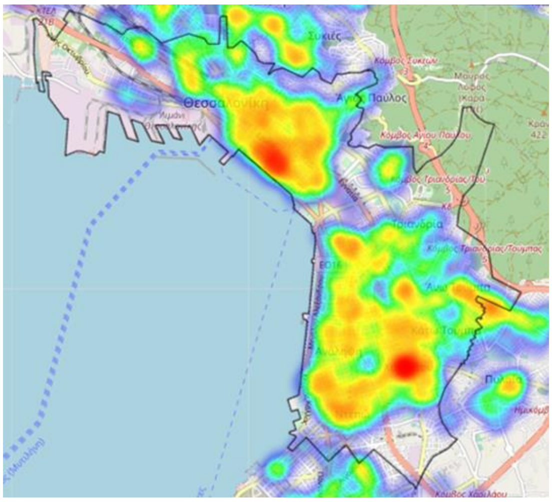


FIGURE 13: URBAN ACTIVITY DENSITY WITHIN THE REGION OF THESSALONIKI

3.1.1.4 100 EU Mission climate-neutral and smart cities

It is worth mentioning that Thessaloniki is one of the 100 EU Mission climate-neutral and smart cities by 2030. It is crossed by two TEN-T Corridors (Baltic/Black/Aegean Seas and Western Balkans). Thessaloniki's challenge is to become a zero-emission city by 2030, achieve optimized use of public space and overall enhanced citizens quality of life. Currently, in the historical centre, the main demand generators for last-mile transport are the commercial establishments and, more specifically, from fashion and HORECA. In a sample of 1499 commercial establishments, 23% are hotel/cafes/restaurants, 4% electronics and 44% fashion industry. The refilling of those establishments is implemented by multiple suppliers leading to higher demand for last-mile deliveries, mainly LGVs (52.5%) and vans (40.10%) and only 7.4% is executed with green transport modes (i.e., bikes). Many of the shops receive stock approximately 4 times per week, while the medium distance from the suppliers to the retailers is 15 kms.

3.1.2 The current situation of logistics

The trend of e-commerce has grown significantly during the past ten years. In Greece, the population that shops online increased from ~27% (2012) to more than 40% at 2018 when 10% of the companies made B2C e-commerce sales online2. This has been driven by the increased use of mobile and internet technologies, which have made it simpler for customers to shop online whenever they want, from anywhere. Almost the 90% of the consumers, use the internet to search for information and products.3 Global demand for e-commerce has increased as a result of the convenience of online shopping, a broader selection of goods, affordable prices, and faster delivery times. The COVID-19 epidemic, which has caused many consumers to switch to internet shopping due to lockdowns, social distancing measures, and health concerns, has further expedited this trend; specifically, during the first three months in 2021, the online shopping was increased by 22% in relation to the same period for the previous year4. As a result, conventional retailers have increased their online presence, and new competitors have entered the market, making e-commerce a significant influence in the retail sector.

According to IEA, 37% of CO_2 emissions from end-use sectors in 2021 were attributable to transportation. In addition to that, pandemic caused an approximate increment of 8% in CO_2 emissions in 2015, and led the EU to adopt strategies for cities to minimize their CO_2 emissions and achieve climate neutrality which steered logistics operators to focus on sustainable delivery methods. For that reason, logistics companies are turning to more eco-friendly and effective ways of carrying goods in cities, such as cargo bikes, electric cars etc. and adopting technology such as route optimization software and delivery tracking systems to ensure the most effective delivery of goods and minimize their CO2 footprint. In general, logistic operators tend to choose innovative business models such as Hub & Spoke.

Recently, Thessaloniki was selected to participate in the European mission for the 100 Climate Neutral and Smart Cities by 2030 and the RCM encouraged logistics operators to implement innovative mobility solutions.

3.1.2.1 BPMN Diagram of the AS-IS situation

The first BPMN diagram (Figure 14) illustrates the process from customer order to final home delivery (also available at [Link] – Sheet: As-is). The process begins with the customer selecting a product on the retailer's platform and providing detailed delivery information, including the address and preferred delivery time. Once the order is placed, the retailer prepares the parcel by packaging the product securely and generating a shipping label. The retailer then notifies the logistics operator to arrange for pickup.

The logistics operator picks up the parcel from the retailer and transports it to a central sorting centre. Here, the parcel is sorted based on the delivery routes to ensure efficient dispatching. In the last-mile delivery phase, the sorted parcel is assigned to a courier who plans the most efficient delivery route considering factors such as traffic, distance, and delivery priority. The courier then proceeds to deliver the parcel to the customer’s home. Upon successful delivery, the customer confirms receipt, completing the process. This streamlined sequence of activities ensures timely and accurate home deliveries, enhancing customer satisfaction and operational efficiency.

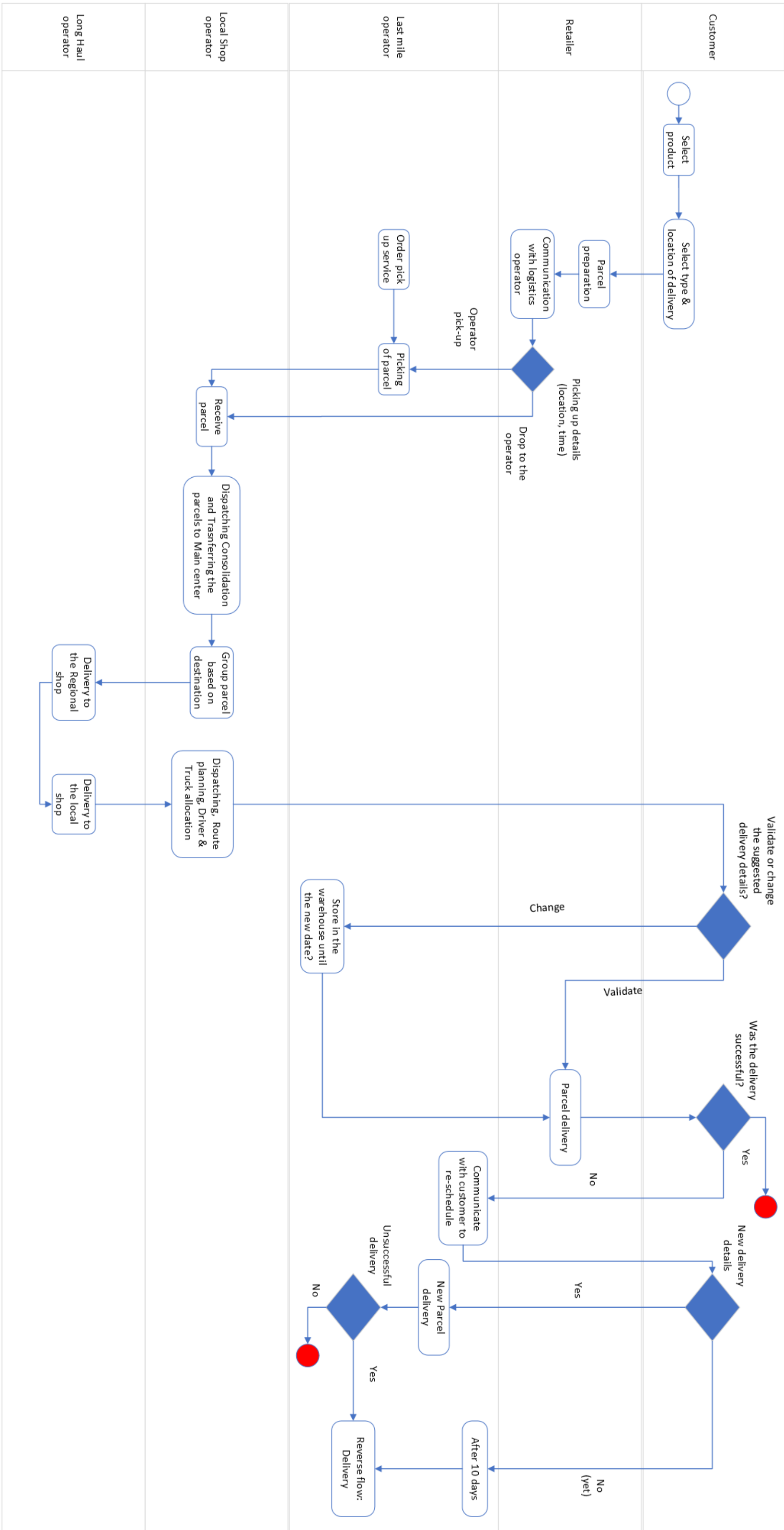


FIGURE 14: THE AS-IS SITUATION OF THESSALONIKI LL SOLUTION [LINK]

3.1.3 Governance and Business models

Thessaloniki is a city with many universities and institutes which is also an important economic and commercial center, with a busy port and a thriving business community.

In terms of city logistics business models, the retailers nowadays are usually following omnichannel logistics techniques for providing the customer multiple delivery options and thus a more cohesive shopping experience. The retailers, and especially those from large chain stores, usually offer to the customer the option to either pick up or return the product from multiple points (parcels, in-store, at home, at work e.t.c.). The role of the logistics operators is to deliver the product to the right location, unharmed and as fast as possible.

In order to meet customer expectations, the new concept of on-demand last mile deliveries is generally characterized by smaller, more frequent orders to customers scattered in a region with complicated lead times of the very next day or even the following hour. Taking into consideration the relatively high risk of a low drop rate on the first attempt to deliver and the need to reassign, results to a significant increment in freight traffic with more light commercial vehicles operating on streets, leading to more negative environmental consequences of logistics processes to the broader society.

Some indicative business models and practices followed by the industry operating in Thessaloniki are the following:

- **Next Hour/Next Day Deliveries**, which is a business model for logistics operators that usually follow flexible employment techniques for the drivers that are operating the last mile. This Business model is usually seen in the freight products chain (food and grocery deliveries)

- **Click and Collect Business Models** as a hybrid e-commerce model in which people order a product online and they pick it up in the store. This business model is usually seen in large chain stores in the clothing sector (i.e. ZARA, Marks & Spencer, Mango etc.), in the furniture industry (i.e. IKEA, JYSK e.t.c.)

- **Green Deliveries** implemented either by cargo bikes or electric vehicles. These means are usually used for short-distance deliveries implemented inside the historical city centre.

- **Micro consolidation schemes** led by the industry. The lockers are usually operated by only one transport operator and are established in a shared private space with other companies (i.e. oil stations, supermarkets e.t.c.).

- **Collaborative schemes & PP partnerships** for sharing infrastructure and services (i.e. on demand collaborative warehousing, cargo consolidation)

- **Reverse Logistics** which aims to optimize the flow of products, materials, and information in the reverse direction, from the point of consumption to the point of origin (i.e., Zara's business model, OMNI channel logistics).

3.1.4 Supporting market-based measures

In order to avoid traffic problems, air pollution and noise, city has applied many policy measures:

- **Time windows** for loading and unloading restrictions (At the most pedestrian areas of the historical centre, loading unloading is permitted from 06:30 to 08:30 (morning) for trucks up to 8 tns at the historical centre, trucks up to 1,5 tns are permitted regardless the time or day),
- **Night operations** for loading and unloading (Trucks up to 8tns: weekdays from 20:30 to 08:30 next day and weekends from 17:00 (Sat) to 08:30 (Monday)),
- **Parking regulations** for loading and unloading restrictions (1.5 tn trucks are allowed to park only at special spaces)
- **Size or Weight restrictions** for trucks entering the city.

The next Urban mobility policy measures that are planned to be applied at Thessaloniki as proposed by the SUMP:

- **Zero emission zones** (allowing only electric cars and emergency vehicles to use the specific road)
- **Low emission zone** to the historical city centre (electric light commercial vehicles (LCVs) only during specific time window)
- **Urban Delivery management system**
- **Low traffic zones.**

3.2 Vision and challenge to be addressed in URBANE

3.2.1 LL Objectives

The implementation of a holistic Sustainable Urban Logistics Plan (SULP) and Sustainable Urban Mobility Plan (SUMP) for the Region and Municipality of Thessaloniki is essential to address future challenges. ACS, as the primary logistics operator of Greece, focuses on decarbonizing and enhancing the efficiency of its delivery process. Understanding the benefits of a large-scale installation of parcel lockers and future collaborative business models is crucial. Currently, the myopic network design of each company's lockers results in multiple nearby lockers with low utilization, sparse networks often reached by car due to significant walking distances, restricted access based on private space working schedules, public space occupation, and a mushrooming effect. Furthermore, the low number of parcels per locker visit from Logistics Service Providers (LSPs) does not significantly reduce the kilometers driven.

FIGURE 15: AN INDICATIVE LOCKER OF ACS

A nationwide courier service, ACS has large and mid-sized consolidation centres as well as a diverse fleet of long-haul trucks, mid-range city trucks, light vans, and motorcycles. Orders are distributed across consolidation centres by the service network's fixed service paths. The last mile leg consists primarily of home (or any other destination point) delivery as well as order pickup operations. Annually, ACS handles 12 million parcel deliveries, reflecting its extensive operational scope and market penetration. The fleet covers a substantial 4 million kilometers per year, emphasizing the scale of logistical operations required to meet customer demand. In line with these extensive operations, ACS reports a total CO2 consumption of 8.2 thousand tones per year, highlighting the environmental impact and the necessity for sustainable practices. Moreover, the success rate of deliveries on the first attempt stands at 82%, indicating a relatively high efficiency in meeting delivery targets but also suggesting room for improvement in reducing failed delivery attempts and associated costs.

In this context, ACS as the primary logistics operator of Greece (about 35% of the urban deliveries) aims to implement a Hub & Spoke delivery business model integrated with last mile delivery as a service enabling tools. Specifically, micro-fulfilment centres installed at the historical centre and surrounding areas and tested in real operational environment to achieve higher load factors and lower vehicles, enhancing the effectiveness of the operational planning process and the customer experience. During the URBANE, Thessaloniki had the chance to study, develop, and test the operational impact of the installation of parcel lockers to supplement the current network. For RCM (Region of Central Macedonia, Greece) the objectives were multi-fold, satisfying the need to test innovative last mile delivery services and intelligent tools for planning & monitoring. The creation of an ecosystem enabling scalability and transferability of the measure supported RCM in the transition towards climate neutral last mile logistics and finalize the Regional SULP.

3.2.2 Specific vision & ambition and the LL Problem/Challenge to be addressed by URBANE

The digital service last mile delivery platform will support a) predictive analytics for demand forecasting and site selection for the locker's establishment, enabling this new business model. b) Making decisions about where to locate facilities (combining sustainable business and city planning for last-mile delivery); c) Traffic-aware dynamic routing; d) Simulating new services and vehicles (zero emission and modular) in last-mile operations and teaming up for solutions during disruptive events (International Fair, Pandemic, extreme weather events). The outputs and knowledge of the project about Thessaloniki Logistics Living Lab should be answer the following research initiatives:

- Why should Thessaloniki's related stakeholders adopt the Hub & Spoke Lockers solution?
- Which are the strategic benefits?
- How to design a network that serves both the courier companies, citizens, and sustainability goals of the city?
- Where should the companies locate the Lockers?
- What is the future (and induced) demand after the first round of lockers installation?
- How should the city and the companies be prepared for a locker alliance network with shared boxes?
- What will be the impact on the impact on: Emissions, costs and public space allocation?
- Tarif/cost & business model selection for lockers in public spaces (new)
- Schedules of ACS routes at tactical planning level according to Traffic Aware dynamic Routing based on Thessaloniki TMC data
- Simulation infra for supporting new fleets and services planning
- Demand data from ACS & descriptive analytics (HIT tools or ACS)
- Demand segmentation for being served by new fleet or new service (HIT descriptive analytics tool enriched with business rules)
- Optimum Sizing of green fleet & planning (OR HIT tools)
- Holistic Impact Analysis including business and public policy perspective under cost aware optimization lens

3.2.3 BPMN diagram of the TO-BE Situation

The second BPMN diagram (Figure 16) introduces an additional decision point where the customer can choose between home delivery and parcel locker delivery (also available at [Link] – Sheet: To-be). After selecting a product on the retailer's platform, the customer decides whether they prefer the parcel to be delivered directly to their home or to a nearby parcel locker. The customer then provides the necessary delivery details, including the address for home delivery or the selected parcel locker location.

Once the order is placed, the retailer prepares the parcel, generates a shipping label, and notifies the logistics operator for pickup. The logistics operator collects the parcel and transports it to the sorting center, where it is sorted based on the chosen delivery method. If the customer has opted for home delivery, the parcel follows the same process as in the first BPMN diagram: it is assigned to a courier, who plans the delivery route and delivers the parcel to the customer's home, with confirmation of receipt upon delivery.

If the customer chooses parcel locker delivery, the parcel is routed to the specified locker location. The logistics operator transports the parcel to the locker, where it is securely placed. The customer is then notified with details on how to retrieve the parcel, including a pickup code and locker location. The customer retrieves the parcel from the locker at their convenience, and the pickup is confirmed. This flexible delivery option caters to varying customer preferences, providing convenience and enhancing the efficiency of the delivery network by utilizing parcel lockers strategically placed in accessible locations.

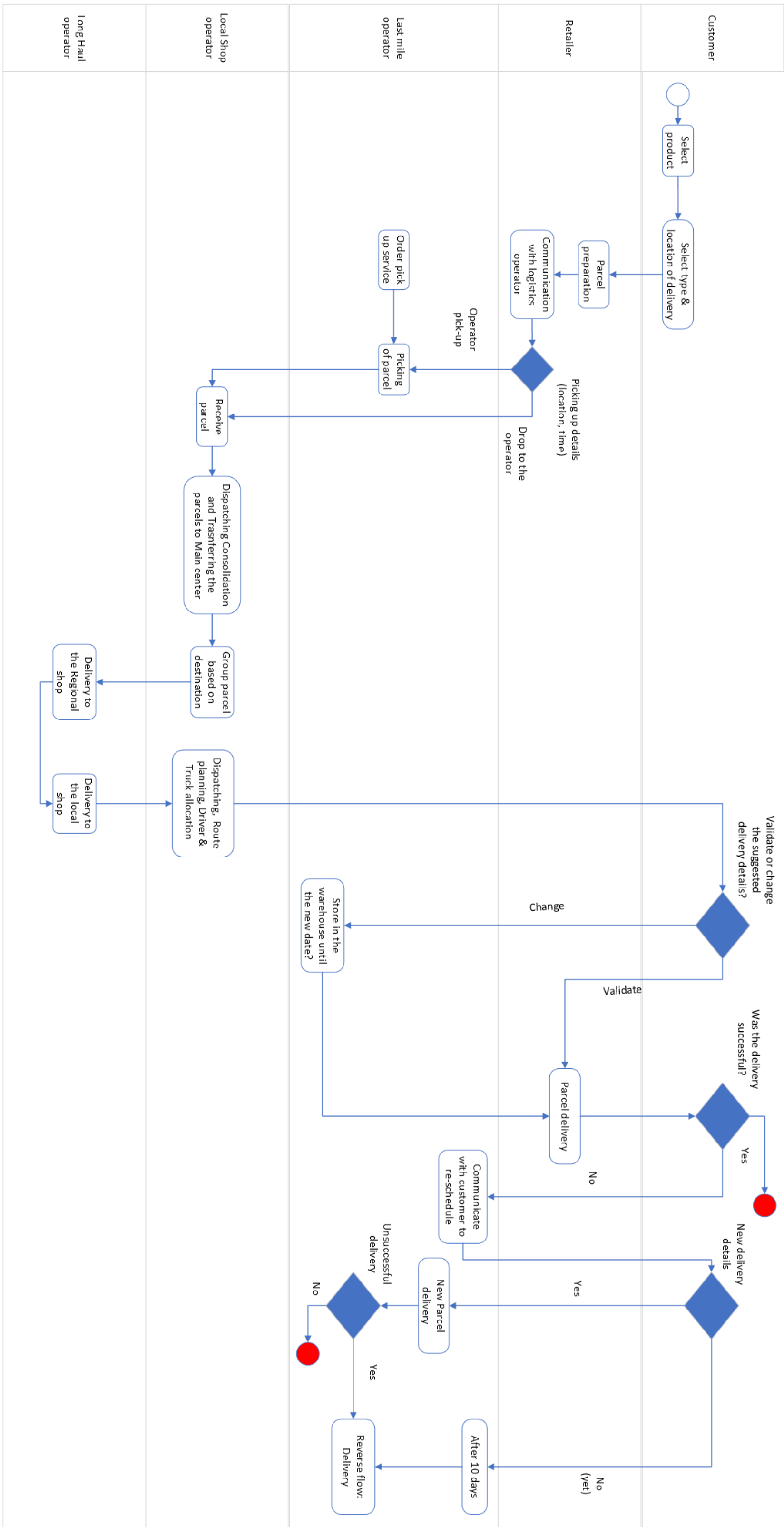


FIGURE 16: THE TO-BE SITUATION OF THESSALONIKI LL SOLUTION [LINK]

4. URBANE Use cases in Thessaloniki Living Lab

4.1 Use case 1: Installation of Micro-Hubs to Public spaces

To conduct the innovation tests during the URBANE project within the Thessaloniki Living Lab, a stepwise approach was meticulously followed. Initially, a comprehensive understanding and documentation of the baseline processes employed by last-mile delivery companies were achieved. The first intervention proposed the development of a private locker network designed to enhance the operational efficiency of the industrial partner, ACS.

Subsequently, utilizing the agent-based model HUMAT-MASSGT, the induced demand was extracted. Based on these findings, the implementation of a locker alliance network was proposed. In preparation for integrating ACS into this locker alliance network, aligned with the principles of the Physical Internet, blockchain technology was demonstrated and implemented within ACS's locker network.

Building on these insights, Use Case-2 explores the scenario where this alliance network is accessible to all service providers and is served and fulfilled using a central Urban Consolidation Centre (UCC). This structured approach ensures that ACS is well-prepared to participate in a collaborative locker network, leveraging innovative technologies to optimize last-mile delivery operations.

4.1.1 Interventions done in the scope of URBANE

The primary objectives of this use case include supporting companies in designing their parcel locker alliance networks to optimize green last-mile operations. It aims to provide arguments for city authorities to guide LSPs towards collaborative business models with shared infrastructure. Additionally, the use case seeks to assist city authorities in designing SULPs by considering new urban space allocation policies and facilitating the fusion of different data sources for feasibility checking. To achieve these objectives, several datasets are utilized. These include the distribution of parcel locker demand in Thessaloniki provided by ACS, socio-economic spatial data from RCM, and existing infrastructure data from ACS and open-source platforms. Candidate and selected locations for new parcel lockers are also considered in the analysis.

The use case is closely related to the Physical Internet concept. By implementing a unified locker alliance network in Thessaloniki using advanced facility location and network optimization models, the project supports the application of Physical Internet principles to address real-world urban logistics challenges. This approach aims to improve efficiency and reduce environmental impact, setting a potential benchmark for other cities facing similar challenges. In developing the locker and micro-hub network, decision support tools are essential for both the city and the LSPs. These tools include models for optimizing the overall last-mile delivery network performance, reducing total travel distance and service time for delivery, and creating a resilient distribution network that can handle significant demand variations. Strategic positioning of lockers in public spaces is also considered, along with consumer behavioral surveys to define decision parameters that maximize locker usage and minimize storage time for each order. The Regional SULP is integrated into this development process in order to enhance the proposed measures with data driven quantitative results.

The development process follows several stages. The baseline scenario involves analyzing demand, existing lockers, ACS points, and key performance indicators (KPIs). The facility location stage evaluates demand and expansion scenarios, planning for new locker placements. Agent-based adjustments use agent-based results to recalculate and resize the locker network as necessary. Finally, the shared locker network stage involves implementing a blockchain-supported shared network of lockers, sized according to the needs of all LSPs in the city.

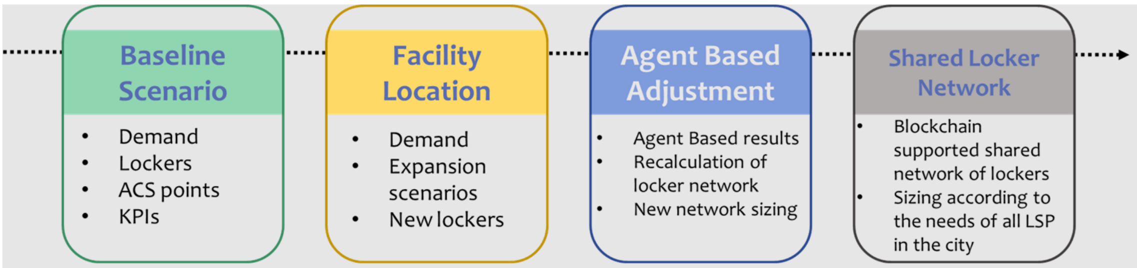


FIGURE 17: THE STEP-WISE PATH OF SELECTING LOCKERS ON THE USE CASE 1

Through this pilot, the Thessaloniki Living Lab (LL) aims to investigate and evaluate several critical and emerging topics in last-mile delivery. Initially, a comprehensive analysis of the ACS dataset, alongside external data sources, was conducted to identify demand patterns and assess the need for greener solutions in ACS operations at both the regional and local levels. This analysis is crucial for understanding how to enhance the sustainability of last-mile logistics.

Furthermore, the pilot examines the Locker Alliance Network to evaluate the impacts of a shared locker network from both business and social perspectives. This evaluation aims to determine the feasibility and benefits of collaborative infrastructure in reducing environmental footprints and improving operational efficiency.

Additionally, the implementation of blockchain technology is being tested on a representative locker and within the shared locker network concept. This aspect of the pilot seeks to explore the potential of blockchain to enhance transparency, security, and efficiency in parcel locker operations. By integrating advanced technologies and innovative approaches, the Thessaloniki LL pilot aspires to set new benchmarks for sustainable and efficient urban logistics solutions.

4.1.2 BPMN diagram of the TO-BE situation for use case 1

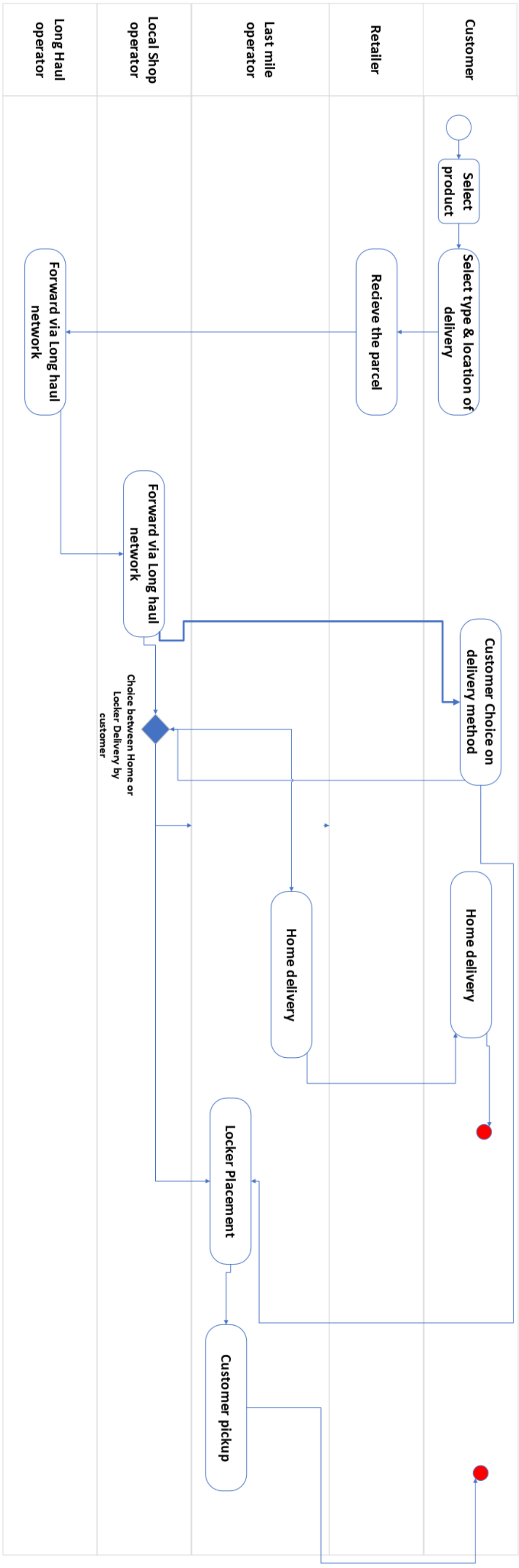


FIGURE 18: THE TO-BE SITUATION ON THE USE CASE 1 WORKFLOW [LINK]

4.2 Use case 2: Simulation of PI green last-mile solutions

4.2.1 Interventions done in the scope of URBANE

The second use case explores a scenario where all last-mile delivery players utilize a shared locker alliance network in conjunction with an UCC strategically located within the urban landscape. The primary objective is to further enhance delivery efficiency by minimizing the distance traveled and reducing vehicle operational costs.

In this use case, the UCC serves as a central node, allowing multiple LSPs to consolidate their deliveries. By coordinating through the UCC, delivery routes are optimized via a shared fleet of eLCVs, leading to a significant decrease in the total kilometers driven. This collaborative approach not only lowers fuel consumption and emissions but also reduces traffic congestion in urban areas.

Moreover, the pilot includes the demonstration of a traffic-aware dynamic routing algorithm. This advanced algorithm adjusts delivery routes in real-time based on current traffic conditions, ensuring that deliveries are made in the most efficient and timely manner possible. By integrating dynamic routing with the UCC, the pilot aims to set new standards for sustainable urban logistics, highlighting the potential for significant operational improvements and environmental benefits.

Overall, this use case aims to provide empirical evidence on the effectiveness of combined strategies—utilizing shared infrastructure and dynamic routing algorithms—to achieve greater efficiency and sustainability in last-mile delivery operations. Through this pilot, the Thessaloniki Living Lab continues to pioneer innovative solutions for urban logistics challenges.

4.2.2 BPMN diagram of the TO-BE situation for use case 2

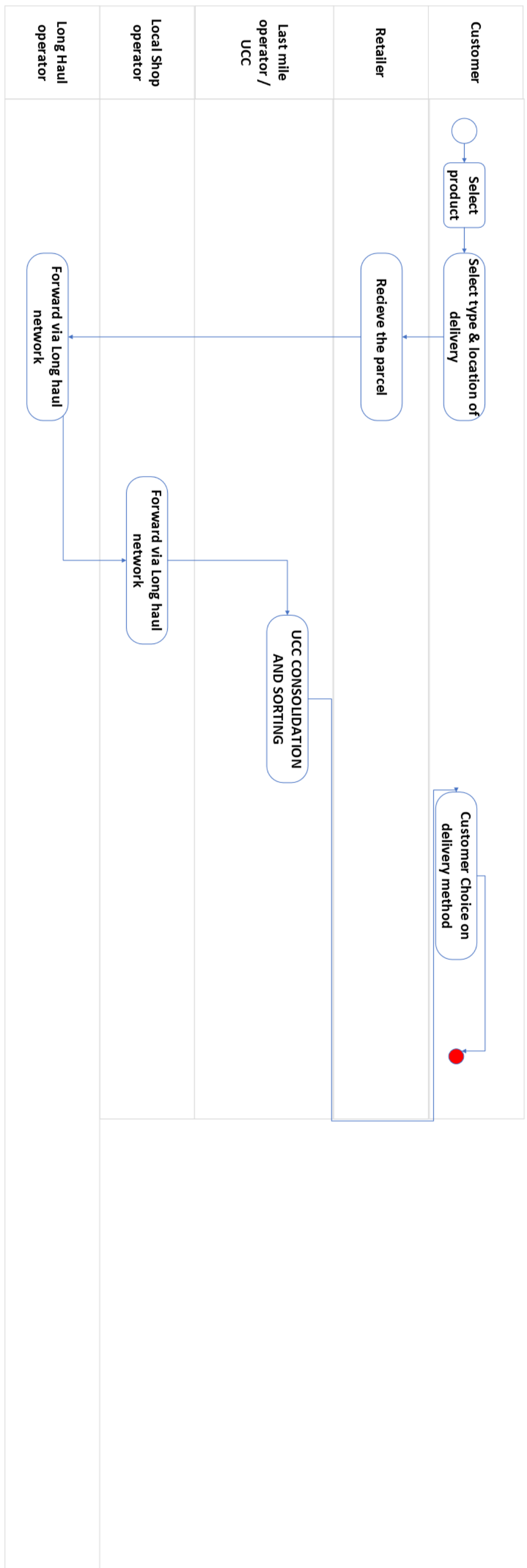


FIGURE 19 : THE TO-BE SITUATION ON THE USE CASE 2 WORKFLOW [LINK]

5. Stakeholders and their role

The URBANE project aims to revolutionize urban logistics in Thessaloniki through innovative last-mile delivery solutions. By leveraging a diverse range of stakeholders, including public authorities, last-mile delivery providers, technical experts, and research institutions, the project seeks to address the growing demands of e-commerce while promoting sustainability and efficiency:

- **Users:** The users of the Living Lab are individuals who will directly interact with the parcel lockers installed throughout Thessaloniki. Their engagement is crucial as they will provide feedback on the usability and accessibility of the lockers, which will inform future improvements and adaptations. By utilizing these lockers, users can experience a more efficient and convenient method for receiving their parcels, thereby contributing to the overall success of the last-mile delivery model being tested in the city.
- **Retailers:** Retailers play a significant role in the Living Lab by utilizing the parcel lockers as a delivery option for their customers. Their participation is essential for integrating the lockers into the existing e-commerce logistics framework. By adopting this innovative delivery solution, retailers can enhance customer satisfaction through improved delivery options, while also contributing to the reduction of urban congestion and emissions associated with traditional delivery methods.
- **Last Mile Delivery Providers:** Last mile delivery providers, particularly the ACS Couriers company, are integral to the operation of the Living Lab. They will utilize the parcel lockers for their delivery services, facilitating a more efficient and organized approach to last-mile logistics. Their involvement includes the installation of the lockers, implementing traffic-aware dynamic routing, and transitioning from conventional delivery vehicles to electric vehicles (EVs). This shift not only aims to improve service efficiency but also aligns with sustainability goals by reducing carbon emissions in the urban environment.
- **Technical Providers:** Technical providers, including infrastructure operators like ACS Couriers, are responsible for the technological aspects of the Living Lab. They will lead the installation and maintenance of the parcel lockers, as well as implement smart sensors and GPS systems to collect operational data. Their expertise is vital for ensuring that the technological infrastructure supports the efficient functioning of the lockers and contributes to the overall data-driven approach of the project, enabling continuous improvement and optimization of last-mile delivery services.
- **Public Authority (RMC):** The public authority, represented by the RMC, plays a pivotal role in supporting the Living Lab's initiatives. Their involvement includes providing the necessary political backing and facilitating the implementation of actions required for the project's success. The RMC's objective is to ensure that the innovations tested within the Living Lab contribute to the transition towards climate-neutral last-mile logistics. By fostering collaboration among stakeholders and promoting sustainable practices, the RMC aims to enhance the overall urban mobility system in Thessaloniki.

Dedicated to the use case of Thessaloniki, the different stakeholders, their objective and the KPIs that they can contribute to are included in the following Table 7.

TABLE 7 LL STAKEHOLDERS AND ROLES.

Stakeholder	Role	Internal/External	Objective	KPI
Users				
Last mile delivery providers				
Last mile operators	- ACS Couriers company will be the locker's users.	Internal (ACS)	- Installation of parcel lockers at Thessaloniki - Traffic aware dynamic routing - Replacement of conventional fleet with EVs	ID_1, ID_3, ID_6, ID_7, ID_8, ID_10, ID_13, ID_16, ID_18, ID_21, ID_24
Technical Providers				
Infrastructure operators	- ACS Couriers company will be the leading locker provider. - *smart sensors and GPS systems for collecting operational data on e-scooters.*	Internal (ACS)	- Installation of parcel lockers at Thessaloniki - Traffic aware dynamic routing - Replacement of conventional fleet with EVs	ID_1, ID_3, ID_6, ID_7, ID_8, ID_10, ID_13, ID_16, ID_18, ID_21, ID_24
Others*				
Public Authority	RMC will support the scaling up and the viability of the innovations tested through the provision of the appropriate political support and the implementation of the necessary actions for harnessing and their adaptation to the under-development SULP.	Internal (RCM)	The overall objective of RCM is to support the transition towards climate neutral last mile logistics. Specifically aims to: - test innovative last mile delivery services and intelligent tools for planning & monitoring. - create an ecosystem enabling scalability and transferability of the measure. - Finalize the Regional SULP.	

Stakeholder	Role	Internal/External	Objective	KPI
Research & Academia	The testing of this pilot, the data analysis collected by the scooters and the development of the AI algorithms will be done by CERTH/HIT. Data will be available to the ThessM@ALL analysis for problems definition and solutions provision and monitoring, enabling the implementation of the Thessaloniki Digital Twin tools for generalizing the results achieved, putting into practice the CIVITAS Process and Impact Evaluation Framework.	Internal (CERTH/HIT)	Develop Algorithms for: - **Predictive analytics** for demand forecasting. - **Facility location** (combined sustainable business & city planning for last mile delivery), - **Traffic aware dynamic routing**. Do simulations for: - new services and vehicles (zero emission & modular) in last mile operations and collaborative solutions	ID_1, ID_3, ID_6, ID_7, ID_8, ID_10, ID_13, ID_16, ID_18, ID_21, ID_24

6. Governance Analysis

The development and deployment of Living Lab (LL) innovations in Thessaloniki are heavily influenced by a multi-tiered regulatory framework spanning local, regional, and national government policies. These policies collectively shape the operational landscape for LL projects, driving the city's transition towards a smarter, more sustainable urban environment.

6.1 Local government policies and regulations

The LL had to align with several local government mandates to achieve its current development phase. Notably, the implementation of the SUMP, as mandated by the sub. no. 161620 decision of the Deputy Minister of Infrastructure and Transport, outlines specific requirements related to urban mobility. These include the establishment of UCCs, multimodality nodes, and low emission zones, which are integral to addressing urban logistics challenges faced by the LL projects.

While there is currently no established regulatory framework for the installation of parcel lockers in public spaces, special licenses issued by municipal authorities are required, suggesting a regulatory flexibility that can influence the LL's operational strategies.

To progress to the market stage, LL innovations must comply with the Operational Programme of the Municipality of Thessaloniki. This program serves as a local policy tool that defines the framework within which first-tier local authorities operate, emphasizing the need for projects that align with the municipality's strategic goals for economic growth, sustainability, and technological integration.

The Municipality of Thessaloniki is actively facilitating the rollout of LL innovations, particularly through its involvement in the NZC Mission 100 cities by 2030. As part of this mission, the municipality has developed an Action & Investment Plan that includes provisions for low emission zones, the installation of lockers and micro-consolidation centres in public spaces, and the use of green vehicles. This plan not only underscores the municipality's commitment to sustainable urban development but also highlights its strategy to leverage public-private partnerships. These partnerships allow for private investment in public space developments, essential for the LL innovations to be effectively implemented and sustained in the urban fabric.

Moreover, the lack of a specific national regulatory framework for such initiatives indicates a reliance on local strategies and the municipality's discretion in fostering an environment conducive to innovation. The documented political will and vision within the municipality's strategic and action plans provide a solid foundation for LL innovations to thrive, demonstrating a proactive approach to integrating these technologies into the city's infrastructure and community services.

Finally, with a special focus the installation of parcel lockers it is necessary to comply with specific city's measures and regulations.

- Thessaloniki has specific parking spaces for urban freight vehicles in the context of **parking regulations**. The location of the parcel lockers should be selected in accordance with the available parking spaces for LCVs.

- As part of 100 climate neutral cities, Thessaloniki will potentially apply **emission restrictions** (LEZ – Low emission zones) to reduce the CO2 in the city centre, thus the installation of parcel lockers should also consider this factor.

6.2 Regional government policies and regulations

To meet regional requirements and advance to its current stage, the LL has aligned with strategic plans like the Regional Plan for Adaptation to Climate Change, which focuses on identifying and prioritizing actions needed for the adaptation of the region to climate variations. This alignment ensures that the LL's initiatives are relevant and contribute directly to regional resilience goals.

Furthermore, the Integrated Sustainable Urban Development Strategy of Thessaloniki mandates improvements in mobility and overall quality of life within the metropolitan area. Compliance with this strategy ensures that the LL projects align with broader urban development goals, making them integral to regional development.

The Operational Plan of the Region of Central Macedonia 2021-2027 serves as a critical financial and policy tool, guiding the LL's developments. This plan categorizes regional development into five axes, providing a structured approach for integrating and funding innovative projects, including those associated with the LL.

Reaching the market stage for LL innovations requires adherence to the vision of the Central Macedonia government, which aims to establish the region as a hub for entrepreneurship and innovation in Southeast Europe. This vision emphasizes strengthening the connections between industry, research, governmental bodies, and society—an ecosystem supportive of innovative solutions. Therefore, LL innovations must demonstrate their ability to contribute to this interconnectivity and the overall innovation ecosystem to move towards commercialization.

While the regional government of Central Macedonia does not directly regulate urban space use—typically a municipal domain—it plays a crucial role in financially supporting innovation through funding and strategic policy alignments. By leveraging regional plans and operational programs, the regional government facilitates the rollout of LL innovations by providing the necessary financial resources and policy infrastructure. This support is crucial for pilot projects and scaling innovative solutions across the region, ensuring that they align with the broader goals of sustainable and resilient urban development.

6.3 National government policies and regulations

To reach its current stage, the LL in Thessaloniki has had to comply with several key national laws and strategic plans. For example, Law 4936/2022, Greece's National Climate Law, requires measures and policies that support the country's transition to climate neutrality by 2050. This law necessitates that innovations within the LL contribute to or accommodate this long-term goal by incorporating sustainable practices and technologies.

Similarly, Law 4710/2020 promotes electromobility and includes provisions for expanding the use of low- and zero-emission vehicles. This law also outlines the development of necessary infrastructure, such as publicly accessible charging stations, which directly impacts LL initiatives focused on sustainable urban mobility.

The National Energy and Climate Plan (NECP) and the National Plan for the Promotion of Electromobility further elaborate on the strategic direction for achieving energy and climate targets by 2030. These plans include detailed roadmaps that influence LL projects, particularly those related to energy efficiency, renewable energy integration, and the electrification of transportation.

For LL innovations to advance to the market stage, they must align with national investment initiatives and regulatory frameworks that facilitate the transition to smart and sustainable urban environments. The Greek Smart Cities investment initiative, fueled by the Recovery Fund, is pivotal in this context. This initiative aims to transform 11 Greek cities into smart cities through investments in infrastructure and systems essential for a sustainable and green urban future.

Meeting the requirements of this initiative involves not only the deployment of advanced technologies but also the integration of these technologies into the existing urban fabric in ways that enhance environmental sustainability and improve the quality of urban life. For LL innovations to reach the market stage, they must demonstrate their efficacy in contributing to these goals, potentially through pilot projects that showcase their impact on enhancing urban mobility, reducing emissions, and improving energy efficiency.

The following table (Table 8) includes all the different local, regional and national policies and regulations in place for the city of Thessaloniki.

TABLE 8 LOCAL, REGIONAL AND NATIONAL POLICIES AND REGULATIONS FOR THE CITY OF THESSALONIKI

Level	Name of Regulation	Description
Local	Sustainable Urban Mobility Plan (SULP)	Focuses on UCCs, multimodality nodes, and low emission zones.
	Operational Programme of the Municipality of Thessaloniki	Defines the framework for the municipality's strategic goals in economic growth, sustainability, and technological integration.
	NZC Mission 100 Cities by 2030	Includes an Action & Investment Plan with provisions for low emission zones, lockers, micro-consolidation centres, and green vehicles.
	Special Licenses for Parcel Lockers	Allows installation of parcel lockers in public spaces through municipal authority licenses.
	Thessaloniki 2030 Urban Resilience Strategy	Aims to ensure prosperity for citizens, strengthen the local economy, and respect natural resources.
	Digital Transformation Strategy for the City of Thessaloniki (2017-2030)	Roadmap for digital transformation aimed at improving public administration, reducing exclusions, and creating jobs.
	Sustainable Energy and Climate Action Plan (SECAP)	Action plan for achieving energy targets.
	Covenant of Mayors on Climate and Energy	Voluntary commitment to achieve European climate and energy targets.
	Memorandum of Understanding with THESSM@LL	Joint actions for mobility data collection and infrastructure support.
Regional	Regional Plan for Adaptation to Climate Change	Identifies and prioritizes actions needed for regional adaptation to climate changes.
	Integrated Sustainable Urban Development Strategy of Thessaloniki	Mandates improvements in mobility and quality of life in the metropolitan area.

Level	Name of Regulation	Description
	Operational Plan of the Region of Central Macedonia 2021-2027	Financial and policy tool guiding LL developments, categorizing regional development into five axes.
	Vision for Central Macedonia	Aims to establish the region as a hub for entrepreneurship and innovation in Southeast Europe, emphasizing the connection between industry, research, government, and society.
	Financial Support for Innovation	The regional government facilitates the rollout of LL innovations through funding and strategic policy alignments.
National	Law 4936/2022 - National Climate Law	Requires measures for the transition to climate neutrality by 2050.
	Law 4710/2020 - Promotion of Electromobility	Expands the use of low- and zero-emission vehicles and develops recharging infrastructure.
	National Energy and Climate Plan (NECP)	Detailed roadmap for achieving energy and climate targets by 2030.
	National Plan for the Promotion of Electromobility	Action plan for developing charging infrastructure and the electromobility ecosystem.
	Greek Smart Cities Investment Initiative - Recovery Fund	Aims to transform 11 Greek cities into smart cities through investments in sustainable and green urban infrastructure.

7. URBANE LL implementation

7.1 Timeline

The comprehensive implementation process within the Thessaloniki Living Lab is set to unfold over a period of 24 months, segmented into 10 strategically defined actions. These actions encompass the entire lifecycle of the project from the initial ecosystem identification to the final monitoring stages. The meticulously planned timeline facilitates a clear view of the sequential and overlapping phases, ensuring a systematic approach to project execution in the next table (Table 9).

TABLE 9 THESSALONIKI LL TIMEPLAN

Activities / Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	S22	O22	N22	D22	J23	F23	M23	A23	M23	J23	J23	A23	S23	O23	N23	D23	J24	F24	M24	A24	M24	J24	J24	A24
Stakeholder involvement & Strategic Framework setting	■	■	■	■																				
Assessment of the results of Thessaloniki Strategic plan towards urban logistics	■	■	■	■	■	■																		
Business requirements mapping	■	■	■	■	■	■	■	■																
Data input requirements							■	■	■	■														
Data Generation and Validation										■	■	■	■											
Related Models Development and Implementation											■	■	■	■	■	■	■	■	■	■	■	■		
Public authority request for public space License																			■	■				
Field study and Installation																				■	■			
Upscale models KPIs generation																					■	■	■	
WP management	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

The project kicks off with a four-month intensive phase dedicated to engaging stakeholders and establishing a strategic framework. This initial stage is crucial for aligning the interests and objectives of all parties involved, setting a solid foundation for the subsequent actions. From the third to the fifth month, the team will evaluate the results of Thessaloniki's strategic urban logistics plan. This assessment is vital for pinpointing the current logistics landscape and identifying requisite enhancements to meet future urban logistics demands. Over the following three months, the project will focus on mapping out business requirements. This stage involves a detailed analysis to define the specific needs and goals of the business stakeholders, ensuring that the project's outputs are aligned with commercial expectations and realities. Concurrently, between the seventh and eighth months, the project will establish the data input requirements. This involves determining the types of data needed, sources, and methodologies for data collection, setting the stage for robust data-driven decisions. This critical six-month phase is dedicated to generating and validating data. The extended duration underscores the complexity involved in collecting accurate and relevant data, which is fundamental for the reliability of the project's outcomes. Spanning from the twelfth to the twenty-second month, this phase involves the development and fine-tuning of models essential for the project. This prolonged period allows for iterative improvements and integrations, ensuring the models are robust and effective. In the twelfth month, the project will seek necessary regulatory approvals for the use of public spaces. This brief but crucial phase is pivotal for ensuring that the installations comply with local laws and regulations. Over four months, the team will conduct field studies and begin the physical installation of infrastructure. This phase is crucial for translating theoretical models and plans into practical, operational solutions. In the final three months, the project focuses on developing and finalizing Key Performance Indicators (KPIs) for the upscale models. This stage is essential for measuring the effectiveness and impact of the implemented solutions. Work Package (WP) management is a continuous activity throughout the project duration. This involves overseeing and coordinating all work packages, ensuring the project remains on track, within budget, and aligned with its objectives.

7.2 LL trial set up and preparation

This living lab consists of two different use cases:

i. The first use case is a **real implementation** about the design and the installation of a parcel lockers network based on the current demand for the city and
ii. The second explores a **simulation** scenario where all last-mile delivery players utilize a shared locker alliance network in conjunction with an UCC strategically located within the urban landscape using green last mile vehicles.

At the beginning of the pilot, stakeholder engagement actions were conducted for the suitable design and preparation of the use case 1 and use case 2. The results of use case 1 were further used for the preparation of use case 2.

7.2.1 Use case 1: Installation of Micro-Hubs to Public spaces

In the project aimed at urban logistics within Thessaloniki, the first goal was the involvement of stakeholders and the establishment of a strategic framework as the foundational phase. This initial step was considered critical, with the delineation of goals, the development of a strategic vision, and the creation of an implementation roadmap being undertaken, while legislative considerations were also taken into account. It was ensured that the project's underpinnings were solid, with a clear focus on enhancing urban logistics in a sustainable manner. Subsequently, an in-depth assessment of the strategic plan for urban logistics in Thessaloniki was carried out. The needs within the urban ecosystem were pinpointed and strategies were adapted to future urban logistics policies through this step. A comprehensive understanding of the current state was gained, and future challenges were anticipated, allowing strategies to be tailored to better serve the city's evolving needs.

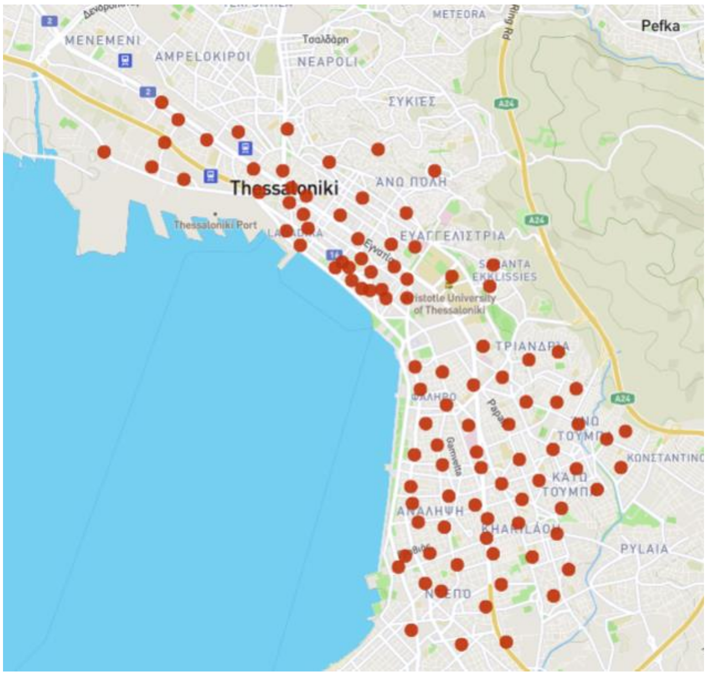


FIGURE 20 PROPOSED NETWROK OF LOCKER ALLIANCE

Figure 20: The proposed network of locker alliance network for the period 2023-2024The mapping of business requirements was another pivotal aspect of the strategy. Efforts were dedicated to comprehending the industry's drive towards decarbonization and the imperative for collaboration during this phase. It was ensured that the project's objectives were aligned with the broader aims of the logistics and transportation sectors, facilitating a unified approach to urban freight challenges. Data acquisition and analysis were established as cornerstones of the project. Input data requirements, including detailed descriptions of ACS delivery data and socioeconomic data obtained from the RCM's GIS portal, were meticulously outlined. Surveys aimed at gathering data on user preferences were established, offering valuable insights into the expectations and requirements of end-users. The process of data generation and validation was characterized by targeted management actions from both ACS and RCM, ensuring that data were extracted in formats allowing a comprehensive analysis. The conduction of surveys further enriched the data pool, grounding strategies in tangible insights from the real world.

FIGURE 21: THE LOCKER AT WHICH BLOCKCHAIN TESTED (IS ONE OF THESE PROPOSED BY THE URBANE ACTIONS)

The development and implementation of analytical models were central to the project. The execution of the Facility Location (FL) model, tailored to meet the specific needs of the action plan, was undertaken. This model, along with the implementation of the MASS-GT/HUMAT model to measure induced demand, was crucial in optimizing strategies for urban logistics. In seeking authorization to utilize public spaces, quantitative results based on preliminary results of the FL model and available data were produced to underscore the necessity for shared public lockers. This step was crucial for integrating the project into the urban landscape, ensuring that it complemented existing infrastructure and served the public interest effectively. Lastly, the Blockchain event tracking technology deployed and tested in order to demonstrate a process ready to accept data signals for a locker alliance network of shared lockers served by a common in order to prepare ACS for a “last mile delivery marketplace” that will manage the complex operations.

7.2.2 Use case 2: Simulation of PI green last-mile solutions

Extensive data collected from Use Case 1 is utilized, providing a detailed overview of existing logistics operations within the city and the existing infrastructure of the company within the city (parcel lockers, consolidation centers). This data serves as a foundational resource for establishing baselines in our simulations and modeling efforts.

The advanced digital infrastructure of Thessaloniki's Logistics Living Lab is incorporated, employing the city's Digital Twin. This critical component allows for the visualization and simulation of the logistics network in a controlled, virtual environment. By replicating Thessaloniki’s physical and logistical landscapes, various scenarios were tested to assess their impact on the city's logistics system without real-world risks. Operational profiles provided by ACS, the primary LSP, are used to offer essential insights into current delivery patterns, vehicle utilization, and operational challenges. These profiles are crucial for configuring Digital Twin accurately, reflecting real-world conditions and optimizing logistics strategies effectively. A significant enhancement is made by integrating a traffic-aware dynamic routing algorithm into the Digital Twin. This allows delivery routes to be optimized based on real-time traffic data, aiming to reduce delivery times and alleviate urban congestion. The dynamic adjustment of routes ensures efficient logistics operations throughout Thessaloniki.

Scenarios involving a network of parcel lockers and UCCs, serviced by a fleet of green vehicles, are co-created through collaboration with the Region of Central Macedonia (RCM) and ACS. These scenarios were developed through iterative consultations with all stakeholders, ensuring the solutions are practical, sustainable, and meet the community's diverse needs. They were then tested within the Digital Twin environment, where insights into their potential effectiveness and impact on urban logistics are provided. This comprehensive approach not only emphasizes the use of innovative technologies but also highlights the importance of stakeholder engagement and regulatory compliance. Solutions that are scalable and adaptable are aimed to be created by the LL, potentially serving as models for urban logistics systems globally.

8. Existing infrastructure

8.1 Existing physical infrastructure

The existing physical infrastructure in Thessaloniki provides a robust foundation for implementing advanced urban logistics solutions. This infrastructure encompasses various facilities and assets that support efficient logistics operations and last-mile delivery services. Key elements of the existing infrastructure include consolidation centres, urban logistics hubs, and specialized delivery networks designed to streamline the movement of goods within the city.

One of the significant components of Thessaloniki's infrastructure is the network of consolidation centres. These centres serves as pivotal points where goods are aggregated before being dispatched to their final destinations. By centralizing the sorting and distribution processes, these centres enhances operational efficiency and reduce transportation costs.

Urban logistics hubs further complement the consolidation centres by acting as intermediary points for goods transfer. These hubs are strategically located to facilitate quick and efficient distribution across different parts of the city. They also support various delivery schemes, including off-hour deliveries and the use of environmentally friendly vehicles like cargo bikes and electric vehicles.

Additionally, Thessaloniki's infrastructure includes an extensive network of smart logistics solutions, such as parcel lockers and automated delivery systems. These solutions provide convenient and flexible options for last-mile delivery, catering to the diverse needs of urban consumers.

In summary, Thessaloniki's existing physical infrastructure is well-equipped to support advanced logistics operations. The combination of consolidation centres, urban logistics hubs, and smart delivery solutions creates a comprehensive logistics ecosystem that can efficiently handle the city's growing demand for urban freight services.

TABLE 10 INFRASTRUCTURE OF INDUSTRY PARTNER

<table>
<tr><th colspan="2">Consolidation & Network Infrastructure</th></tr>
<tr><td colspan="2">Hub & Spoke business model (micro consolidation centres)</td></tr>
<tr><td>Main ACS delivery Centre/Depots (owned by ACS):
▪ Number of vehicles: 15
▪ Vehicle type- technology: 4 auto diesels ,10 auto petrol and gas, 1 petrol and CNG
▪ Emission standards: N/A
▪ Capacity: 1000 – 1200 kg
▪ Max range: 80 km (per travel)
▪ Sensors- communication protocols: N/A
▪ Age :15 years</td><td>External agents
• Number of vehicles: 113
• Vehicle type- technology: 88 diesel, 22 petrol, 2 LPG, 1 CNG
• Emission standards: N/A
• Capacity: N/A (most of vehicles are small to medium sized like: Doblo, Kangoo, Florino, Caddy and etc and fewer larger vehicles like: Transit, Ducato, etc)
• Max range: N/A (average consumption about 8,5 lt/100 kms)
• Sensors- communication protocols: N/A
• Age: N/A</td></tr>
<tr><th colspan="2">Land-use planning & City infrastructure</th></tr>
<tr><td colspan="2">• Dynamic traffic management system
• Parking restriction system</td></tr>
<tr><th colspan="2">Delivery Schemes & smart logistics solutions</th></tr>
<tr><td colspan="2">Parcel Lockers</td></tr>
<tr><th colspan="2">Vehicle Technologies</th></tr>
<tr><td colspan="2">Electrical vehicles (only in simulation level)</td></tr>
</table>

Table 10 provides a detailed overview of the various components of Thessaloniki's logistics infrastructure. It categorizes the infrastructure into different types, such as consolidation centres, urban logistics hubs, and delivery schemes, and outlines their specific characteristics and roles within the city's logistics network. This table is instrumental in understanding the scope and capabilities of the existing infrastructure, highlighting the assets that can be leveraged for improving urban logistics operations. By presenting a structured summary of the physical infrastructure, Table 10 facilitated the identification of key areas for enhancement and integration with new technologies and solutions introduced through the URBANE project.

8.1.1 Additional equipment/infrastructure needed for URBANE

The Thessaloniki Smart Mobility Living Lab contains series of data collection devices that sense the city in order to process these data and monitor the traffic flow in real time. The data collection includes a real time monitoring of a fleet of 1500 taxis, Bluetooth devices in selected links of the network to capture travel times and loops in selected links. These data processed via AI and advanced algorithms and produce an accurate status of the whole road network (TrafficThess - LIVE Traffic in Thessaloniki, Greece (imet.gr)). These data utilized in the Traffic aware dynamic Routing demonstrated in URBANE.

FIGURE 22: A SNAPSHOT OF THESSALONIKI TRAFFIC IN THE ROAD NETWORK (USED ON THE TRAFFIC AWARE DYNAMIC ROUTING)

8.2 Existing digital infrastructure

8.2.1 Existing ICT Solutions and Operational information systems

Thessm@ll's platform has a collection of freight services that have been created as part of EU projects and are integrated there, supporting the idea of an "Intelligent Logistics hub" (example of services: environmentally friendly routing, C-ITS services, EVs routing & management, Traffic forecasting, Path prediction, collaborative city logistics service & matchmaking tools for consolidation of cargo, on-demand warehousing services, distribution planning optimization tools and services. as well as tools for policy making and consensus building).

The Thessm@ll has all necessary tools. For policy response and creative solutions adopted in mobility and city logistics, the SPROUT CIVITAS H2020 (GA number 814910) project[1] developed and used a conflict resolution model and the open innovation community approach. The largest demo CCAM project under SHOW H2020 (GA number 101006943)[2] for the integration of autonomous & automated solutions in the

[1] https://sprout-civitas.eu/

[2] https://show-project.eu/

operation of urban systems is coordinated by CERTH. Momentum H2020 (GA number 815069)[3] provides a data-driven decision support tool for innovative mobility options.

8.2.2 Digital models and Decision Support tools already in place

CERTH's scientific infrastructure is equipped with a collection of sophisticated tools designed to address various challenges in the realm of digital modeling and decision support for mobility and logistics purposes. These tools are pivotal in advancing research, improving operational efficiencies, and fostering innovation in logistics, urban mobility, and sustainable city planning.

CERTH provides **advanced operational research (OR) algorithms**, essential for solving complex optimization problems. These algorithms form the backbone of many logistics and transportation solutions, enabling efficient route planning, resource allocation, and operational improvements. Another cornerstone of CERTH's offerings is **Machine Learning (ML)-based forecasting tools**, which leverage historical data to predict future trends, demands, and challenges in transportation and logistics. This predictive capability is crucial for planning and decision-making.

Facility location and fleet sizing tools are tailored to optimize the distribution of logistics facilities and the composition of fleets. These tools consider various factors, including cost, demand, and geographic constraints, to determine the most efficient logistics networks. **Fleet management tools** are provided to streamline operations, enhance vehicle utilization, and reduce operational costs. These tools offer real-time insights into fleet operations, facilitating proactive management.

Dynamic fleet dispatching tools are available to adapt to real-time conditions, such as traffic congestion or delivery urgencies, ensuring timely and efficient delivery services. Another vital tool is the emissions footprint calculator, which enables the assessment of carbon footprints and other environmental impacts of logistics operations, supporting efforts towards sustainability.

Fair pricing tools are designed to ensure competitive and equitable pricing strategies, taking into account operational costs, market dynamics, and customer value. Decision support tools round out CERTH's digital modeling offerings, providing comprehensive analyses and recommendations to aid in strategic decision-making processes.

The **Innovation Readiness** online self-assessment tool allows organizations to evaluate their readiness to adopt new innovations, identifying strengths and areas for improvement. Similarly, the Liveability online self-assessment tool enables cities and communities to assess their quality of life and sustainability, informing policy and development initiatives.

System Dynamics Tools are specialized for assessing the impact of city logistics and mobility measures. These tools model the complex interactions within urban systems, helping stakeholders understand the potential outcomes of various initiatives. Consensus-building tools facilitate stakeholder engagement and collaboration, which is essential for the successful implementation of urban logistics projects.

Lastly, CERTH offers a toolkit for City Logistics (CL) measure selection, guiding users through the process of identifying, evaluating, and selecting the most appropriate logistics interventions for their specific contexts. Together, these tools form a comprehensive suite of resources that empower researchers,

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[3] https://h2020-momentum.eu/

policymakers, and industry professionals to make informed, strategic decisions that drive efficiency, sustainability, and innovation in urban logistics and mobility solutions.

8.2.3 Available datasets related to LL scope

The fusion of different data sources and the availability of historical data in the THESSM@LL data lake provide a comprehensive foundation for analysis and decision-making. This data lake integrates various types of data, including demand data form Urban Logistics profiles (retail, HoReCa, etc) , scheduling data (PuT, Traffic signals, Regulations) , business-related data (e.g., Fleet size, type of vehicles, emissions), workforce data, traffic management data, OD (Origin-Destination) matrices, data from the IoT network in the city, TMC (Traffic Management Centre) data, and fleet management as well as other types of technological systems in use. The THESSM@LL further enriched the knowledge database for research purposes with the data collected and generated through the URBANE project and described in section 2.

To effectively utilize this diverse data, various software tools are employed, including MATLAB, Python, Java, Anylogic, and SUMO. These tools facilitate the processing, analysis, and modeling of the integrated data, enabling robust solutions for urban logistics and transportation challenges.

8.2.4 Existing Digital Twin

The City Logistics Digital Twin integrates advanced technologies and methodologies to create a comprehensive and dynamic representation of urban logistics systems. This includes the use of Discrete Event and Agent-Based simulation to model and analyze the complexities of city logistics operations. The integration of Operational Research (OR) algorithms enhances the simulation by optimizing various logistics processes, such as route planning and resource allocation. Additionally, the Digital Twin enables thorough impact assessment, allowing stakeholders to evaluate the effects of different logistics strategies and interventions. Urban freight modeling is also a critical component, providing detailed insights into the movement and management of goods within the urban environment. This tool supports decision-making and strategic planning, ultimately improving the efficiency and sustainability of urban logistics systems. The development was part of URBANIZED project that were applied to the HoReCa market segment in order to access the impact of the project’s proposed urban logistics Light Commercial Vehicle.

FIGURE 23: THE THESSALONIKI TECHNOLOGY STACK FOR THE DIGITAL TWIN

The Facility Location & Planning Intelligence module is a sophisticated tool designed to optimize the placement and planning of logistics facilities within an urban environment. This module leverages advanced algorithms that extend traditional facility location models by incorporating real-world data, customer choice models, and cost-aware optimization features.

By integrating real-world data, the module ensures that the facility location models are grounded in actual conditions, enhancing their relevance and accuracy. This data includes demographic information, economic indicators, and geographical constraints, providing a comprehensive foundation for the models.

FIGURE 24: EXAMPLE OF THE THESSALONIKI LL TOOL TO ANALYSE AND PLAN MICROMOBILITY AND LOGISTICS SHARING ASSETS

Customer choice models are a key component, allowing the module to simulate and predict customer behavior and preferences. This capability ensures that the proposed facility locations are not only optimal from an operational perspective but also aligned with customer needs and expectations. By understanding where customers are likely to choose services, the module can enhance accessibility and service levels.

Cost-aware optimization features further refine the facility location models by balancing operational costs with service efficiency. These features take into account various cost factors, such as transportation expenses, facility maintenance, and labor costs, ensuring that the selected locations are economically viable. The optimization process seeks to minimize costs while maximizing service coverage and efficiency, resulting in a well-balanced logistics network.

Overall, the Facility Location & Planning Intelligence module provides a robust and comprehensive solution for strategic logistics planning. It supports decision-makers in identifying optimal facility locations that meet both operational requirements and customer expectations, ultimately enhancing the efficiency and effectiveness of urban logistics systems.

8.3 Models & tools developed/used/extended in URBANE

8.3.1 New services in the URBANE

In the context of the URBANE project, the Thessaloniki Living Lab (LL) employed two principal models from the urban transferability platform. The initial model, known as the facility location model, utilizes demand data supplied by industry participants within the LL to ascertain the optimal positioning of parcel lockers. The comprehensive implementation of these models necessitated several preparatory steps. An extensive dataset, encompassing 10 months of delivery data provided by ACS to the CERTH, was analyzed to discern demand patterns and insights. The initial phase of the methodology involved delineating zones and proposing candidate locations for lockers within each zone. For the sake of simplicity and without compromising generality, 350 station candidates were identified as potential locker sites within the Municipality of Thessaloniki. Data analysis revealed that daily demand within the city fluctuates between 10,000 to 12,000 parcels, depending on the season. Given that each parcel locker consists of 32 compartments, the proposed 350 lockers would sufficiently meet a significant portion of this demand. Nonetheless, this figure was deemed excessively high, prompting the need to identify an optimal subset that balances the operational metrics of the courier company and societal externalities. The initial step involved employing the Continuous Approximation tool from the Impact Assessment Radar to determine the optimal number of lockers. After evaluating multiple scenarios, a target of 60 lockers was deemed reasonable. This determination is grounded in Erlang's formula for the M/M/c/c queue, where the probability of a locker being unavailable to a customer is maintained below 3%. Consequently, this configuration is estimated to accommodate approximately 2,000 parcels daily. Employing parcel lockers to fulfil 50% of the demand is projected to reduce CO2 emissions by at least 30%. Subsequently, the selection process identified representative days for the facility location model, ensuring these days encapsulated the widest range of potential demand scenarios. This led to the selection of 20 days, providing a comprehensive demand profile across the 350 zones. The facility location model then pinpointed the optimal locations for the lockers. These locations were subsequently integrated into an Agent-Based Model (ABM) developed using the HUMAT/MASS-GT framework. The ABM served a dual purpose: assessing customer acceptance and induced demand and evaluating the broader benefits of the shared lockers initiative across all levels of the impact assessment framework. The findings from this model will refine the input for the facility location model, enabling the derivation of a final, optimal network for public parcel lockers.

8.3.1 Decision Support Digital models

Thessaloniki LL is Greece’s second-largest city. The city centre experiences a dense population and a scarcity of public spaces. Due to the increasing commercial activities that contribute to high levels of passenger traffic and urban freight movements, Thessaloniki LL aims to propose PL facilities in the city for LMDs.

To explore the acceptability of PL facilities by consumers (i.e. how consumers choose a delivery method, and whether they tend to choose PL delivery or not), an integrated agent-based simulation model is designed and developed. In this model, the HUMAT modules (NORCE) simulate consumer choices between the parcel locker service and home delivery options over time, while MASS-GT (TUD) is used to allocate carrier trips based on the capacity of parcel lockers in each zone (i.e. to transfer the remaining parcels which cannot be delivered to a PL) and to generate household demand.

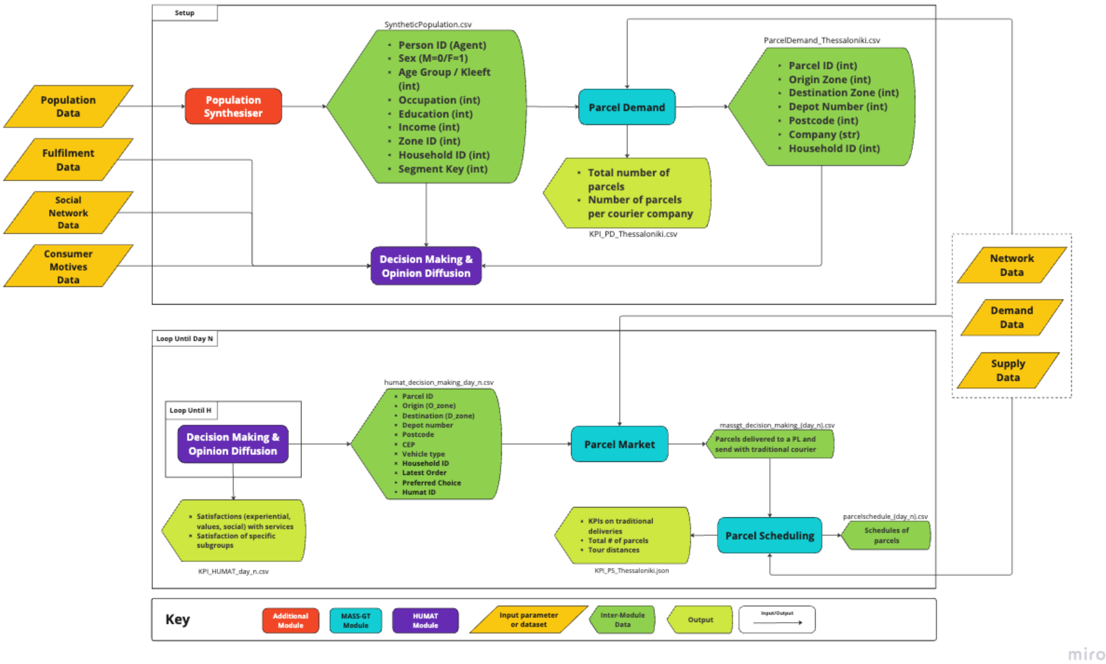

FIGURE 25: THE LOGICAL FLOW OF HUMAT AND MASS-GT INTEGRATION FOR THE THESSALONIKI USE CASE

The integrated model is conceptualized as depicted in Figure 25. In summary, during the setup phase firstly an artificial Thessaloniki population is synthesized, then the parcel demand is initialized and after the decision-making of consumers is configured. The simulation runs through multiple days, with iterative decision-making and parcel market optimization (i.e. assigning parcels to PL delivery and to home delivery). Outputs are tracked in terms of satisfactions of consumers, parcel delivery efficiency and environmental impact, with continuous feedback loops to refine the model. More information on the results can be found in URBANE D3.2 Modelling Framework and Agent-Based Models.

The Agent-Based Model (ABM) tool has the potential to be highly beneficial in our operations, particularly for examining strategic plans and estimating induced demand and other critical operational metrics. The key added value lies in its ability to facilitate the running of multiple complex scenarios involving various stakeholders, making it an excellent resource for decision-making and long-term planning. Once the tool is set up, it streamlines the process of exploring different strategies, enabling us to assess outcomes more effectively and make informed decisions. However, one area for improvement would be the organization of data input requirements and formats. Currently, setting up the tool demands significant effort, and simplifying this process would enhance its usability and efficiency, allowing for even more seamless integration into our operational workflows.

8.3.2 DT Decision support capabilities, services and requirements to facilitate the vision

Implementing a Hub&Spoke delivery business model combined with tools that facilitate last mile delivery as a service. In order to obtain greater load factors and fewer trucks, micro-fulfilment centres will be placed around the perimeter of the historical centre and tested in a genuine operational setting.

The Digital Twin model is fed with different scenarios, and feedback on the predicted outcome of each one is provided to help the planner answer the “what if” questions. When it comes to the monitoring level, actions are taken by planners with the help of the DT tool to further improve the situation. In the case of ThessM@LL, the best locations for the parcel lockers are explored and selected by the DT based on the current demand of the city. At a further step, the DT is used to assess if more parcel lockers even improve the situation and to find their potential locations. This tool utilized during USE-CASE-2 of the Thessaloniki LL actions.

The tactical and strategic levels are implemented through the Impact assessment radar. The outcomes of the DT are used to provide evidence-driven planning for city logistics to understand which measure is to be chosen. The strategic level is applied at a higher level to understand which mobility solution is to be chosen for the city, based on their transferability.

8.3.3 Blockchain Technology in LLs

The objective of the blockchain system is to guarantee non-repudiation throughout the shipment process when multiple parties are involved. The Thessaloniki LL aims to implement a locker alliance network that requires transaction tracking on multiple competitors and therefore the transparency of actions is vital. The first step was to identify the events at which the package is transferred, and tracking is required. For purposes of clarity, the list of events for this use case is presented in Table 11.

TABLE 11 EVENTS INCLUDING TSN CODES

1. Order registered (84)	4. Order delivered (21)
2. Order in compartment (64B)	5. Order not delivered (23)
3. Order retrieved from compartment (13)	6. Order delivered to secondary location (82)

The second key objective of the system is to assess performance to guarantee that the service has been delivered in line with the previously agreed Service Level Agreements (SLA). To achieve this, a range of rules can be selected by the user including missed events, damaged shipments, and delayed shipments. The ACS backend send the event data through an API to the platform where it is processed and stored on the blockchain. The information is then displayed in the URBANE dashboard (Figure 26).

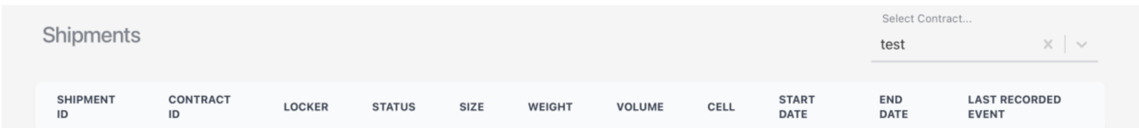

FIGURE 26: SHIPMENT OVERVIEW

Prior to monitoring the events a smart contract must be created using the contract generator (Figure 27). The user may select the events to be monitored and the rules to be checked at this stage. Once the contract is in place and data from new events is sent to the platform via the API, these events will be visible in the Shipments Dashboard (Figure 26).

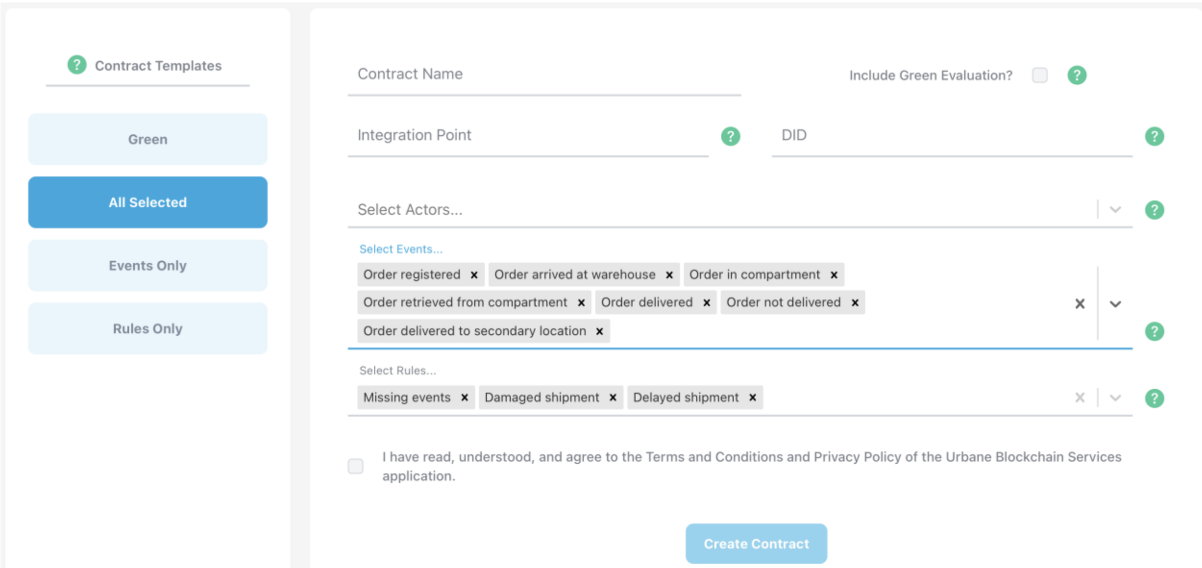

FIGURE 27: CONTRACT GENERATOR INTERFACE

To gain a more detailed overview of the events, one can select the Last Mile Events tab to view all events that have already been registered under a shipment. Additionally, alerts will appear when the rules have been executed with the corresponding result. Further information on the URBANE blockchain infrastructure is available in D3.1. and by the demonstration of the tool prepared using link.

The integration of blockchain technology in Thessaloniki Living Lab operations offers a substantial benefit by providing a trustworthy and transparent system for managing events in shared lockers. This transparency is crucial for building trust among multiple logistics service providers (LSPs), ensuring that all parties have confidence in the integrity of the system. The added value of blockchain lies in its ability to securely track and verify transactions, reducing the potential for disputes and fostering smoother collaboration between different LSPs. To enhance its effectiveness, it would be beneficial to make the blockchain system more modular and adaptable to the various data formats that each LSP might use. This flexibility would allow for easier integration across diverse operational systems, further streamlining processes and improving overall efficiency in the shared logistics network.

8.3.4 Facility Location Model and Traffic aware dynamic routing

The facility location model employed for parcel locker placement, integrates several advanced operational research techniques to optimize the placement of these lockers, ensuring both efficiency and user satisfaction. The model is grounded in stochastic optimization, which accounts for the inherent uncertainties in demand and other operational variables. By using stochastic methods, the model is capable of providing robust solutions that perform well under various possible future scenarios, ensuring that the parcel lockers are optimally located even when demand patterns are unpredictable.

Furthermore, the model incorporates utility function integration, which focuses on maximizing the total utility for users. This approach ensures that the locker locations are chosen not only based on cost and logistics but also on the benefits they provide to users. By integrating a multinomial logit choice model, the facility location problem considers customer preferences and behavior, making the solution more aligned with user needs. This integration is critical in urban environments where user satisfaction can significantly impact the success of last-mile delivery services.

Additionally, the model applies queueing theory to optimize service levels and capacity design. This aspect is essential for managing the flow of customers at the lockers, ensuring that the system can handle varying levels of demand without compromising service quality. By considering factors such as arrival rates and service times, the model determines the optimal number of lockers and their placement to minimize wait times and maximize service efficiency. Cost-aware decision-making is another key element, where the model balances installation and operational costs against the expected benefits, ensuring that the locker placement is economically viable while meeting service level requirements. This comprehensive approach ensures that the facility location model is both user-centric and cost-effective, providing a robust solution for parcel locker placement in urban settings.

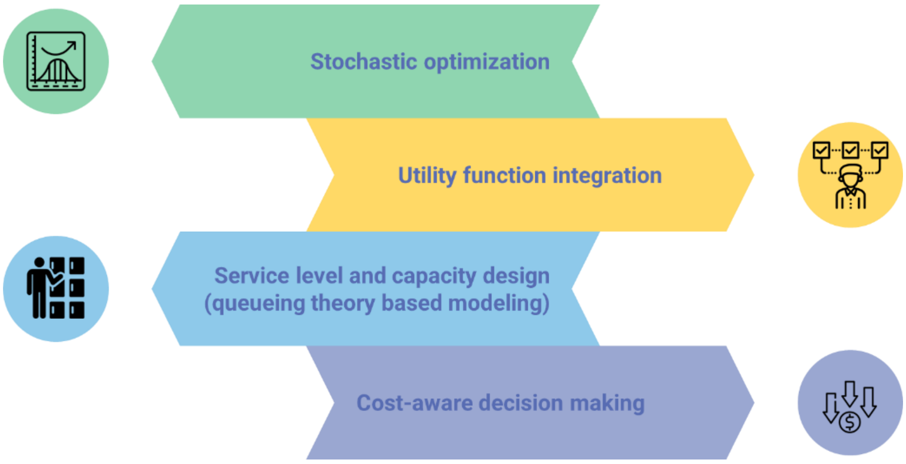

FIGURE 28: THE 4 PILLARS OF FACILITY LOCATION MODEL

In addition to the facility location model, I developed a traffic-aware dynamic routing method to further optimize parcel delivery efficiency. This method leverages real-time traffic data collected from the Thessaloniki Living Lab (LL) through various sources. By integrating this traffic data, the method continuously updates the distance matrix every 15 minutes, reflecting the current traffic conditions in the area. This dynamic updating process ensures that the delivery routes remain optimal as conditions change throughout the day. The updated distance matrix is then fed into a Capacitated Vehicle Routing Problem with Time Windows (CVRP-TW) algorithm, which re-solves the routing problem considering the latest traffic information. This approach allows for more adaptive and responsive delivery operations, reducing delays and improving overall service reliability in urban logistics.

The facility location model developed for Thessaloniki LL plays a vital role in optimizing the placement of parcel lockers by ensuring that they are strategically located to maximize efficiency and accessibility. The model's primary added value is its ability to analyze various factors such as demand patterns and user preferences, enabling data-driven decisions that enhance operational effectiveness. By accurately predicting where lockers should be placed, the model helps reduce delivery times and costs, contributing to a more efficient last-mile logistics network. However, to further improve the model's utility, it would be beneficial to incorporate the existing infrastructure as an input. This enhancement would allow the model to consider the current logistics landscape, leading to more accurate and practical solutions that better align with the real-world constraints and opportunities.

8.3.5 Impact Assessment Radar

In Thessaloniki, the Impact Assessment Radar played a crucial role in guiding the URBANE project's urban logistics interventions. Initially, the first level of the Radar was applied to comprehensively assess the city's ecosystem for weak points that required enhancement. This strategic planning phase was crucial before implementing the pilot projects, ensuring that the interventions were well-targeted and addressed the specific needs of Thessaloniki's urban logistics landscape.

FIGURE 29: IMPACT ASSESSMENT RADAR UTILIZATION EXAMPLE (LEVEL 1)

Following this, the second level of the Radar was utilized to optimize the logistics infrastructure placement within the city. For Use Case 1, this involved determining optimal locations for the installation of micro-hubs and parcel lockers, enhancing the operational efficiency of last-mile delivery services. The facility location analysis was conducted using advanced modelling tools, which helped in strategically placing these lockers to maximize accessibility and efficiency. In preparation for Use Case 2, similar facility location strategies are planned for the placement of an UCC, which will centralize operations and further streamline delivery processes.

In the first case, the tool is set up for different scenario to understand the different dynamics and try to capture the current situation in the city to draw the future.

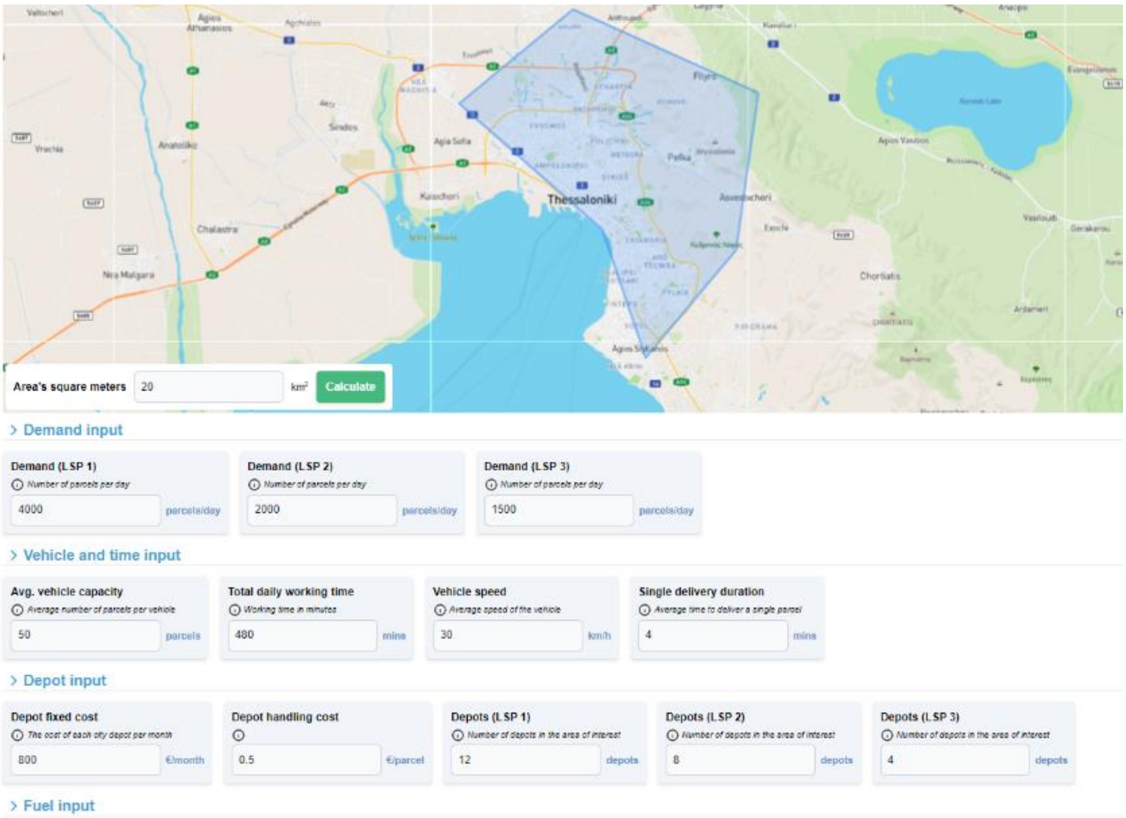

FIGURE 30: IMPACT ASSESSMENT RADAR UTILIZATION EXAMPLE FOR PLANNING PURPOSES (LEVEL-2)

The results provide the impact of the new locker network design in the context of multiple aspects such as efficiency, costs and externalities to understand the impact of the current system in the city.

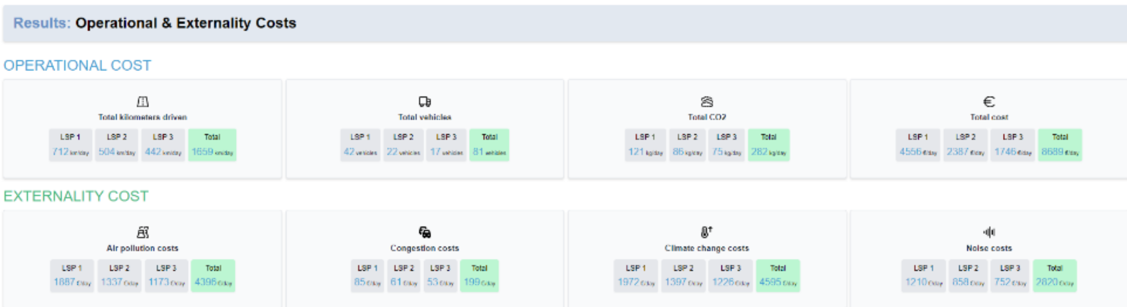

FIGURE 31: IMPACT ASSESSMENT RADAR RESULTS OF LEVEL 2

Lastly, aiming to build an alliance lockers network with shared lockers for shared operations, the impact assessment radar also displays the impacts of an alliance network against the impacts of the individual networks.

FIGURE 32: IMPACT ASSESSMENT RADAR UTILIZATION OF LEVEL 2

Finally, the third level of the Radar came into play during the operational phase of the pilot, where it was used to display and monitor various KPIs in specific frequences. This operational planning enabled continuous assessment of the pilot's performance, providing valuable data on the efficiency, sustainability, and overall impact of the implemented logistics solutions. By measuring these KPIs throughout the pilot, stakeholders could gauge the success of the interventions and make informed decisions on potential adjustments or expansions of these innovative urban logistics models.

FIGURE 33: IMPACT ASSESSMENT RADAR LEVEL -3 (KPIS MONITORING)

The selected KPIs for last mile deliveries focus on both operational efficiency and environmental impact. CO2 emissions per parcel provide insight into the ecological footprint of delivery operations. The mobility of delivery vehicles is tracked through distances travelled by vans and scooters in urban areas, reflecting fuel efficiency and routing effectiveness. Operational efficiency is assessed by the average number of deliveries per trip, indicating route optimization. Additionally, the effectiveness of parcel lockers is measured by the pickup and fill rates, evaluating customer interaction and locker utilization. Lastly, the reliability of the delivery process is gauged by the rates of successful first-attempt deliveries and failed deliveries, offering a clear view of delivery performance and areas for improvement. These KPIs together provide a holistic understanding of the efficiency and sustainability of delivery operations, feeding data driven decisions.

The Impact Assessment Radar used in the Thessaloniki Living Lab provides a comprehensive tool for evaluating the effectiveness and sustainability of logistics operations. Its added value lies in its ability to offer a multi-dimensional view of the impact of various initiatives, allowing for informed decision-making that aligns with both operational goals and sustainability targets. By visualizing key performance indicators and assessing the outcomes of different strategies, the radar supports continuous improvement and strategic planning. However, to further enhance its effectiveness, it would be beneficial to embody more models at Level 2 of the assessment. This would provide a deeper and more nuanced understanding of the impacts, enabling more precise adjustments and optimizations in logistics operations.

9. Evaluation/Impact assessment

9.1 KPIs

During the pilot phase, a series of KPIs were utilized as defined in task 3.2 to capture the dynamics of the last-mile delivery system based on the proposed innovations. The CO2 emissions per parcel (g/parcel) KPI is crucial for quantifying the environmental impact of delivery operations by measuring the amount of carbon dioxide emissions produced per parcel delivered. This KPI is vital for assessing the carbon footprint, setting sustainability goals, tracking progress in emissions reduction, enhancing operational efficiency, and ensuring compliance with environmental regulations. The choice of the parcel unit as the basis for this measurement allows for clearer scaling of operations and innovative solutions, compared to other unit bases.

The average number of kilometers per vehicle (Km/vehicle) KPI indicates the efficiency and effectiveness of route planning and vehicle utilization by measuring the average distance traveled by each delivery vehicle. This metric is essential for route optimization, cost management, fleet management, and performance benchmarking, helping organizations minimize travel distances, fuel consumption, and maintenance costs while ensuring optimal fleet utilization. However, this KPI alone may not fully capture the overall dynamics of delivery efficiency, particularly concerning kilometers driven. To obtain reliable analytics on transportation costs and overall spending in this category, it is recommended to also consider the total kilometers per day. Additionally, unitary kilometers per delivery can provide crucial quantitative metrics for decision-making by both companies and policymakers. An increase in kilometers per route might necessitate larger fleets, consequently raising operational labor costs.

The average deliveries per trip (parcels/route) KPI measures the average number of parcels delivered per trip by a delivery vehicle, offering insights into delivery efficiency and productivity. This KPI supports productivity measurement, resource allocation, cost efficiency, and customer satisfaction. Optimizing the number of deliveries per trip can enhance operational performance and reduce delays. The use of a locker network facilitates carrying and delivering more parcels on single routes. If a fixed number of deliveries per trip is considered, an alternative KPI, such as the average kilometers per additional delivery, may be used to better capture the dynamics.

The parcel lockers pickup rate/retention time (B2C) (mins/parcel) KPI measures the average time a customer takes to pick up a parcel from a locker in a B2C context. This indicator is critical for evaluating customer convenience, service efficiency, operational planning, and identifying areas for improvement to enhance the pickup process and overall customer experience. It is closely related to the profitability of parcel lockers and the acceleration of depreciation costs.

The parcel lockers fill rate (B2C) (%) KPI measures the percentage of occupancy of parcel lockers, indicating how often and fully the lockers are used. This metric is crucial for assessing capacity utilization, demand planning, cost management, and service optimization. Understanding utilization rates helps businesses better plan the location and number of parcel lockers, ensuring high utilization and efficient service delivery. This KPI complements the parcel lockers pickup rate/retention time KPI.

Collectively, these KPIs provide a comprehensive view of delivery operations, enabling businesses to make informed decisions to improve efficiency, reduce environmental impact, and enhance customer service.

9.2 The AS-IS situation

The evaluation and impact assessment of the pilot phase employ a set of KPIs defined in Task 3.2 to analyze the effectiveness of the proposed innovations in last-mile delivery systems. These KPIs include CO2 emissions per parcel, average kilometers per vehicle, average deliveries per trip, parcel lockers pickup rate, and fill rate, among others. They provide a quantitative basis for understanding various aspects such as environmental impact, route efficiency, customer service, and operational performance. The KPIs are measured using data sourced from the ACS database and supported by various models and tools such as the Agent-Based Model, Facility Location Model, and Impact Assessment Radar. Table 12 presents the "AS-IS" KPIs for Thessaloniki's living lab, detailing the current metrics, baseline measurements, and the supporting tools from the URBANE platform that assist in assessing and optimizing last-mile delivery operations. This comprehensive evaluation framework aims to identify areas for improvement, enhance sustainability, and optimize the logistics infrastructure for more efficient and effective city logistics solutions.

TABLE 12 : AS-IS KPIS OF THESSALONIKI LL

KPI name	Measurement unit	Data source	Baseline	Support from URBANE platform/models/other tools	Comments
CO2 emissions	g per parcel	ACS db	0.648	Agent-based Model, Facility location Model, Impact assessment Radar (Level 3)	The aim is to minimize route km for home delivery and replace it with walking distance to reach the locker. Also putting multiple parcels at one place.
Average number of km per Delivery	Km per parcel	ACS db	3.63	Impact assessment Radar (Level 3) Agent-based Model, Facility location Model,	In a route that can deliver e.g. 10 parcels at once the total km driven expected to be reduced
Average deliveries per trip	Parcels per route	ACS db	37	Impact assessment Radar (Level 3)	This KPI also expected to be improved as the per visit

KPI name	Measurement unit	Data source	Baseline	Support from URBANE platform/models/other tools	Comments
				Agent-based Model, Facility location Model,	delivery (on locker) will be increased
Parcel Lockers pickup rate (B2C)	Mins per parcel	ACS db	1123	Impact assessment Radar (Level 3) Agent-based Model, Facility location Model	The time that a single parcel stays on a locker is critical to the overall utilization of the lockers
Parcel Lockers fill rate (B2C)	%	ACS db	4.15%	Agent-based Model, Facility location Model, Impact assessment Radar (Level 3)	The aim of this KPI is to utilize the locker space as much as possible
Rate of successful delivery from 1st attempt	%	ACS db	82	Impact assessment Radar (Level 3) Agent-based Model, Facility location Model,	The goal of this KPI is to reduce failed deliveries even from the first attempt
Number of freight vehicles of All last mile providers on the network	n. Vans	ACS db	720	Impact assessment Radar (Level 3) Agent-based Model, Facility location Model,	The goal is to reduce the number of vehicles operate in the city

TABLE 13 : SDG KPIS

KPI name	Measurement unit	Data source	Baseline Value	Comments
Personnel turnover	%	ACS	40%	D Parcel lockers are likely to reduce personnel turnover as they make last-mile delivery tasks more manageable. Safer and more comfortable working conditions, thanks to the automation and convenience of parcel lockers, can lead to increased job satisfaction and retention.
Average salary	€	Gov.gr	1187€	While parcel lockers might not directly influence average salaries, they could lead to more efficient operations, allowing companies to optimize labour costs. With fewer manual deliveries needed, savings could potentially be redirected to improve wages or other employee benefits.

Education level	%	ACS	Primary and Secondary education: 76.51%, Higher education: 10.51%, Post-secondary Education or Master 12.83% Doctorate: 0.15%	The shift towards a parcel locker alliance network not only reduces the demand for traditional courier roles but also positively impacts the Education KPI. As the network increasingly relies on digital infrastructure, there is a growing need for IT professionals, logistics coordinators, and data analysts, all of which typically require higher levels of education and specialized skills.
Gender diversity	%	ACS	79% males / 21% fem	Parcel lockers could improve gender diversity by making delivery roles less physically demanding, which might attract more female workers. The automation and reduced need for heavy lifting or extended physical exertion could create a more gender-neutral job environment.
Percentage of self-employed workers	%	ACS	0%	The use of PI- led parcel lockers alliance network may reduce the need for self-employed workers (such as gig economy couriers) by consolidating deliveries in central locations. This could lead to a more stable, employed workforce rather than relying on self-employed contractors.
Percentage of part-time workers	%	ACS	39%	Parcel lockers could lead to a more stable workforce with regular hours, potentially decreasing the percentage of part-time workers. The efficiency gains from automated lockers could support the transition to more full-time roles.
Precariousness rate	%	ACS	0	Parcel lockers can help maintain or further reduce precarious work by providing more stable employment opportunities. The reduction in manual delivery tasks can support a more secure job (less km driven) environment with predictable hours and duties.
Flexibility of working hours	Yes/No	ACS	No	The alliance network inherently promotes flexibility. Freelancers can choose when and where to pick up deliveries from lockers, working as much or as little as they prefer. This model addresses the inflexibility of traditional roles by leveraging the

				decentralized nature of parcel lockers, thus providing significant work-hour flexibility.
Percentage of remote work	%	ACS	1-2%	The introduction of a parcel locker alliance network reduces the demand for traditional courier roles as the need for door-to-door deliveries decreases. Instead, this shift creates new opportunities for IT professionals and educated staff who manage and maintain the digital infrastructure that supports the network. Jobs in logistics coordination, software development, data analysis, and customer support become more prominent, reflecting a move towards a more skilled workforce. This change aligns with the broader trend of automation and digitalization, where physical tasks are increasingly supplemented by roles that require higher education and technical expertise.

10.Implementation Results

The analysis of urban logistics solutions in Thessaloniki is structured around four distinct scenarios , each progressively integrating more collaborative and technologically advanced approaches to last-mile delivery. These scenarios are designed to evaluate the impact of various logistics strategies on key performance indicators such as transportation costs, labor costs, and CO2 emissions per parcel and they reflect the demonstrated use cases. The purpose of this analysis is to provide a clear understanding of how each incremental innovation affects the efficiency and sustainability of urban logistics operations, both within the Municipality and the broader Agglomeration of Thessaloniki. The analysis based on the Thessaloniki DT for urban logistics (CERTH) and the data provided by ACS, RCM, and processed from the URBANE models.

The **baseline scenario (AS-IS)** represents the current state of logistics operations, where each delivery company operates independently without shared resources or coordinated efforts. This scenario serves as the control case, providing a benchmark against which the effects of subsequent innovations can be measured. In this setup, transportation and labor costs are relatively high due to the lack of optimization, and CO2 emissions per parcel are at their peak due to inefficient route planning and vehicle utilization.

In the **second scenario**, **individual locker networks (use case -1)** are introduced, allowing for a more efficient distribution of parcels by consolidating deliveries to central locations rather than multiple individual addresses. This scenario begins to show the benefits of resource optimization, with a significant reduction in both transportation and labor costs, as well as a decrease in CO2 emissions per parcel. The introduction of lockers reduces the number of trips required, thereby decreasing fuel consumption and operational expenses.

The **third scenario** builds on the locker network by implementing an **alliance locker network (use case -1)**, where multiple logistics providers collaborate to use a shared network of lockers. This scenario represents a more advanced level of integration and cooperation among last-mile delivery companies, leading to further reductions in costs and emissions. The shared network not only optimizes the use of locker infrastructure but also enhances route efficiency, as deliveries are pooled together, minimizing redundant trips.

The **final scenario** involves the implementation of an **UCC (use case -2)**, which acts as a centralized hub for all last-mile deliveries in the region. The UCC scenario is the most integrated and comprehensive approach, combining the benefits of the locker alliance network with additional efficiencies gained from centralizing operations. In this scenario, eLCVs are employed for final deliveries, further reducing CO2 emissions. The UCC also enables dynamic routing adjustments based on real-time traffic data, ensuring that routes are not only the shortest but also the most time efficient.

In addition to the digitally demonstrated outcomes, we also gathered real measured KPIs from the Thessaloniki Living Lab operations, providing tangible evidence of the impact of the implemented logistics solutions. Among these KPIs, the **Parcel Lockers Pickup Rate (retention time)** showed a **decrease of 10.2%** in the ILN scenario, indicating that parcels are being collected faster as network get more dense, which is critical for maximizing the turnover and utilization of the lockers. A quicker pickup rate directly correlates with improved efficiency in parcel handling and increased availability of locker space for new deliveries.

The **Parcel Lockers Fill Rate (B2C)** demonstrated a significant improvement (Figure 34), particularly in the ILN scenario, where the **fill rate surged by 606%.** This dramatic increase highlights the success of optimizing locker utilization, ensuring that each locker is used to its full potential, which in turn reduces the need for additional infrastructure and lowers operational costs.

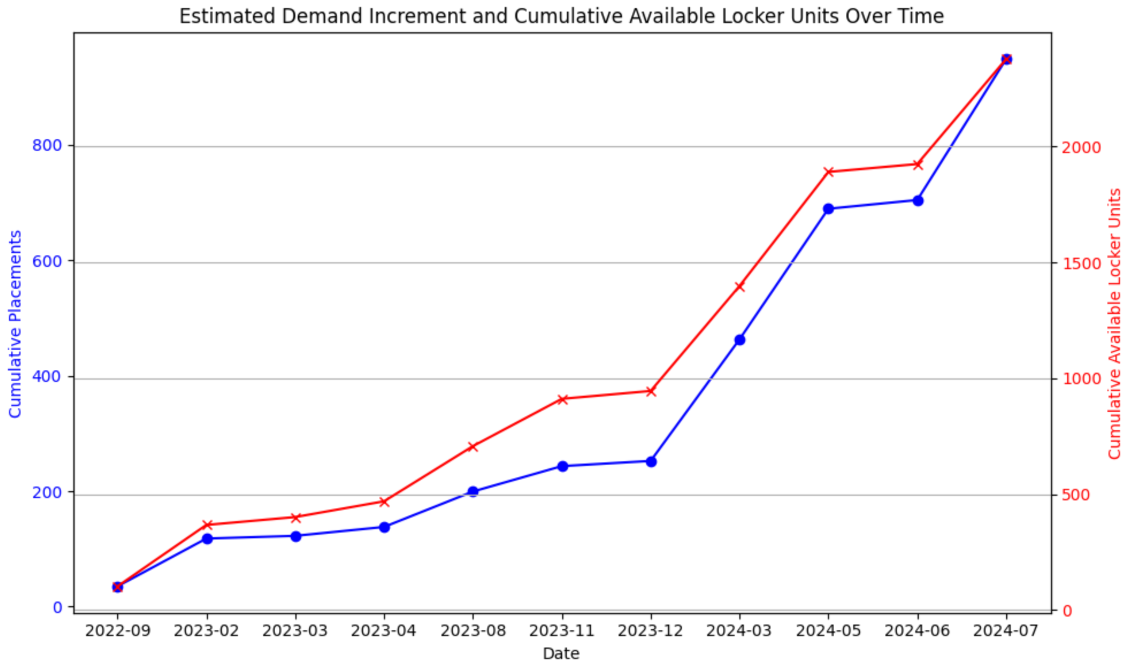

FIGURE 34: LOCKER AVAILABILITY AND DEMAND ON SELECTED LOCKERS IN THE PERIOD SEP-2022 TO JUL-2024

The analysis conducted across these four scenarios aims to provide a detailed comparison of the potential impacts of different logistics strategies on urban transport efficiency and environmental sustainability. By systematically assessing the outcomes in both the Municipality and Agglomeration of Thessaloniki, the analysis highlights the scalability of these solutions and their potential to significantly reduce operational costs and carbon footprints across different urban settings.

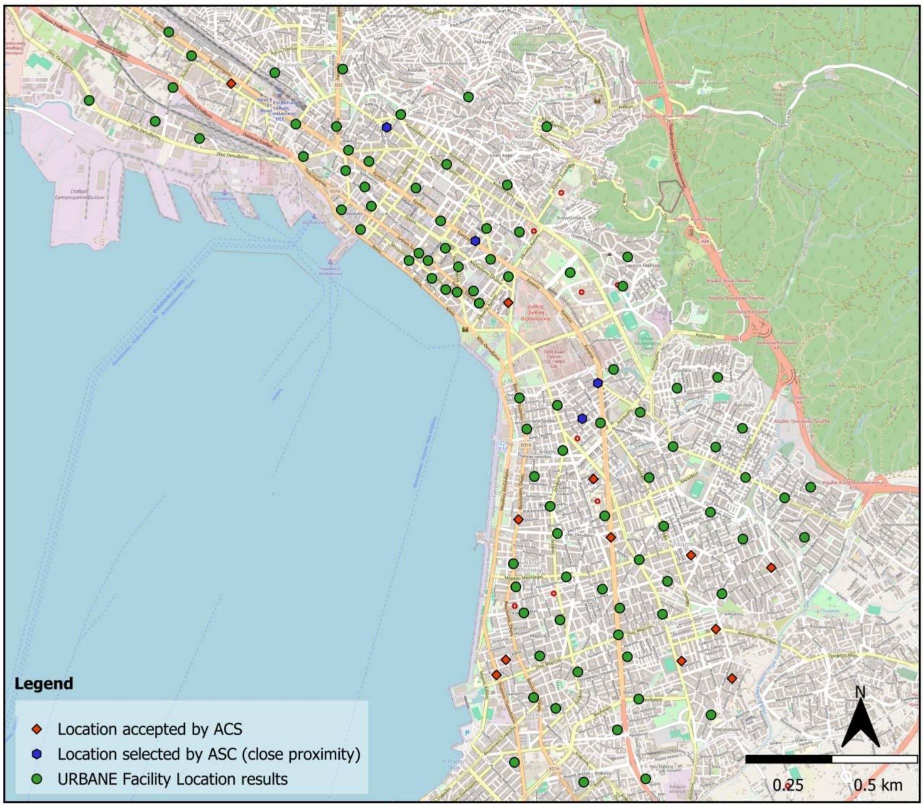

FIGURE 35: THE ACS LOCKER NETWORK IN AUGUST 2024 AS RESULT OF URBANE ANALYSIS

Based on the Figure 35, it is evident that the URBANE project has made significant steps in optimizing parcel locker locations across Thessaloniki. Out of the 100 locations proposed to ACS, 11 have already been adopted into their operations, with an additional of 5 being selected in very close proximity to the recommended points. This demonstrates ACS's commitment to enhancing their logistics network through strategic placement of lockers according to research results. Notably, one of these adopted locations has also been integrated with the blockchain solution developed by the URBANE project, effectively demonstrating the feasibility and benefits of a shared locker system. This integration highlights the potential for innovative technologies to create more efficient and collaborative urban logistics solutions.

10.1 CO2 Emissions per Parcel

The reduction in CO2 emissions per parcel is another critical benefit observed as more collaborative logistics solutions are implemented. In the Municipality of Thessaloniki, CO2 emissions drop by 47.1% when moving from the baseline to the locker scenario, further decreasing by 22.1% with the alliance locker scenario, and achieving a total reduction of 88.6% with the UCC scenario. In the Agglomeration, the baseline to locker transition results in a 51.7% reduction, with an additional 24.3% decrease in the alliance locker scenario, and a final reduction of 90.0% in the UCC scenario. The comparison between the Municipality and Agglomeration shows that while both areas see substantial environmental benefits, the Agglomeration once again leads with slightly higher reductions in CO2 emissions, underscoring the greater impact of integrated solutions when applied across a larger, more diverse geographic area.

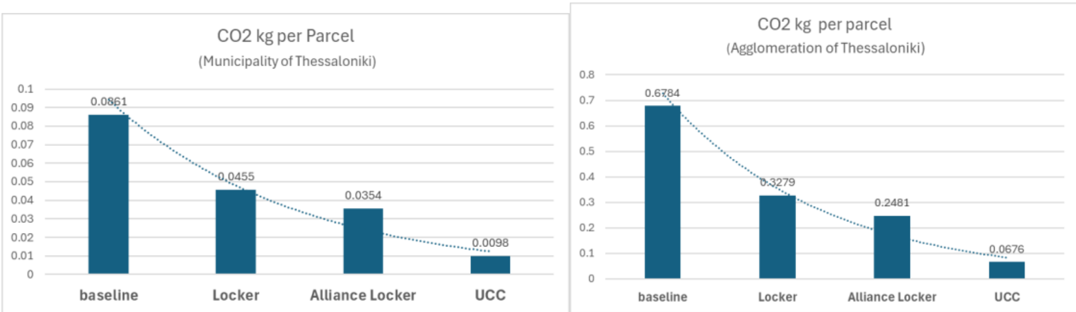

FIGURE 36: CO2 PER PARCEL IN A) AGGLOMERATION OF THESSALONIKI AND MUNICIPALITY OF THESSALONIKI IN DIFFERENT USE CASES

10.2 Transportation Costs

The analysis of transportation costs in both the Municipality and Agglomeration of Thessaloniki reveals a consistent trend of cost reduction as more integrated and collaborative logistics solutions are implemented. Starting from the baseline scenario, transportation costs significantly decrease with the introduction of lockers, followed by an additional reduction when moving to the alliance locker network, and finally reaching the lowest point with the UCC. Specifically, in the Municipality of Thessaloniki, the transition from the baseline to the locker scenario results in a daily cost reduction of approximately 44.3%, and further decreases by 31.3% with the alliance locker scenario, ultimately achieving a total reduction of about 86.5% in the UCC scenario. In comparison, the Agglomeration of Thessaloniki shows a similar pattern but with even greater reductions: transportation costs drop by 56.1% from the baseline to the locker scenario, followed by an additional 30.5% reduction with the alliance locker, and culminating in a total reduction of around 90.5% with the UCC implementation. This comparison indicates that while both regions benefit significantly, the Agglomeration experiences slightly more pronounced cost savings, possibly due to larger scale efficiencies.

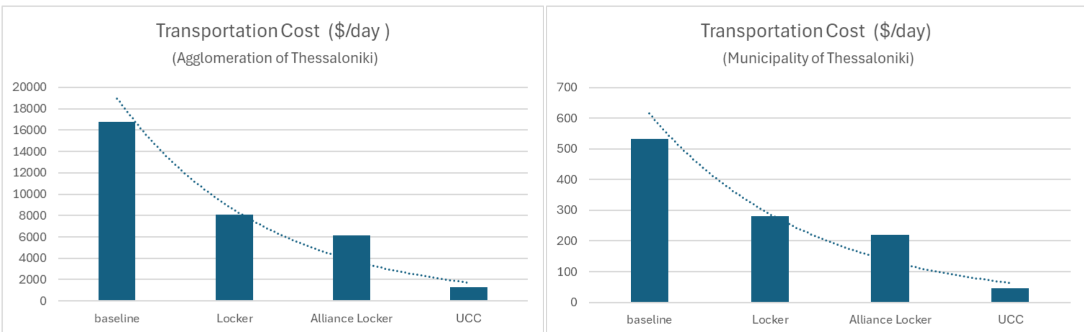

FIGURE 37: TRANSPORTATION COST PER DAY IN A) AGGLOMERATION OF THESSALONIKI AND MUNICIPALITY OF THESSALONIKI IN DIFFERENT USE CASES

10.3 Labor Costs

Labor costs follow a parallel downward trajectory across the scenarios in both the Municipality and Agglomeration of Thessaloniki. In the Municipality, labor costs decrease by 49.6% from the baseline to the locker scenario, and by another 39.6% when transitioning to the alliance locker scenario, leading to an overall reduction of 83.2% in the UCC scenario. For the Agglomeration, the reduction is even more pronounced, with labor costs decreasing by 45.4% from the baseline to the locker scenario, followed by an additional 41.1% reduction in the alliance locker scenario, and ultimately reaching an 88.5% reduction in the UCC scenario. Comparing the two use cases, it's evident that while both benefit from reduced labor costs, the Agglomeration achieves slightly higher reductions, again likely due to economies of scale and broader implementation areas.

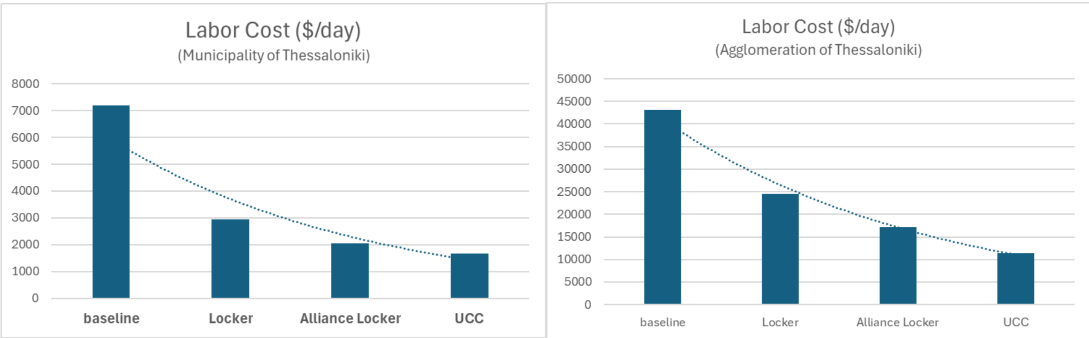

FIGURE 38: LABOR COST PER DAY IN A) AGGLOMERATION OF THESSALONIKI AND MUNICIPALITY OF THESSALONIKI IN DIFFERENT USE CASES

11.Lessons Learned

The implementation of innovative urban logistics solutions in Thessaloniki has yielded valuable insights and results that can guide future projects and policy developments. The impact evaluation was conducted in a systematic, stepwise manner, enabling a comprehensive analysis of the effects at each stage. These stages included the installation of independent locker networks by various companies, the development and exploitation of a locker alliance network, and the implementation of an UCC accessible to all last-mile providers utilizing a fleet of eLCVs.

Moreover, the deployment of critical infrastructure and advanced algorithms was essential to support and enhance both current and future services. The use of Agent-Based Modeling (ABM), Facility Location Model, traffic-aware dynamic routing, and blockchain technology played a crucial role in evaluating the proposed innovations from multiple perspectives. The integration of these cutting-edge technologies at the software and planning levels was instrumental in understanding the potential impact and interactions of the proposed solutions.

To achieve a robust evaluation, an ecosystem approach was adopted, encompassing the design, measurement, and implementation phases. This approach ensured that data collection and generation were handled meticulously, gathering multi-source data to create an accurate model of the complex urban logistics landscape.

The implementation of innovative urban logistics solutions in Thessaloniki has provided a wealth of insights that are critical for informing future initiatives. The following are the most important lessons learned from this project, highlighting the key successes, challenges, and strategies that emerged during the evaluation of each stage. These insights offer valuable guidance for the continued development and optimization of sustainable urban logistics networks:

- **Stakeholder Engagement and Adaptation:** Although initially hesitant, ACS ultimately agreed to participate in the locker alliance network after recognizing the potential for increased delivery efficiency demonstrated by the project's promising results. This shift highlights the critical importance of stakeholder engagement and the need for flexibility when adopting new technologies and practices. A key factor was the involvement of governance bodies such as the Region of Central Macedonia (RCM), which set regional goals for urban planning and SUMP vision, alongside research institutions like CERTH, which can model and quantitatively validate proposed plans to serve both industry needs and the public good. By providing solid quantitative results, coupled with the political directive to reduce e-commerce externalities in the region, ACS was persuaded of the broader benefits of exploiting solutions like a collaborative forwarding network in terms of reducing congestion, enabling greener deliveries, and minimizing noise and accidents.
- **Validation of Blockchain as a Trustworthy Technology Does Not Require Groundbreaking Restructuring of IT infrastructure:** The adoption of blockchain solutions during the pilot tests demonstrated the technology's capability in enhancing logistics transparency and security. One of the primary concerns for last-mile operators in adopting the alliance network model was the transparency in the use of shared assets, as well as the effort required to reshape their software logic to integrate with the blockchain. During the URBANE pilot actions, Thessaloniki LL demonstrated blockchain solutions and proved that, thanks to the generalized design of the module, the integration of ACS's tracking system was relatively straightforward.
- **Strategic Placement of Lockers Should Incorporate Multiple Data Sources and Stakeholder Needs:** The analysis of locker locations led to ACS adopting at least five of the proposed locker sites out of a hundred identified to date. This strategic placement not only serves ACS but also aligns with the broader objective of establishing a comprehensive locker alliance network, demonstrating the practical benefits of data-driven logistics planning. The analysis included detailed demand data provided by ACS, results from the stated preference survey conducted with potential customers, urban planning data such as available public spaces for locker installation, and CERTH's digital twin, which processes and fine-tunes the network configuration to achieve a cost-effective optimization outcome. Additionally, crucial inputs were provided by RCM, which set the strategic sustainability goals that need to be achieved.
- **Traffic-Aware Routing Improves Fleet Management Operations:** The traffic-aware dynamic routing module showed promising results, with early tests indicating up to a 15% reduction in route time. These technologies have proven to be valuable additions to urban logistics operations. The data used for traffic-aware dynamic routing was a joint effort between ACS, CERTH, and RCM. Specifically, ACS provided operational data to demonstrate the algorithm, while the traffic layer was supplied by CERTH and RCM, based on data collected by CERTH through the THESSM@LL (Thessaloniki Smart Mobility Living Lab), including sources from car floating data, Bluetooth devices, and road loops. This approach underscores the importance of integrating multiple stakeholders via the ecosystem approach (Living Labs) to exchange knowledge and improve operational efficiency.
- **Incremental Implementation Yields Manageable Insights:** By evaluating the impact of each stage separately, the project was able to identify the specific benefits and challenges associated with each innovation. This stepwise approach facilitated a manageable implementation and assessment process, ensuring that the results of each phase were well understood before

advancing to the next stage. Additionally, it helped to comprehend the trade-offs involved in transitioning from lightweight strategies to more radical and progressive ones. This method made it easier to identify the barriers encountered on the path to establishing a fully collaborative Physical Internet urban logistics network, as well as the costs and effects of decarbonization.

12.Conclusions

The Thessaloniki Living Lab during URBANE project has provided and gained valuable insights into the complexities and opportunities within urban logistics. By integrating innovative models and technologies, such as the Facility Location Model, Traffic-Aware Dynamic Routing, and Blockchain solutions, the project has demonstrated significant improvements in last-mile delivery efficiency, environmental sustainability, and stakeholder collaboration. The successful implementation of these solutions has not only contributed to the overarching goals of decarbonizing urban logistics and enhancing service efficiency but also set a precedent for future urban logistics projects across Europe.

Despite the significant advancements made, the project encountered several limitations that warrant consideration in future endeavors. Firstly, the data input requirements for the various models used, particularly the Facility Location Model, were extensive and required considerable effort to organize and standardize. This complexity occasionally delayed the decision-making process and required additional resources to manage. Secondly, the dynamic nature of urban environments posed challenges in maintaining the accuracy of real-time traffic data, which is critical for the Traffic-Aware Dynamic Routing system. Although the system performed well, it was often dependent on the reliability and coverage of external traffic data sources, which were not always consistent.

Furthermore, the blockchain solution, while effective in enhancing transparency and trust among stakeholders, faced challenges in scalability and adaptability across different logistics service providers (LSPs). The diversity in data formats and operational processes among LSPs made the integration process more complex and time-consuming than initially anticipated. Additionally, the pilot scale of the project, while providing valuable insights, limits the generalizability of the results to larger, more complex urban environments.

Based on the experiences and findings of the Thessaloniki Living Lab, several recommendations can be made for future projects and implementations. Firstly, it is essential to simplify and streamline data input processes for decision-support models. Developing standardized data templates and automation tools can significantly reduce the time and effort required for data preparation, enabling faster and more efficient decision-making.

Secondly, to enhance the effectiveness of the Traffic-Aware Dynamic Routing system, future projects should consider investing in the development of more robust and localized traffic data sources. Collaborating with local authorities and leveraging emerging technologies like IoT (Internet of Things) sensors could provide more accurate and granular traffic data, further improving routing efficiency.

For the blockchain solution, a modular approach is recommended, allowing for greater flexibility and adaptability across different LSPs. By creating a standardized yet flexible framework, the blockchain system can be more easily integrated into various operational environments, facilitating broader adoption and collaboration among stakeholders. Additionally, the development of comprehensive training programs for LSPs and other stakeholders can help mitigate the challenges associated with the adoption of new technologies, ensuring smoother transitions and more effective implementation.

Looking ahead, several areas of future work have been identified to build on the successes of the Thessaloniki Living Lab. Expanding the scope of the project to include a larger geographic area and more diverse urban environments would provide valuable data on the scalability and adaptability of the proposed solutions. Future projects should also explore the integration of additional technologies, such as AI-driven predictive analytics and machine learning, to further enhance the accuracy and efficiency of logistics operations.

Moreover, the development of a comprehensive framework for multi-stakeholder collaboration is critical. This framework should include standardized protocols for data sharing, communication, and decision-making, ensuring that all stakeholders can effectively contribute to and benefit from the system. The integration of sustainability metrics into all levels of decision-making processes is also recommended to ensure that environmental considerations remain at the forefront of urban logistics planning.

Lastly, there is a need for continued research into the social impacts of these innovations, particularly concerning consumer behavior and acceptance of new delivery methods, such as parcel lockers. Understanding these social dynamics will be crucial for the successful implementation and long-term sustainability of urban logistics solutions.

In conclusion, while the Thessaloniki Living Lab has made significant strides in improving urban logistics, the lessons learned and the limitations encountered provide a roadmap for future work. By addressing these challenges and building on the project's successes, future initiatives can further advance the field of urban logistics, contributing to more sustainable, efficient, and collaborative urban environments.

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Project Coordinator: **Ioanna Fergadiotou**
ioanna.fergadiotou@inlecomsystems.com

Project Manager: **Maria Kampa**
maria.kampa@inlecomsystems.com

Communication, Dissemination, and Upscaling Manager: **Antonios Tsiligiannis**
atsiligiannis@polisnetwork.eu

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