D3.4 Madrid Value Case

Final demonstrator

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Acronyms

Acronyms	Explanation
ABM	Agent based model
AECOC	Spanish Association of Manufacturers and Distributors
API	Application Programming Interface
ATA	Actual time of arrival
BAU	Business as usual
B2B	Business to business
B2C	Business to consumer
CLOGIN	CityLogin (Project partner)
CoP	Communities of Practice
COPERT	EU standard vehicle emissions calculator
CO2-eq	Carbon dioxide equivalent
DDDAS	Dynamic Data-Driven Application System
DT	Digital Twin
EISMEA	European Innovation Council and SMEs Executive Agency
EIT	European Institute of Innovation and Technology
EMT	Madrid Public Transport company
ES	Spain (acronym in Spanish)
ETA	Estimated time of arrival
FUA	Functional Urban Area
GDP	Gross domestic product
GitHUB	Web-based hosting service for software development projects
INLE	Inlecom (Project partner)
KPIs	Key Performance Indicators
LEZ	Low Emissions Zone
LL	Living Lab

Acronyms	Explanation
LL1	Living Lab 1 (Madrid)
LMT	Last Mile Team (Project partner)
LSP	Logistic Service Provider
MAD	Madrid
MVP	Minimum Viable Product
ST	Sub Task
STAR	Sustainability Tool for the Appraisal of Road Projects
TENT-T	Trans-European Transport Network
UCC	Urban consolidation centre
UPM	Universidad Politécnica de Madrid – Madrid Polytechnic University (Project partner)
URL	Uniform Resource Locator (colloquially termed a web address)
UVAR	Urban Vehicle Access Regulations
WP	Work Package
ZLC	Zaragoza Logistic Centre (Project Partner)

Executive Summary

In Madrid, as many other big cities, city logistics is one of the main contributors to its economic activity as well as one of the main challenging sectors due to the various impacts that it generates. Today, most of the urban logistic flows are originated in peripheral municipalities in the metropolitan area.

The overall mission and goal of Madrid Living Lab is to help improving urban logistics by using a digital twin model fed by data coming from a real urban consolidation centre pilot placed at the Plaza Mayor parking facility (city centre) from which to make last mile delivery to the city centre by using electric vehicles. This pilot has been running between October 6th 2021 (start of operations) and May 31st, 2023 (end of operations), in a facility managed by EMT Madrid, and whose Logistic Service Provider (LSP) has been CityLogin (also LEAD partner).

The objective of this deliverable is to report modelling activities and data sources used in the Madrid Living Lab, including a description of the Pilot in Madrid following the "minimum viable product" approach and conceptual diagrams to detail the stakeholders involved and the different interactions for the "BAU" (Business as usual, how it is made today) and "UCC" (With an Urban Consolidation Centre, how we would like it or "to be" scenarios.

The deliverable includes detailed description of Madrid LL Digital Twin as well as the finalization of the modelling. It also includes the verification process for validating the simulation scenarios and the KPIs baseline measurements. The results of the final KPIs show very good results in terms of savings of Km driven (up to 33% reduction) and driving time (up to 14% reduction), among other ones, and beyond the evident reduction of emissions due to the use of electric vehicles. This final KPIs are aligned with the previous measurements presented in D3.3.

The development of the pilot and the Digital Twin (DT) have provided key learnings for scaling and transferring this solution to other locations. It helped identify the administrative procedures, the technical arrangements for the parking as the electric supplier. The LSP has been already able to test the new business model and visualize the operational improvements and the challenges experienced to make the new business model more efficient based on the abovementioned "what if" scenarios, avoiding taking risky decisions based on the modelling from the DT.

The deliverable also explains how the DT provides insights on the sustainability performance of the two scenarios implemented in LL1. After verifying the results with the business owners for the BAU and UCC scenarios, the LL1 has simulated hypothetical "what if" scenarios based on the four alternatives defined in D1.4, (2021) and the users' needs..

D3.4 also includes the description of the different exchange sessions with the LL1 Community of Practice, including the final workshop. In total there has been 4 workshops which have been key to define social KPIs, and to validate the user acceptance, the pilot scope and the DT.

Amongst the most relevant outcomes and conlusions from the interactions with the Community of Practice the following could be pointed out.

- Wide user acceptance: there is a common agreement in the feasibility of the Madrid LL approach
- Regarding the Real Pilot it is advisable to start as soon as possible to overcome administrative issues
- Matching the needs of the local administration with the requirements of the logistics operator is important. Idea of being sustainable at all levels
- It is advisable to take advantage of the policies established in the city (regulatory framework, strategies, etc.) to promote this type of activities
- Establishment of objectives and KPIs must be useful for the operator
- Collaborative scenarios do not impact the transport efficiency and emissions while the service quality is improved
- Synchronous planning: manufacturers may benefit from real-time digital twins to enable collaborative distribution schemes with local businesses
- Effective collaboration between public and private entities has been identified as a key strength of Madrid LL.

Finally, the involvement of Panasonic as a global manufacturer allows to explore the real impact of opening the direct e-commerce channel with their customers. Moreover, it helps identify the data agreements for building the DT with data from all the stakeholders involved in the last mile operation of the supply chain. It has also helped understanding the impact of different distribution models and last mile operations and estimating the emissions they produce.

1 Introduction

1.1 Scope and objectives

This deliverable provides an updated and final version of the activities and results presented in D3.3. It discloses the last release of the demonstrator, including user acceptance, recommendations and lessons learned from the implementation of the new business model and the digital twin. The report includes an update of the final artefacts, the models of the LL1 Digital Twin and the configuration of the LL1 in the LEAD Digital Twin. This D3.4 assesses the sustainability impact of the new business model based on comparing the KPIs for the before and after network configurations. Finally, it describes a set of explanatory simulation what-if scenarios demonstrating the potential of digital twins for decision-making from the business users' and policymakers' perspectives. Table 1 contains the deliverable adherence to LEAD LL objectives covered during the final phase.

Table 1. Deliverable's adherence to LEAD objectives and Work Plan

LEAD GA Requirements	Section(s) of the present deliverable addressing LEAD GA	Description
ST3.2.1 Preparation. MVP Specification and Modelling.	Chapter 2. Madrid pilot Chapter 5. Panasonic case	This section contains a description of the Pilot in Madrid following MVP approach and conceptual diagrams to detail the stakeholders involved and the interaction (based on agent-based models' concept) for the "BAU" and "What if" scenarios. Chapter 5 describes how Panasonic, a global company explores the impact the e-commerce channel based on the DT virtual environment and how a DT can help improve last-mile operations.
	Chapter 3 Simulation Environment	This section contains conceptual diagrams of the "BAU" and "What if" scenarios following the MVP approach. It includes detailed descriptions of the models developed by the LL and those configured from the Generic Reference Model Library.
ST3.2.2. Digital Twin Verification.	Chapter 3, Simulation environment and Chapter 4. KPIs measurements	This section describes the verification process for validating the simulation scenarios and validating the KPIs baseline measurements.
	Chapter 4. KPIs measurements	This Chapter reports the results of the KPIs described in D3.1 for the baseline measurements.

LEAD GA Requirements	Section(s) of the present deliverable addressing LEAD GA	Description
ST3.2.3. Real-life implementation.	Chapter 2. Madrid Pilot	This section reports all the details regarding the physical implementation of the pilot.
ST3.2.3. Real-life implementation.	Chapter 3. Simulation environment	This Chapter reports the modelling conditions/ assumptions; the data sources and data ingested used for calculating the baseline KPIs measurements and verifying and validating the DT.
	Chapter 7. Next steps and Chapter 8. Summary and lookout	Update of the implementation plan reported in the D3.1 and description of the next steps for finishing the DT and real experiments.
ST3.2.4 Evaluation/Impact Assessment:	Chapter 4. KPIs measurements Chapter 5. Panasonic case Chapter 6. Business value validation and user acceptance	Final KPIs values and validation with the Community of Practice

1.2 How does this deliverable relate to other deliverables?

This report is the updated version of the D3.3 and contributes to the D3.2 and D3.15.

1.3 Structure of the document

The document provides an overall vision of Madrid physical Pilot, its description, implementation and main characteristics. It also provides a description of the different workshops that have been carried out to assess, with the community of practice, the different steps and achievements. The document also explains how the simulation environment has been designed and developed, including the models and connectors, both the real (business as usual) and what if scenarios, as well as the KPIs to monitor the performance.

The document also includes a specific chapter related to Panasonic contribution to Madrid LL.

Last but not least, the document includes the business value validation and user acceptance, and a last chapter with learnings and recommendations and a final outlook.

- Chapter 1: Introduction
- Chapter 2: Madrid pilot
- Chapter 3: Simulation environment
- Chapter 4: KPIs measurements
- Chapter 5: Panasonic case
- Chapter 6: Business value validation and user acceptance
- Chapter 7: Learnings and recommendations
- Chapter 8: Summary and outlook

2 Madrid pilot

2.1 Description

The overall mission of Madrid Living Lab is to help improve urban logistics in the city for the sake of all citizens and stakeholders. To do so, the Madrid pilot has successfully deployed an urban consolidation centre (UCC) at the Plaza Mayor parking facility (city centre) from which to make last-mile delivery to the city centre using electric vehicles.

As reported in the D3.3, the Madrid pilot involves the company CityLogin (the freight operator) and EMT (the public entity in charge of providing public urban transport services and managing public infrastructures such as private car parkings). This demonstrator served as a testbench to validate an innovative business model based on dividing the conventional configuration with direct shipments into a two-echelon network (direct shipments from San Fernando to an EMT's parking in Plaza Mayor Madrid using electric vans and from the UCC to the final consumers with round-trips with multiple pickup delivery points using E-trikes (Figure 1).

Figure 1. LL1 Madrid: "UCC" scenarios (source: (LEAD D3.3, 2022))

2.2 Pilot activities

2.2.1 Pilot implementation

One of the first steps as soon as the project started on the June 1st 2020, was to look for a suitable location for the setting of an urban consolidation centre, UCC, within the city centre (inner ring road of the city) among the network of potential public parking facilities managed by EMT (D1.4, 2021).

The Pilot started its operations on October 6th, 2021. Previously, Living Lab Madrid conducted some preparatory work (administrative, adaptation of the infrastructure, installation of electricity charging modules, etc.) (D3.3, 2022). Regarding the charging infrastructure, CityLogin installed two Mennekes type chargers for the e-vans, and 10 shucko type chargers (conventional) for the light three wheelers.

For the use of the EMT facilities, it was required the signing of a public-private agreement between CityLogin and EMT which states that CityLogin will use this facility for free during the LEAD project life. Afterwards, it is expected the pilot continuous working. In this way, once the LEAD project is finished, CityLogin and EMT will have to sign a new agreement/contract under a commercial basis that will include the different conditions and a monthly fee. CityLogin contemplates expanding the offer of services from the microhub such as the installation of lockers or collection points for e-commerce packages; these points will always be duly treated and agreed with EMT.

Since then, and until May 31st, 2023, when the pilot ented its operations, CityLogin has been operating two fully electric vans and seven electrical light commercial vehicles (three-wheelers). Early in the morning, the vans access the city centre from the San Fernando logistic hub, entering the Plaza Mayor parking. Once there, parcels are consolidated and cross-docked to electric light commercial vehicles (three-wheelers brand Scoobic Mini) used for last-mile delivery within the city centre (LEZ). Each day, seven rounds are created on average using the 100% of vehicles available in UCC. The vehicles have a capacity of 40 regular-size packages on average (Figure 2). Around 280 packages go through the UCC every day. Three people are employed as Dispatcher managers to support operations from Monday to Sunday between 08:00 am to 10:00 pm (D3.3, 2022).

Avg weight	Avg volume	Avg density
1 kg	0,036 m^3	28 kg/m^3

Figure 2. LL1: regular package representation

2.2.2 Madrid Living Lab workshops and events

Madrid Living Lab has organized four workshops with the Community of Practice (CoP) and other players. The main objective was to demonstrate the Living Lab (the Pilot and the digital twins), and to conduct different surveys to measure KPIs (see Section 4) and validate and test the user acceptance of the new business models (see Section 6 and Deliverable 3.15).

The first two workshops were organized in November and December 2020 (further information in D1.4), which allowed to present the project and to select the best scenario (evaluating different factors) which was the use of a UCC within the Low Emission Special Protection Zone “Madrid Distrito Centro” (Madrid Low Emission Zone).

Workshop 3: June 14th 2022

In addition to those ones, on June 14th, 2022, between 9:30 and 14:30, Madrid LL organized a public local workshop which included a technical visit to the Plaza Mayor logistics micro-hub operated by CityLogin that has been launched in the framework of the project. The Technical Visit in Plaza Mayor Microhub was welcomed by EMT representative Carlos Mateo and CityLogin representatives Daniel Latorre and Alfonso Medina. After the site visit, a subsequent working meeting (open to public) was organized at the Global Mobility Call conference[1], at IFEMA (Figure 3). There were 28 participants, including representatives from several municipalities (Madrid, León, Murcia), sector associations (CMTC – FENADISMER MADRID, AECOC, Asociación Empresa por la Movilidad Sostenible), companies (Capillar IT), and research (CIVINET Spain & Portugal and the Observatorio Movilidad Metropolitana) and the main aim of the workshop was to gather input from the different stakeholders regarding the approach towards the key performance indicators and how to assess the acceptance of the initiative

[1] *https://www.ifema.es/global-mobility-call*

Figure 3. View of the 3rd local workshop celebrated during the Global Mobility Call in Madrid (June 14th, 2022).

The working group meeting started with an introduction to LEAD project and Madrid Living Lab by Sergio Fernández (EMT). Then, Digital Twins and preliminary impacts results were shown by Ángel Batalla (LMT) and Alfonso Molina (CityLogin). Finally, the impact assessment methodology and selection of KPIs were described by José Manuel Vassallo (UPM). At the end, several questions were distributed to estimate the qualitative KPIs regarding quality of employment and quality of life resulting from UCC development in Madrid pilot. Working groups were also organized to collect ideas on how to encourage more sustainable behaviour in last mile logistics and solutions for better cooperation between stakeholders involved in last mile logistics.

The workshop was published in Madrid City Council diary, available at this link.

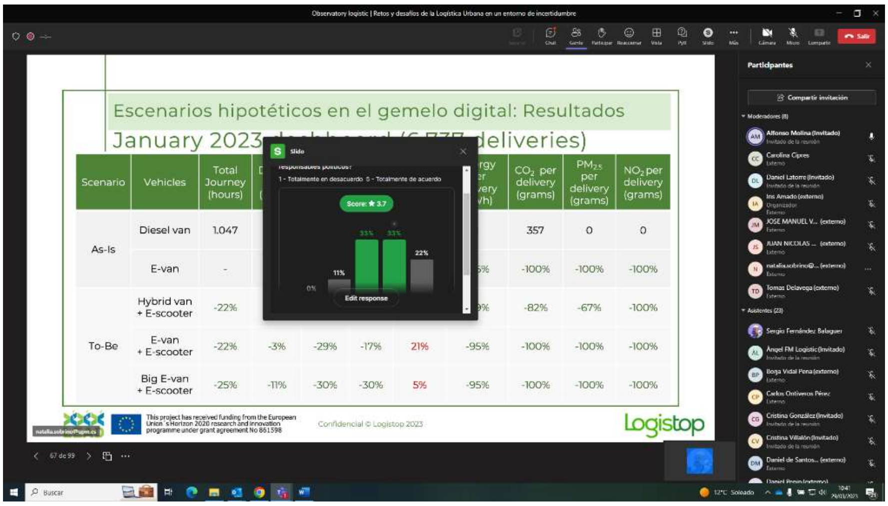
Workshop 4: Final Madrid LL workshop March 2023

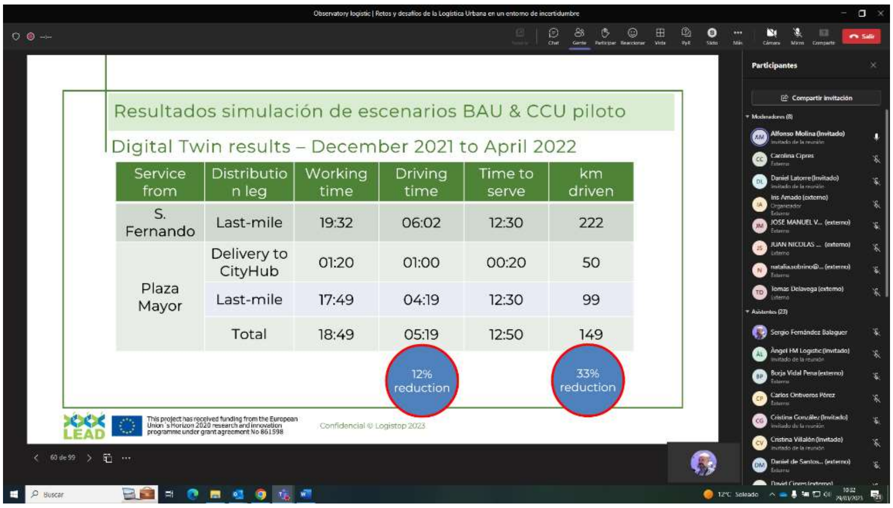
With the objective of validating the LEAD solutions (see Section 6 and Task 3.8), on March 29th, 2023, the Final Madrid LL workshop was conducted online as part of a logistics workshop organized by Logistop called "Observatory Logistic: Retos y desafíos de la Logística Urbana en un entorno de incertidumbre" with the introduction of: Tomás de la Vega from Logistop, Carolina Ciprés from ZLC, and Daniel Latorre from CityLogin Iberia; and the participation of LEAD partners: Alfonso Molina from CityLogin Iberia, José Manuel Vassallo from UPM, and Natalia Sobrino from UPM[2].

The main objective was to present the Madrid pilot in the LEAD project, to explain the functioning of the digital twin-based decision tool for the Madrid pilot, to show the economic, social and environmental impacts of the pilot and its scalability in the medium and long term, and to maintain an interactive exchange with workshop participants (Madrid stakeholders and CoP) by launching questions for the validation of the pilot and its impacts. To that end, the workshop started with the introduction and explanation of main objectives and the connection to Slido to conduct the validation survey by Natalia Sobrino (UPM). Then, introduction to LEAD project and Madrid Living Lab were done by Alfonso Molina (CityLogin). After that, Digital Twins and preliminary impacts results were also shown by Alfonso Molina (CityLogin). Finally, the impact assessment results, future estimates and scalability were described by Natalia Sobrino and José Manuel Vassallo (UPM). At the end of this part, validation questions were asked to the audience using Slido and an open debate was done at the end of the workshop based on the results from the survey.

The number of Final Madrid LL workshops' participants were 35 from different sectors. The attendees were categorized into five groups, which included public authorities (14%), researchers (21%), consultants (21%), logistics operators and shippers (17%), and other stakeholders (27%). The diverse backgrounds of the attendees provided a range of insights and feedback, which was critical for refining the solution being tested. By bringing together experts from various sectors, the workshop was able to provide a comprehensive Madrid value case validation (see Section 6).

[2] *https://logistop.org/descarbonizacion-y-transformacion-digital-definen-desafios-logistica-urbana/*





2.2.3 Conferences and Recognitions

It is worth mentioning that the LL1 has participated in several conferences and has been included as one of the Sustainable City Logistics best practices by the EIT urban mobility. Images and videos are available on the website (eitUrbanMobility, 2022). Among other dissemination events, Madrid LL has been presented in the Transport Research Arena 2022, Eurocities Mobility Forum 2022, Polis Annual Conference 2022, the MOVE21 technical webinar: Business models for consolidation hubs in February 2023, the International Urban and Regional Cooperation (IURC) programme exchange meeting in Melbourne, Australia, in March 2023, and many others. All the information is available in D4.4 (Communication and Outreach Activities – Period 2).

3 Simulation environment

The deliverables (D3.3, 2022) and (D2.2, 2023) introduce a detailed description of the LL1 digital twin models developed and used from the LEAD models' library, the data structures, the anonymization process and the wrapper functions implemented to connect the user with the digital twin and the different models automatically.

This section has three key objectives. First, to complement the previous deliverable D3.3 with an explanation of the final refinements needed to compare the sustainability performance of the pilot implementation after introducing the UCC in the parking of Plaza Mayor vs. the BAU scenario ("BAU" vs. "UCC" scenarios). Second, to define the different "what if" scenarios that can be simulated with the digital twin. Finally, present the results of the scenarios simulated with the digital twin.The were presented to policymakers and logistics operators to validate the digital twin as an enhanced decision support system to improve the decision-making process. In addition, it explains how the LL1 digital-twin has been integrated in the LEAD platform.

3.1 LL1 Madrid real scenarios

3.1.1 Description

For reproducing the logistics operations of the Madrid real scenarios (BAU scenario vs. UCC in the parking of Plaza Mayor scenario) in the Digital Twin, LL1 has taken a unique data input request to the user(s), using a two-step modelling approach that meets Madrid ambition and that integrates with the LEAD vision and could be easily extended to other cities (Figure 4).

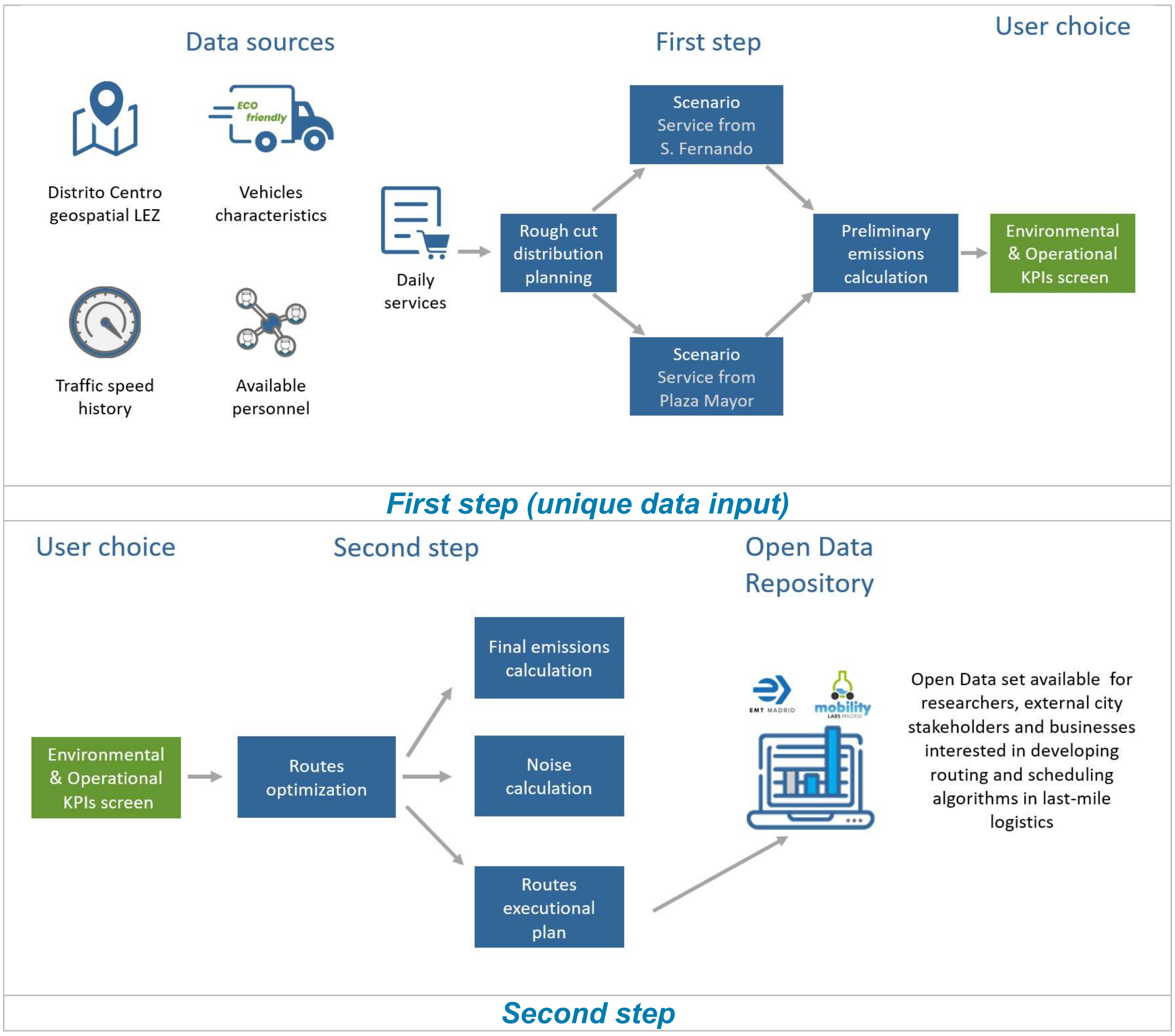


Figure 4. LL1 overarching scenario.

The first step is a rough-cut delivery planning to quickly evaluate the required resource in any two different scenarios (BAU vs UCC), followed by a vehicle emissions and energy consumption calculator of both. The user will receive a comparison table from LEAD Dynamic Data-Driven Application System (DDDAS) and decide to select which scenario will be implemented.

The second step is a route optimization of the selected scenario during step 1. It will provide step-by-step routes per vehicle, feed the vehicle emissions and energy consumption calculator to get more accurate results, feed the vehicle noise calculator, and give the logistics partner relevant, detailed data that will serve as the foundation to estimate some of the economic KPIs too.

The end of the second step, which is not represented in Figure 4~~,~~ will take the lists of 19 KPIs detailed in the D3.1 of both scenarios (BAU vs UCC) and feed the UPM STAR Sustainability model. It will allow comparing the sustainability assessment of the baseline scenario (BAU) with the sustainability assessment of the UCC scenario.

Finally, as mentioned above, during Phase C the models will respond to different “what if” scenarios.

3.1.2 Generic models and connectors

The tables below contain an updated summary of the models and connections of the LL1 digital twin pipeline already explained in (D3.3, 2022).

Table 2. Summary of the generic models developed in the framework of LL1.

Model	Description
2-Echelon_v2 model (ZLC)	This model allows estimating the resources needed (vehicles, drivers), total distance and delivery time per type of vehicle of 1-echelon network configuration or 2-Echelon network configuration. This model is useful when the user (LSP, shipper) aims to understand the impact of different scenarios with relatively low data granularity. The updated version and more detailed information are available in GitHub[3] and in the updated version of the (D2.2, 2022).
Noise Model (UPM)	The noise model is a simplified methodology that determines the percentage of residents in a given area exposed to noise emissions. This methodology comprises two interconnected models: a noise emission model from the vehicles used for goods delivery and a sound propagation model. The results of the noise emission models inform the propagation model, which determines the noise incidence level on the facades of residential buildings in the LL area. The methodology employs noise emissions from vehicles, as well as census, geographic, and cadastral open data, and step-by-step routes geospatial information by vehicle type, all fed by LMT Digital Platform. The model's output is the percentage of residents exposed to noise emissions relative to a reference threshold, and it will be used in the noise KPI. The model is available on GitHub, and additional information can be found in (D2.2, 2022).
STAR Logistics Model (UPM)	The STAR Logistics model evaluates sustainability by performing a multicriteria analysis with multiple inputs to compare the baseline and news delivery scenarios. UPM updated this model within the scope of the LEAD project. STAR Logistics will serve as an evaluation tool for the final assessment of the sustainability of the project's logistics solutions. The following steps are taken to define the STAR framework: (i) Data gathering and sustainability criteria definition, (ii) Updating expert panel criteria and (iii) Methodology application and reporting. Additional information about the model is available in (D2.2, 2022).

[3] *https://github.com/Horizon-LEAD/2echelon_v2*

GHG emission from EV	The methodology proposed for estimating the CO2eq emissions from electric vehicles is associated with the electrical mix used to produce electricity. The proposed method estimates the electric vehicles CO2eq emissions based on mean kWh consumed by each vehicle and the carbon intensity for the electricity generation (g CO2eq /kWh). In the case of Madrid Living Lab, the calculation is based on the report "Emisiones de CO2 asociadas a la generación de electricidad en España" (CITE) of the Spanish electricity system operation and transport company (Red Electrica de España) estimates the CO2eq (CO2 equivalent emission) emission factors associated with electricity generation power sources. These factors are constantly updated at the same time as the emissions inventory. More detailed information about the model can be found in (D2.2, 2022).

Table 3. Summary of the proprietary models integrated into the framework of LL1.

Model	Description
COPERT calculators	COPERT is the EU standard vehicle emissions and energy consumption calculator. LEAD uses COPERT in several LLs to estimate and compare the environmental impacts of implementing different scenarios. As an output, COPERT estimates: Energy consumption, GHG Emissions - CO2-eq, and Air pollution - [PM; NOx; VoC]. More detailed information about the model can be found in (D2.2, 2022).
Route Optimisation model	At the core of the model are road transport-specific Artificial Intelligence algorithms plus in-house developed, IP registered, tech stack. The core enables to build of Digital Twins of urban logistics networks in cities considering not only the technology but also driver working conditions and well-being. The model supports experiment, evaluate and fact-based decision making about different scenarios of scheduled, same-day and on-demand distribution operations without risk and with very low investment, resulting in fairer, smarter and greener urban logistics and last-mile delivery business models. It Is built to share information with all stakeholders and easily integrate other deep-tech solutions in Cognitive Systems, Big Data & Analytics, Predictive Models, Smart Contracts and other Blockchain applications, etc.

Table 4. Summary of the LL1 model connectors.

Model	Description
model1_LEAD_to_from_COPERT	It is a Python Jupyter notebook to connect any model1 outputs with COPERT further detailed in LEAD GitHub repository.2Echelon model and LMT engine use this connector to calculate the energy consumption and environmental KPIs for the Internal Combustion Engine vehicles (CO2, PM2.5, VoC).
model1_LEAD_to_from_EVCO2	It is a Python Jupyter notebook to connect any model1 or model 2 outputs with EVCO2 model, further detailed in LEAD GitHub respository. 2Echelon model and LMT engine use this connector to calculate the energy consumption and CO2 for electric vehicles.
LMT_LEAD_to_NOIS	It is an R script to connect the model1 output with the Noise Model. The connector reads, estimates, and transforms LMT output in the required format for Noise Model through some spatial procedures. More detailed information about the connector is in the LEAD GitHub repository

3.1.3 Data collection and anonymization

The input data required in the Madrid Digital Twin are as follows (see Figure 3):

- Vehicle characteristics
- Geospatial data
- Facilities data
- Other data

Vehicle characteristics

Table 5 shows the attributes of the characteristics of the vehicle used in the BAU scenario (D3.3, 2021) and UCC scenario that are common to 2-Echelon and Route Optimization models. The logistics service operator “CityLogin” provided such data.

Table 5. LL1 Vehicle used in the "BAU" and "UCC" scenarios.

Attributes	LL1 Madrid "BAU" scenario	*LL1 Madrid "UCC" scenario (Echelon-1)*	*LL1 Madrid "UCC" scenario (Echelon-2)*
VehicleTypeId	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Light Commercial Vehicles,Hybrid,N1-III,Euro 6 a/b/c	Three-wheeler, Electric, Cargo, Vehicle
Capacity	161 parcels	161 parcels	34 parcels
Velocity (km/h)	45	45	35
FixedCost	175 €	175 €	165 €
StartTime	09:00	09:00	09:00
EndTime	17:30	17:30	17:30
WorkBreakStart	13:30	13:30	13:30
WorkBreakEnd	14:00	14:00	14:00
WorkBreakDuration	00:30[4]	00:30[5]	00:30[6]

Geospatial data

Geospatial data is available in (D3.3, 2022)

Facilities data

Table 6 shows the minimum data characteristics of the San Fernando de Henares facility required by the underlying models.

Table 6. LL1 Facility in the "BAU" and "UCC" scenarios.

Attributes	LL1 Madrid "BAU" scenario	*LL1 Madrid "UCC" scenario (Echelon-1)*
Name	San Fernando	UCC Departure
Id	1	2
Country	ES	ES
Address	Avenida del Sistema Solar	San Felipe Neri
Zipcode	28830	28013
Coordinates	40.4504720,-3.494262	40.4161737, -3.7087409
Starting time	09:00	
Ending Time	17:30	0
Type		

[4] A WorkBreak of thirty minutes is taken in the time window 13:30 (not before) and 15:00 (not after)
[5] A WorkBreak of thirty minutes is taken in the time window 13:30 (not before) and 15:00 (not after)
[6] A WorkBreak of thirty minutes is taken in the time window 13:30 (not before) and 15:00 (not after)

Other data

This category represents the information used by specific models such as COPERT or EVCO2.

COPERT requires the monthly maximum and minimum temperatures, and the humidity of the city as well as the average peak and off-peak traffic speed and time share. This information is available in the (D3.3,2021).

EVCO2 requires a connection to the Spanish Electric Network Authority API[7] to collect the daily electricity generation source mix and the energy consumption in kWh of the vehicles to calculate the energy consumption and the generated CO2 equivalent for electric vehicles.

3.1.4 Definition of the modelling conditions

Available personnel

For planning the routes, the optimization and the 2-echelon assume that every vehicle required one driver. None case exceeded the nominal resources available.

Service time

- 2Echelon is a rough-cut planning model, thus uses an average service time of 5 minutes.
- Route Optimization model uses the Logistics partner (CLOGIN) observed average service times for more than 300 and less than 300 services, as follows:
  < 300 services – Vans 7 minutes, Three-wheeler Scooters 5 minutes.
  > 300 services – Vans 6 minutes, Three-wheeler Scooters 4 minutes.

EVC02

For the CO2 equivalent for electric vehicles, the emissions factor for each energy technology was extracted from the report “Emisiones de CO2 asociadas a la generación de electricidad en España” of the Spanish electricity system operation and transport company, see Table 7 .

Table 7 Emission Factor for each technology of energy generation

Technology	Emissions Factor
Combined cycle	0.37
Coal	0.95
Diesel engines	0.77
Gas turbine	0.77
Steam turbine	0.77
Cogeneration	0.38
Non-renewable waste	0.24

[7] Spanish Electric Network Authority API: https://www.ree.es/en/apidatos

3.1.5 Verification

The results of the core models were used for the final verification of the LL1 Madrid simulation environment for the UCC scenario. It followed the same approach that the BAU scenario reported in (D3.3, 2022). The focus was on validating the models calculating the operational performance of the freight operator. Thus, the logistics service provider (CityLogin) verified if the average values calculated with the optimization model represent reality accurately. Afterward, the 2-Echelon model was verified by comparing the outputs with the route optimization engine.

The “UCC” scenario is verified using the operational data (facilities, vehicles) and complementary sources and assumptions reported in sections 0 and 3.2 Concerning the services, the previous deliverable (D3.3, 2021) used the logistic provider services that took place in December to verify the “BAU” scenario with a total of 27 working days. This report used the services delivered since December 1st 2022 to December 31st 2022 with the new business model to verify the *configuration “UCC” following the same approach.* Table 8 presents the average values of the data samples of both scenarios.

Table 8. LL1 Madrid real scenarios modelling verification: updated sample of input data.

Madrid LL1 services demand			
Parameter		December 2021 (BAU)	December 2022 (UCC)
Monthly activity	Working days	25	27
	Services	5,701	5,239
	km driven	7,748	3,638
Daily services	Average	228	194
	Min	70	21
	Max	480	748
Daily vehicles used	Average	4	3
	Min	1	1
	Max	8	12
Daily km driven	Average	310	135
	Min	84	29
	Max	674	358

According to the logistics operator CityLogin, the results of the model the route optimization model for the “BAU” and “UCC” configurations (Table 9) are optimal for the real activity referred to in the corresponding periods.

Table 9. LL1 Madrid real scenarios modelling verification: Route optimization results.

Madrid LL1 operational results			
Parameter		December 2021 (BAU)	December 2022 (UCC)
Daily vehicles used	Average	4	3
	Min	1	1
	Max	8	12
Daily km driven	Average	310	135
	Min	84	29
	Max	674	358
Daily time to serve	Average	18:53	15:20
	Min	5:40	1:40
	Max	39:40	49:44
Daily vehicles capacity utilization	Average	35%	84%
	Min	24%	30%
	Max	43%	103%*
Daily average services per vehicle	Average	56	58
	Min	39	21
	Max	70	72
Daily average km driven per vehicle	Average	79	44
	Min	66	29
	Max	91	72
Daily average time to serve per vehicle	Average	4:40	4:45
	Min	3:12	1:40
	Max	5:46	5:58

*There is a minimum threshold that they relaxed the capacity constraint. This is acceptable because it is modelling and we are working with average size for parcels. Therefore, we may not be using 100% of the vehicle in reality and the algorithm would have to send an additional vehicle for only one or two parcels

Table 10 shows the results of the 2-Echelon model for the scenario “UCC” considering the average daily services (Table 8). The results give a rough estimation in absolute values for the distance (133 vs 144) and time to serve (15:20 vs 19:34), However, the number of vehicles is much bigger in the 2-Echelon model than in the route optimization model. This is justified by the average service time used by the two models. 2Echelon uses an average service time of 5 minutes, while Route Optimization model uses the Logistics partner (CLOGIN) observed average service times for more than 300 and less than 300 services, as follows:

- < 300 services – Vans: 7 minutes; Three-wheeler Scooters 5 minutes.
- 300 services – Vans 6 minutes, Three-wheeler Scooters 4 minutes.

Table 10. LL1 Madrid real scenarios modelling verification: 2-Echelon model results (scenario “UCC” considering different policies).

Policy	Parameter	2-Echelon outputs					
		First leg		Second leg		Total	
		Total	By Veh.	Total	By Veh.	Total	By Veh.
Parallel	Number of vehicles	2		6		8	
	Distance(km)	119	59.5	25	4.16	144	18
	Time (h)	2:42	1.34	16:53	2:49	19:34	2:25
Parallel 1st, serial 2nd	Number of vehicles	2		3		5	
	Distance(km)	119	59.5	25	12.5	144	28.8
	Time (h)	2:42	1.34	16:53	5:36	19:34	3:33
Serial	Number of vehicles	1		3		4	
	Distance(km)	119	119	25	12.5	144	36
	Time (h)	2:42	2:42	16:53	5:36	19:34	4.89

3.1.6 LEAD platform configuration

The LEAD Digital Twin (DT) Platform has been configured to support the Madrid LL models and to be able to replicate the decision support offered by the digital modelling tools, as developed and utilized by specialized personnel in their local computing environments. In more detail, the 2-echelon digital model, as it has been developed by Zaragoza Logistics Center (ZLC), has been at the centre of the DT configuration serving as the core of the decision support capabilities offered by the DT platform. Adjacent to the 2-echelon model, two environmental impact assessment models have been integrated, UPM’s EVCO2 model and EMISIA’s COPERT model, forming two separate *DT platform scenarios*:

1. Madrid DT Scenario 1: Focusing on the integration of the 2-echelon model with the EVCO2 model in the case that the CO2 emissions from an electric delivery fleet need to be estimated and,
2. Madrid DT Scenario 2: Focusing on integrating the 2-echelon model with the COPERT model for the cases when environmental emissions from a conventional gasoline- and/or diesel-powered fleet had to be estimated.

To facilitate the configuration of the DT platform and to integrate the three models into two separate scenarios, the development of model connectors has been necessary for the case of Madrid. One connector from 2-echelon-to-EVCO2 and a second from the 2-echelon-to-COPERT model. The connectors are software packages, including models' logic, handling the transformation of results datasets from one model to input datasets for the next model in the model execution order.

To further enable COPERT integration, an Application Programming Interface (API) had to be developed as wrapper software around COPERT, which enabled handling the requests to the COPERT model. This API to COPERT has been re-used in other LLs and model integrations, such as Porto LL and Budapest LL. Figure 5 gives a high-level representation of the two DT Platform scenarios for the Madrid LL.

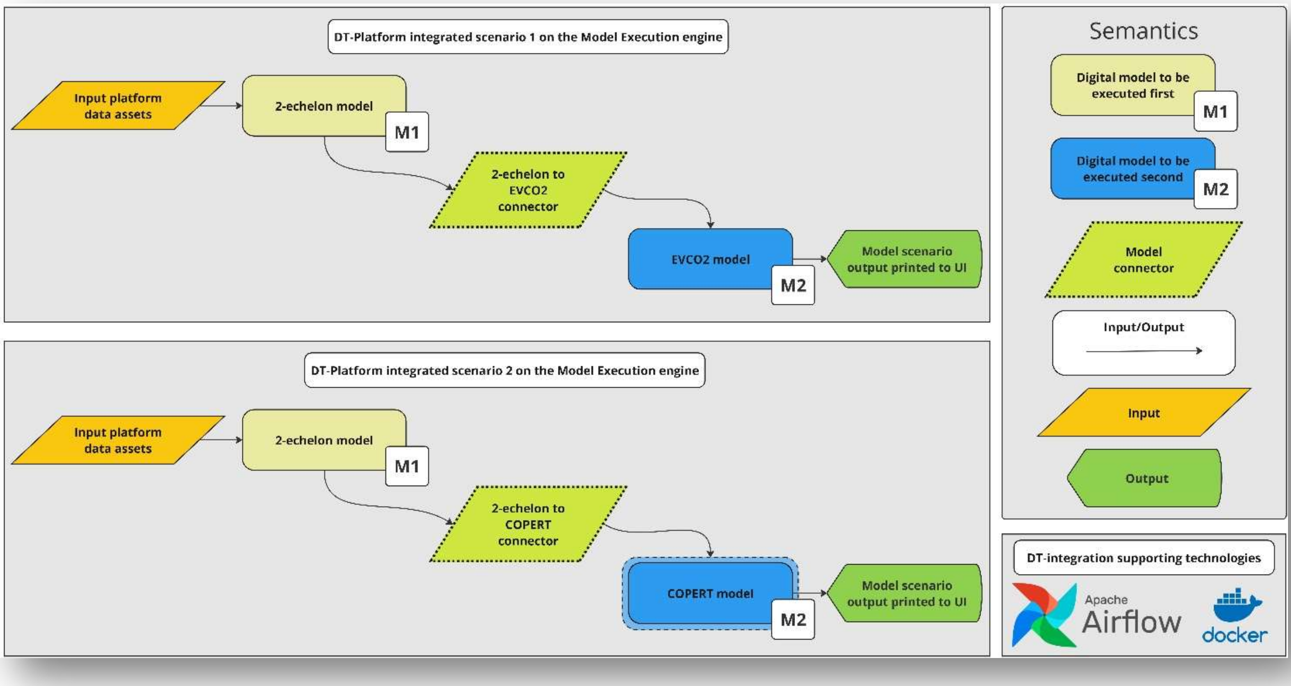


Figure 5: A high-level representation of the two DT Platform scenarios of the Madrid LL

A short reference within this section is made to another crucial tool used to integrate the Madrid LL models, the model metadata specification file. Developed in JavaScript Object Notation (JSON), this specification file included all crucial information for model inputs and outputs (I/O). This file has been based on the open documentation developed by model owners and had to be developed for each model in the DT configuration, with several versions produced throughout the development. The models' metadata specification file has also been developed for all platform models across the different LLs, and the JSON file used to 2-echelon can be found in Figure 6.

Code Blame 54 lines (53 loc) · 1.92 KB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{
    "$schema": "",
    "$id": "path://to/git.repo",
    "title": "Echelon Model",
    "version": "echelon v1",
    "description": "calculating the number of resources and distance for 2 echelon networks (first leg, second leg)",
    "application-information": {
        "application-type": "script",
        "application-language": "R",
        "environment": "5.4.0-66-generic #78~18.04.1-Ubuntu 20.04.2 LTS (Focal Fossa)",
        "application-location": "git://path-to-code",
        "build-required": "yes",
        "build-instruction": "./requirements.sh",
        "environment-variables": "PATH=$PATH:/shared/opt/",
        "execution-instruction": "Rscript PATH/2ECHELON/scenarioASIS_Madrid.R PATH/2ECHELON/INPUT/config.csv PATH/2ECHELON/INPUT/services.csv
    },
    "data-compatibility": {
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                "key": "1",
                "type": "echelon_input_scenario",
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            },
            {
                "key": "2",
                "type": "echelon_input_configure_file",
                "src": "PATH/2ECHELON/INPUT/config.csv"
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            {
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            },
            {
                "key": "4",
                "type": "echelon_input_facilitiesASIS_file",
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            }
            {
                "key": "5",
                "type": "echelon_input_vehiclesASIS_file",
                "src": "PATH/2ECHELON/INPUT/vehiclesASIS.csv"

            }
        ],
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                "type": "echelon_file_output",
                "src": "PATH/2ECHELON"
            }
        ]
    }
}
```


Figure 6: The model metadata specification JSON file for the 2-echelon model (screenshot from LEAD project's GitHub webpage)

One Madrid LL model that has been integrated in the DT platform but not within a *DT Platform scenario*, has been UPM's Noise model for calculating the impact of noise from last-mile logistics operations within urban environments. The model can be executed from the platform as a standalone model, using the outputs of the other models of the scenario.

3.2 LL1 Madrid "What if" scenarios

The digital twin aims to reproduce the sustainability performance of the two scenarios implemented in LL1. After verifying the results with the business owners for the BAU and UCC scenarios, the LL1 simulated hypothetical "what if" scenarios based on the four alternatives defined in D1.4, (2021) and the users' needs. The virtual experiments take reliable and accurate real-life field operations data.

LL1 Madrid Living Lab partners decided to evaluate two delivery system scenarios (BAU and UCC), consisting of five use cases (Figure 7):

- BAU: Direct delivery with internal combustion engine (ICE) and 100% electric (EV) powertrains small cargo vans, from a logistics platform located at 25 km from the city centre.
- UCC: Deliver first to an urban consolidation centre (UCC) in underground parking located in the city centre with hybrid and 100% electric (EV) powertrains small and large cargo vans, executing the last mile delivery with 100% electric powertrains three-wheel delivery trikes.

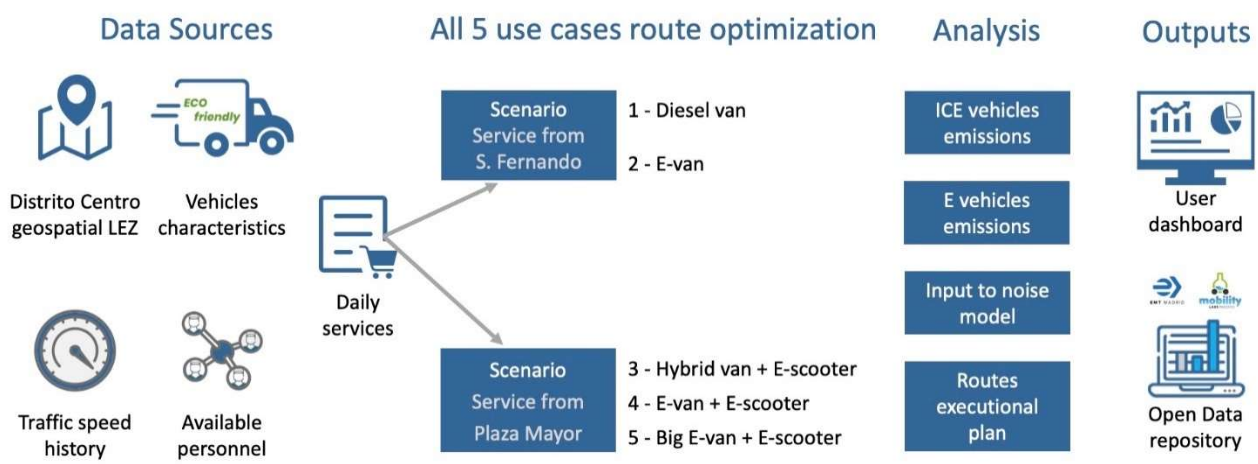

Figure 7. LL1 Madrid: What-if scenarios scheme.

Table 11 presents the input data details that vary from each scenario. The difference between the what-if scenarios is due to the type of vehicles used.

Table 11. LL1 Madrid: What-if scenarios details.

Scenario	Vehicles	Parcel capacity	EV Energy consumption (kWh/100km)
BaU	Diesel van	161	
	E-van	161	
UCC	Hybrid van + E-scooter	161	
		34	8.7
	E-van + E-scooter	161	22.7
		34	8.7
	Big E-van + E-scooter	284	25.0
		34	8.7

This project outcome delivers a thorough analysis of key performance indicators for ground last-mile delivery systems in urban, peri-urban, and suburban areas.

The analysis covers distance travelled, manpower utilization, energy consumption, and greenhouse gas (GHG) emissions for small and large cargo vans powered by internal combustion engine (ICE), Hybrid (HV), and 100% electric (EV) powertrains. The results are displayed in both absolute values (Table 12) and as a percentage (

Table 13) of the baseline scenario, providing a comprehensive picture of performance across all scenarios. The results can be presented in the unit that is most convenient for the target audience, such as per kilometre or per delivery.

Table 12. LL1 Madrid: May 31st 2023 What-if scenarios results.

Scenario	Vehicles	Total Journey (hours)	Driving time (hours)	Serve time (hours)	Km driven	Nº of Vehicles	Energy per delivery (kWh)	CO_2 per delivery (grams)	$PM_{2.5}$ per delivery (grams)	NO_2 per delivery (grams)
BaU	Diesel van	1,151	293	792	10,980	148	1.39	372.86	0.04	0.46
	E-van	1,151	293	792	10,980	148	0.06	0.04	-	-
UCC	Hybrid van + E-scooter	890	271	573	8,519	169	0.26	59.1	0.01	-
	E-van + E-scooter	890	271	573	8,519	169	0.07	0.02	-	-
	Big E-van + E-scooter	890	251	566	7,319	149	0.07	0.02	-	-

Table 13. LL1 Madrid: May 31st 2023 What-if scenarios results in percentage.

Scenario	Vehicles	Total Journey (hours)	Driving time (hours)	Serve time (hours)	Km driven	Nº of Vehicles	Energy per delivery (kWh)	CO_2 per delivery (grams)	$PM_{2.5}$ per delivery (grams)	NO_2 per delivery (grams)
BaU	Diesel van	1,151	293	792	10,980	148	1.39	372.86	0.04	0.46
	E-van	-	-	-	-	-	-96%	-100%	-100%	-100%
UCC	Hybrid van + E-scooter	-23%	-8 %	-28%	-22%	14%	-81%	-84%	-75%	-100%
	E-van + E-scooter	-23%	-8%	-28%	-22%	14%	-95%	-100%	-100%	-100%
	Big E-van + E-scooter	-25%	-14%	-28%	-33%	1%	-95%	-100%	-100%	-100%

The proposed outcome aims to contribute to the LEAD LL1 Madrid expected impacts as follows:

- Impact 1: The outcome will assess the impact of different delivery scenarios, both in terms of energy consumption and greenhouse gas emissions, allowing stakeholders to make informed decisions towards a more sustainable future.
- Impact 2: By considering the range of delivery scenarios and incorporating the perspectives of different stakeholders, including suppliers, shippers, and urban/regional policymakers, the project outcome will provide new tested, demonstrated practices and solutions for better cooperation between these groups. The outcome will promote the implementation of sustainable delivery models, thereby contributing to a more efficient and sustainable urban logistics system.
- Impact 3: The results of the project outcome will provide clear inputs for the preparation and implementation of SULPs, SUMPs, and other planning tools. By highlighting the need for cooperation between different stakeholders and presenting practical solutions, the outcome will support cities and regions in their efforts to create more liveable and sustainable urban environments.

In summary, the proposed outcome of the project outcome is highly relevant to the expected impacts outlined in the LEAD objectives and is poised to contribute significantly to the development of cost-effective, sustainable, and efficient city logistics systems not only in Madrid (Spain) but across Europe.

4 KPIs measurements

4.1 LL1 Madrid real scenarios

The following tables present the calculation and results of the LEAD presented in the D3.1 for the "BAU" and "UCC" scenarios in the LL1 Madrid following the calculation methods presented in Annex 2. All the results of KPIs measurements will be the input for the Impact Assessment Analysis and Solutions Validation in Task 3.8.

The data for estimating the KPIs belong to the month of January 2023.

Table 14 includes the environmental KPIs for the "BAU" scenario and the "UCC" scenario. The environmental KPI results are heavily influenced by factors such as the number and technology of the vehicles used, the service capacity of each vehicle, and the total kilometres driven. The environmental KPIs are estimated using the models integrated in the Digital Twin. As it can be seen, environmental impacts are drastically reduced from the LL1 BAU scenario to the UCC scenario. This is due to the fact that the kilometres travelled are reduced by -19% (see Table 13) and furthermore such kilometres from the UCC are travelled using zero emissions vehicles.

Table 14. LEAD Environmental KPIs: LL1 Madrid "BAU" vs "UCC" scenarios.

KPI	Baseline value (BAU)[8]	Final Value (UCC)
Energy consumption (kWh/delivery)	1.33	0.28
GHG emission (gCO_2/delivery)	357	63.61
Air quality (gPM2.5/delivery)	0.03	0.01
Air quality (gNO_2/delivery)	0.44	0
Air quality (gV_OC/delivery)	1.28×10^{-7}	7.13×10^{-4}
Noise impact (Δ% population affected)	59.73	34.96

Table 15 includes the social KPIs. Regarding the number of jobs, CityLogin has reported that with the implementation of the UCC, new jobs have been created with these characteristic positions:

[8] *Not applied: surveys conducted during the pilot testing phase to compare before and after situations*

- Traffic manager positions in charge of cargo organization, deliveries tracking, driver incidents management, customer service, etc. Working 40 hours per week. Positions covered by promotion of delivery drivers from other operations.
- Delivery driver positions in charge of making deliveries. Working 40 hours per week. Positions occupied by transfers from other operations due to work-life balance and new hires.

The KPIs for quality of the jobs and neighbourhood's quality of life were based on surveys conducted at the Local workshop held in June 2022 (see Section 2.2.2). There were 12 respondents, and the main results of the surveys are included in the following Figure 8 for the quality of the jobs and for neighbourhood's quality of life. With these results and applying the formula for calculating the KPIs, the results of the quality of employment reaches 3.6 in the KPI. As it is higher than 3.5, it is acceptable. In the case of the quality of life in the neighbourhoods, we have a KPI of 4.4 so the KPI is also very acceptable.

At the end of the working group, there were registered eleven ideas that were scored by Madrid LL partners to promote a more sustainable behaviour and cooperative solutions (see Figure 9). Interesting ideas regarding the promotion of more sustainable behaviour were to reward the consumer who pick-up the delivery at convenience points with a zero cost on their shipping charges, to penalize the consumer in returns or exchanges, to reward consumer behaviour such as non-returns, grouping bulk orders, etc. An interesting cooperative solution is the sharing assets among logistics operators (i.e. vehicles) and to develop a regulation that oblige operators to share data with public administration.

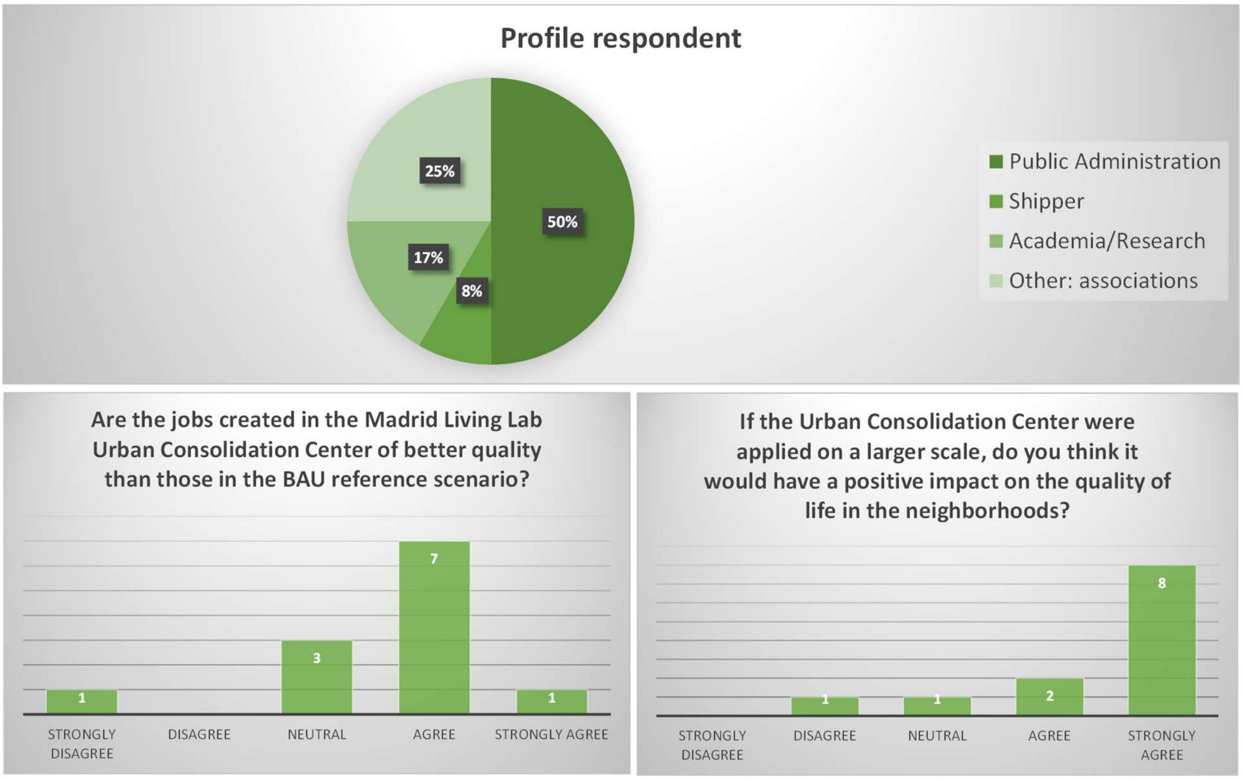

Figure 8.Survey answer to quality of the jobs and neighbourhoods' quality of life KPIs.

IDEAS TO PROMOTE A MORE SUSTAINABLE BEHAVIOR				
IDEA	**SCORE**		**OBJECTIVE**	
To inform consumers of the CO2 or carbon footprint of each delivery.	3,7	≥	3,5	✔
Deliveries to neighborhood stores (convenience stores) as a way to promote neighborhood commerce.	3,7	≥	3,5	✔
To penalize the consumer in returns or exchanges (to assume the cost of transport, to penalize economically more than one return, etc.).	4,3	≥	3,5	✔
Installation of lockers in all public transportation stations.	3,3	≥	3,5	✖
To reward consumer behavior such as non-returns, grouping bulk orders, etc. through discounts on other products, sweepstakes, bonuses, etc.	4,3	≥	3,5	✔
Penalizing the consumer for failed home deliveries or urgent deliveries (financially, etc.)	3,0	≥	3,5	✖
To promote a law to oblige e-commerce services to display in a differentiated way the price of the transport service, as well as the carbon footprint of the delivery.	4,0	≥	3,5	✔
To reward the consumer who picks up the merchandise at convenience points with a 0 cost on their shipping charges.	4,4	≥	3,5	✔

COOPERATIVE SOLUTIONS & INCENTIVE MEASURES				
IDEA	**SCORE**		**OBJECTIVE**	
The competent Public Administrations should draw up specific regulations governing a minimum load ratio for delivery services through the control of KPIs.	3,9	≥	3,5	✔
Logistics operators sharing assets (e.g. vehicles)	4,6	≥	3,5	✔
To develop a regulation that obliges operators to share data with public administrations for better urban strategic planning.	4,0	≥	3,5	✔

	AVG SCORE		OBJECTIVE	
IDEAS TO PROMOTE A MORE SUSTAINABLE BEHAVIOR	3,8	≥	3,5	✔
COOPERATIVE SOLUTIONS & INCENTIVE MEASURES	4,1	≥	3,5	✔

Figure 9. Ideas registration and scoring by experts.

Table 15. LEAD Social KPIs: LL1 Madrid "BAU" vs "UCC" scenarios

KPI	Baseline value (BAU)[9]	Final Value (UCC)
Jobs created (Number of employees)	5	10
Quality of the jobs	Not applied.	3.6
Neighborhoods quality of life	Not applied:	4.4
Ideas to promote a more sustainable behaviour	Not applied:	3.8
Cooperative solutions & incentive measures	Not applied.	4.1

Table 16 includes the economic KPIs. The economic KPIs are estimated using the data from the logistics operators CityLogin and the application of formulas included in Annex 4. As it can be seen, there are some KPIs that improved their results in the UCC scenario with respect to the BAU scenario, such as congestion, the financial rate of return, delivery time or the delivery reliability with respect to the time window. On the contrary, other KPIs such as average delivery cost of the business models or the urban storage and parking space are worse in the UCC scenario with respect to the BAU scenario, though from a business model point of view it has not been critical from the logistic operator perspective.

[9] *Not applied: surveys conducted during the pilot testing phase to compare before and after situations*

Table 16. LEAD Economic KPIs: LL1 Madrid "BAU" vs "UCC" scenarios

KPI	Baseline value (BAU)[10]	Final Value (UCC)
Average delivery cost of the business model	A[11]	>5%
Congestion 1 (Congested Shipments)	Not applied	
Congestion 2 (Congestion from vehicles, %)[12]	300.65	180.56
Urban storage and parking space (m^2)[13]	45.07	245.07
Financial internal rate of return of the investment conducted	Not applied	2%
Shop/retail benefits (shippers)	Not applied in the baseline scenario	3.8
Delivery time	5 minutes	4 minutes
Delivery reliability within the time window	80%	90%

Table 17 includes Madrid LL complementary KPIs. As it can be seen, all of them improved their results in the UCC scenario with respect to the BAU scenario.

Table 17. LL1 Madrid: Stakeholders complementary KPIs "BAU" vs "UCC" scenarios

KPI	Baseline value (BAU)[14]	Final Value (UCC)
ETA Accuracy	81%	90%
Delivery succes rate	95.20%	97%
Distance per delivery	0.84	0,80

[10] *Not applied: surveys conducted during the pilot testing phase to compare before and after situations*
[11] *A: sensitive data. We provide and arbitrary value A.*
[12] *Assuming that the vehicle does not influence congestion when properly parked*
[13] *Assuming that the vehicle does not influence congestion when properly parked*
[14] *Not appied: surveys conducted during the pilot testing phase to compare before and after situations*

4.2 LL1 Madrid "What if" scenarios

As indicated in previous chapter, the following Table 18 shows again the results of some KPIs for the BAU, UCC and 3 what-if scenarios.

Table 18. LL1 Madrid: What-if scenario results

Scenario	Vehicles	Total Journey (hours)	Driving time (hours)	Serve time (hours)	Km driven	Nº of Vehicles	Energy per delivery (kWh)	CO_2 per delivery (grams)	$PM_{2.5}$ per delivery (grams)	NO_2 per delivery (grams)
BaU	Diesel van	1,151	293	792	10,980	148	1.39	372.86	0.04	0.46
	E-van	1,151	293	792	10,980	148	0.06	0.04	-	-
UCC	Hybrid van + E-scooter	890	271	573	8,519	169	0.26	59.1	0.01	-
	E-van + E-scooter	890	271	573	8,519	169	0.07	0.02	-	-
	Big E-van + E-scooter	890	251	566	7,319	149	0.07	0.02	-	-

5 Panasonic Case

As presented in (D3.3, 2021), the Panasonic case aims to explore the e-commerce channel. Considering cities sustainable goals, new regulations and the consumers environmental and social awareness may affect the selection of the last mile service provider based on the environmental impact of the last part of the chain, this section explains how LL1 Madrid has simulated different scenarios to help the shipper understand the environmental impacts of this choice.

Theobjective will be to respond to the question in Table 19 and explore whether the development of the LEAD digital twin brings PANASONIC the opportunity of exploring the technical needs and data arrangements required for the development of the last-mile digital twin as part of the CoP.

Sections below describe how LL1 simulated the Panasonic hypothetical and "what-if" scenarios by adapting the LL1 LEAD digital twin, the results and main conclusions.

Table 19. Industrial manufacturer – potential scenario defined in LL1 (D3.3, 2021).

In this scenario, the 5% of the sales are online and 95% B2B.
How Panasonic can collaborate (agreements considering the data) and leverage the existing distribution channels to make the direct e-commerce channel profitable, accomplish with the emerging regulations and satisfying the increasing sustainability consumers awareness?

Input data

Table 20 presents Panasonic's orders in the LEZ of Madrid.

Table 20. Panasonic orders (D3.3, 2021).

Customer	Number of orders	Business model
Customer 1	257	B2B
Customer 2	179	B2B
Customer 3	131	B2B
Customer 4	11	B2B
Customer 5	1	B2B
Customer 6	1	B2B
Customer 7	1	B2B
Customer 8	1	B2B
Customer 9	1	B2B
Customer 10	1	B2B
Customer 11	1	B2B
Customer 12	1	B2B

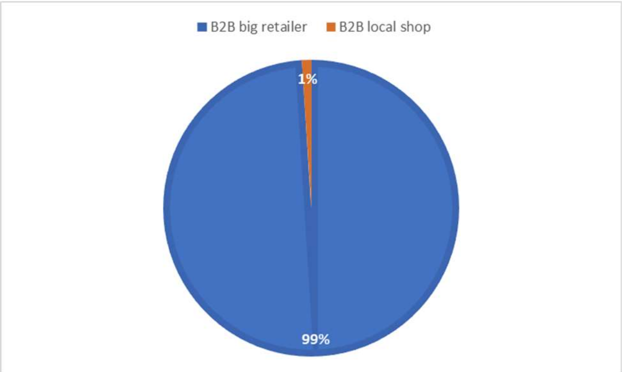

Figure 10. Panasonic delivery business models market share (D3.3, 2021).

Considering the lack of data and the variability in the orders' size, the simulation used the 2-echelon model in combination with COPERT and EVCO2. It required defining a list of assumptions and an analysis of the data available to split the sample into two sets (Table 21) as further detailed in annexe 2.

Scenarios configuration

Table 21 shows the input data used for simulating the scenarios. Details about the calculation and assumptions are available in annexe 2.

Table 21. Panasonic: input data configuration.

Scenario (sales)	Scenario (distribution)	Order size	Delivery points	Delivery time per delivery point (h)
100% B2B	Set 1	189	3	0.5
	Set 2	2	9	0.0083
95% B2B + 5 % B2C	Set 1	180	3	0.5
	Set 2a	2	9	0.0083
	Set 2b	1	9	0.0083
	Set 2c	1.55	18	0.0083

Based on the research question in Table 19, the Panasonic case defined the scenarios in Table 22 below into two categories depending on the distribution channels.

- The first category represents the real case where Panasonic sells products to the final consumer through the local stores. Therefore, Panasonic's distribution is 100% B2B. In this case, LL1 has analyzed the impact of three different network configurations on the operational efficiencies and environmental effects.
- In the second case, we assume that 5% of sales are online from the final consumer to manufacturer. In this case, LL1 has explored three possibilities to satisfy the demand based on the time-window available since the customers sends the order until the parcel is delivered.

Table 22. Panasonic: scenarios configuration.

Scenario (sales)	Scenario (distribution)	Description
100% B2B	Set 1 (Diesel Van) + Set 2 (Diesel van)	Considering the input data in Table 21 and assumptions in Annexe 2, the two sets of orders are delivered independently considering the BAU scenario of LL1 Madrid.
	Set 1(Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)	Considering the input data in Table 21 and assumptions in Annexe 2, the two sets of orders are delivered independently considering the UCC scenario of LL1 Madrid.
	Set 1(Diesel) + Set 2 (Hybrid van + E-scooter)	Considering the input data in Table 21 and assumptions in Annexe 2, the set is delivered considering the BAU scenario and set 2, the UCC scenario of LL1 Madrid

Scenario (sales)	Scenario (distribution)	Description
95% B2B + 5% online	100% 24-hour service	With this type of service, the online orders could be added to set 2 of the 100% B2B scenario and be delivered following one of the three distribution scenarios above.
	Possibility of offering same-day delivery	In this case, it is required that the orders are available close to the final consumer. In this case, the manufacturer needs to know the inventory available in the retail market. If available, the LSP will have to receive the order and reorganize the route dynamically to integrate it with the lowest impact on service quality and efficiency.
	Possibility to offer 1-hour delivery	This case adds complexity to the previous one. The manufacturer will need to have visibility of the inventory available in the retail market and know if the LSP is delivering close to the area.

Category 1 (100% B2B) analysis

Table 23 and Table 24 shows the results of different possibilities to configure the distribution network when the 100% of orders are B2B. The first case would represent the business as usual distribution network. The second case is a hypothetical scenario where the big B2B orders and the small B2B orders are delivered with the UCC configuration of the Pilot of Madrid. As presented, this case es sub-optimal from the operational point of view. The third case is another "what-if" scenario based on combining both distribution configurations. For the big orders in set 1, we use the BAU model and for set 2 with the small orders, we consider the UCC model. The results for this last scenario show that the environmental indicators improve but increases the number of resources and distance (detailed calculations in Annexe 2).

Table 23. Panasonic: 2021 What-if scenarios results (100%B2B).

Scenario (sales)	Scenario (distribution)	Number of vehicles	Distance	EC (MJ)	CO2 (g)	PM2.5	NO2
100% B2B	Set 1 (Diesel Van) + Set 2 (Diesel van)	5	301.56	9.6E-04	0.07215	6.456E-06	8.848E-05
	Set 1(Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)	23	325.92	0.0005692	0.0374875	4.738E-06	3.807E-07
	Set 1(Diesel van + E-scooter) + Set 2 (Hybrid van + E-scooter)	**6**	**304.22**	**0.0008738**	**0.0645975**	**6.057E-06**	**7.019E-05**

Category 2 (95% B2B+ 5% B2C) analysis

Assuming the long-term business model in the LEZ in Madrid is based on configuration 3 (in bolds in Table 23), Table 24 and Table 25 compare this scenario with different possibilities to re-configure the distribution network when 95% of orders are B2B and 5% are online. The first case would represent the first scenario 4 in Table 20. Online orders are neither possible to be 1-hour delivery nor the same delivery. In this case, the number of orders in set 2 increases with a negative impact on all the indicators except the distance. The other second alternative is that the manufacturer collaborates with the retail network and the LSP to offer same-day delivery and even 1-hour delivery. This option may improve the service quality without an impact on the operations or environmental effects (detailed calculations in Annexe 2). However, the materialization of this collaborative scenario needs a high level of synchronization and collaboration among all the actors in the supply chain that would benefit from a digital twin.

Table 24. Panasonic: 2021 What-if scenarios results in percentages (100% B2B)

Scenario (sales)	Scenario (distribution)	Number of vehicles	Distance	EC (MJ)	CO2 (g)	PM2.5	NO2
100% B2B	Set 1 (Diesel Van) + Set 2 (Diesel van)	5	301.56	9.6E-04	0.07215	6.456E-06	8.848E-05
	Set 1(Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)	360%	8%	-41%	-48%	-27%	-100%
	Set 1(Diesel van + E-scooter) + Set 2 (Hybrid van + E-scooter)	20%	1%	-9%	-10%	-6%	-21%

Table 25. Panasonic: 2021 What-if scenarios results (100% B2B vs 95% B2B + 5% B2C)

Scenario (sales)	Scenario (distribution)	Number of vehicles	Distance	EC (MJ)	CO2 (g)	PM2.5	NO2
100% B2B	**Set 1 (Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)**	**6**	**304.22**	**0.0008738**	**0.0645975**	**6.057E-06**	**7.019E-05**
95%B2B + 5% B2C	Set 1(Diesel) + Set 2c (Hybrid van + E-scooter) - (24hours delivery| not collaboration)	7	303.929	0.0012239	0.0871331	8.9E-06	7.025E-05
95%B2B + 5% B2C	Set 1(Diesel) +Set 2a + Set 2b (Hybrid van + E-scooter + E-scooter) - (same day delivery/ one-hour delivery| collaboration)	7	309.27	0.0008738	0.0645975	6.057E-06	7.019E-05

Table 26. Panasonic: 2021 What-if scenarios results in percentages (100% B2B vs 95% B2B + 5% B2C)

Scenario (sales)	Scenario (distribution)	Number of vehicles	Distance	EC (MJ)	CO2 (g)	PM2.5	NO2
100% B2B	**Set 1 (Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)**	6	304.22	0.0008738	0.0645975	6.057E-06	7.019E-05
95%B2B + 5% B2C	Set 1(Diesel) + Set 2c (Hybrid van + E-scooter) - (24hours delivery| not collaboration)	17%	0%	40%	35%	47%	0%

Scenario (sales)	Scenario (distribution)	Number of vehicles	Distance	EC (MJ)	CO2 (g)	PM2.5	NO2
95%B2B + 5% B2C	Set 1(Diesel) +Set 2a + Set 2b (Hybrid van + E-scooter + E-scooter) - (same day delivery/ one-hour delivery| collaboration)	0%	0%	0%	0%	0%	0%

Conclusion

Although the analysis required many assumptions and is a rough estimation of the environmental impacts of different configurations for the shift of the consumers' preferences to the online channel, the results show that collaborative scenarios do not impact the transport efficiency and emissions while the service quality is improved. This level of collaboration is only possible with synchronous planning. Therefore, manufacturers may benefit from real-time digital twins to enable collaborative distribution schemes with local businesses.

6 Business value validation and user acceptance

The LEAD solutions validations is an action included in “Task 3.8. Impact Assessment, Solutions Validation and Learning Conclusions”. With Task 3.8 there have been defined a validation methodology which includes the following phases that correspond with the following subsections:

- LEAD value cases impact validation in which the Living Lab will report the accomplishment of the LEAD KPIs originally set in the grant agreement. See Section 6.1.
- LEAD pilots, scale-up and business value validation based on a questionnaire to expert stakeholders at the final Madrid LL Local Workshop (information of the workshop is in Section 2.2.2). The aim was to ask for the perceived implementation and impacts of the pilots, the perceived scalability of the Pilot and questions regarding the business models of each Living Labs. See Section 6.2.
- LEAD decision support tool based on Digital Twins validation on the basis of a questionnaire to expert stakeholders at the end of the Final Madrid LL Local Workshop. The aim was to verify the accuracy of the results of the Digital Twins’ models, validate decision support tool utility and acceptance. See Section 6.3.
- LEAD decision support tool validation based on Digital Twins based on a questionnaire to expert stakeholders at the end of the Final LLs Local Workshops. The aim was to verify the accuracy of the results of the Digital Twins’ models, validate decision support tool utility and acceptance. See Section 6.4.

6.1 LL1 Madrid value case impact validation.

Table 27. LL1 Madrid value case impact validation: KPIs vs. Target

Criteria	Baseline value (BAU)	Final Value (UCC)	KPI[15]	Target[16]
Energy consumption	1.33 kWh/delivery	0.28 kWh/delivery	-78,95%	-5%
GHG emission	357 gCO_2/delivery	63.61 gCO_2/delivery	-82.18%	-50%
Air quality	0.03 gPM2.5/delivery	0.01 gPM2.5/delivery	-66.67%	-50%
Air quality	0.44 gNO_2/delivery	0 gNO_2/delivery	-100%	-100%
Air quality	$1.28x10^{-7}$ gV_OC/delivery	$7.13x10^{-4}$ gV_OC/delivery	+100%	-10%
Noise impact	59.73 % population affected	34.96% population affected	-41.47%	-30%

[15] *Estimated using the formulas in Annex 1*
[16] *Targets set out in the GA and revised in Deliverable 3.3 Madrid Value Case (v1).*

Criteria	Baseline value (BAU)	Final Value (UCC)	KPI[15]	Target[16]	
Job Creation	5	10	5	5	✔
Quality of the jobs	-	-	3.6	>3.5	✔
Neighbourhood Quality of Life	-	-	4.4	>3.5	✔
Users sustainable behaviour	-	-	3.8	>3.5	✔
Cooperative solutions & incentives measures	-	-	4.1	>3.5	✔
Average delivery cost of the business model	2.3€/delivery	2.5€/delivery	>5%	<5% increase[17]	✖
Congestion 2 (Congestion from vehicles)	300.65	180.56	-39.9%	-10%	✔
Urban storage and parking space	45.07	245.07	-443.7%	-10%	✖
Financial internal rate of return of the investment conducted			2%	6%	✖
Shop/retail benefits (shippers)	-	-	3.8	>3.5	✔
Delivery time	5 minutes	4 minutes	-20%	-5%	✔
Delivery reliability within the time window	80%	90%	12.50%	+10%	✔

6.2 LL1 Madrid pilot, scale-up and business value validation.

In the Final Madrid LL workshop, a brief presentation of the Madrid Pilot was made to give the participants an overview. Some knew the project initially, and multiple questions were asked to assess the Madrid Pilot. Follow a brief summary of those questions is presented:

Please rate how successful the implementation of the Urban Consolidation Centre in the Madrid Living Lab has been. To evaluate the success of the Urban Consolidation Centre in the Madrid Living Lab, a question was posed to participants, asking them to rate the implementation on a 5-point scale ranging from Poor to Excellent. The feedback received was overwhelmingly positive, with almost no

[17] *The target should be an increase of less than 5% cost increase.*

negative opinions being expressed. Of the participants, 14% rated the implementation as Good, 27% as Very good, and 37% as Excellent. A small percentage of participants chose not to respond. These results suggest that stakeholders very well received the implementation of the Pilot and that the Urban Consolidation Centre has successfully achieved its intended objectives.

In your opinion, the business model presented to implement the Plaza Mayor Consolidation Center in Madrid is? Participants were asked to rate the feasibility of the business model presented to implement the Plaza Mayor Consolidation Center in Madrid, using a 5-point scale that ranged from Not at all feasible to Extremely feasible. According to the results, most participants considered the implementation of the **Plaza Mayor Urban Consolidation Center to be highly feasible**. Specifically, 52% of participants rated the feasibility as Very feasible, while 19% considered it Moderately feasible. A small percentage of participants chose not to respond. These results suggest that the business model presented for the Plaza Mayor Consolidation Center is well-supported and has a high potential for success.

Indicate your opinion on the scalability of the public-private partnership/collaboration business model implemented in the Pilot in other areas of the city. The potential for replicating the public-private partnership business model presented in the Pilot in other areas of the city was evaluated using a 5-point scale that ranged from Not at all possible to Extremely possible. The question received a positive response from the participants, **with the majority considering scalability of the public-private partnership to be highly possible.** Specifically, 67% of participants rated the possibility of replicating the model as Very possible, while 10% considered it Extremely possible and 10% Moderately possible. A small percentage of participants chose not to answer. These results indicate a high level of confidence in the potential for replicating the public-private partnership business model in other areas of the city. This feedback is valuable for decision-makers considering implementing similar initiatives in other parts of Madrid.

What aspect/s would you consider outstanding regarding the Plaza Mayor Urban Consolidation Center implemented in the Madrid Living Lab? The following is a summary of the main ideas obtained from this question. The Madrid Living Lab Pilot participants have expressed a favourable opinion on the possibility of replicating the public-private partnership business model in other areas of the city. The **effective collaboration between public and private entities has been identified as a key strength of this model**, allowing for the use of clean vehicles and optimising urban logistics. Additionally, agreements with cities could provide opportunities for charging infrastructure projects and other sustainable transportation initiatives. The Pilot's success can also be attributed **to good coordination**, which has achieved an agile operation without requiring a lot of storage space. The central location of the Plaza Mayor Urban Consolidation Center and **the use of the scoobic scooters** have been highlighted as particularly beneficial for mobility in congested areas. The public/private partnership model has allowed for the optimisation of urban logistics, resulting in fewer vehicles and less pollution. The positioning of the UCC in the city centre has also contributed to a reduction in pollution and congestion at the entrance to the city. Using 100% sustainable and non-polluting vehicles has been key to achieving this success. These findings suggest that the public-private partnership business model presented in the Pilot could be applied in other areas of the city, leading to cleaner logistics and a reduction in pollution and congestion.

<u>What aspect/s would you improve on the Plaza Mayor Urban Consolidation Center implemented in the Madrid Living Lab?</u> During the assessment of the Plaza Mayor Urban Consolidation Center implemented in the Madrid Living Lab, participants were asked what aspects they would improve. Some suggestions included **the application of robotics to improve efficiency**, **maximising the centre's capacity to 100%**, and **using a higher gauge for Vehicle Entry**. Others proposed making the centre available to more companies and expanding the range of hours to adapt to all types of business. One participant raised the concern that the acceptance of the business model by urban logistics operators might be complicated and asked if any business model had been contemplated in this regard. Another suggestion was to increase the space to be able to reach more deliveries with this model and to make it available to other operators. Finally, some participants proposed creating a hub of larger dimensions that could be located farther from the centre and return to a more radial area. These suggestions show the potential for improvement and expansion of the Plaza Mayor Urban Consolidation Center model.

6.3 LL1 Madrid decision support tool based on Digital Twins validation

Section 3 describes the use of LL1 digital twin models to compare the sustainability performance of the Madrid Pilot implementation with and without the Plaza Mayor Urban Consolidation Center (UCC). The section also outlines different "what if" scenarios that were simulated with the digital twin. Results from the simulations were presented in the Final Madrid LL workshop to policymakers and logistics operators to validate the digital twin as a decision support system. A summary of the Madrid simulation environment was also given, and multiple questions were asked to assess the pilot. The overall conclusion is that the DT is feasible and acceptable. Below is a summary of those questions:

<u>From a non-technical perspective, is the objective sound and understandable?</u> From a non-technical perspective, the objective of the simulation environment was assessed in terms of being sound and understandable. Overall, 75% of participants agreed that the objective was sound and understandable, as shown in Figure 11. However, 25% of participants had a neutral or disagreeing opinion on this matter. On average a grade of 4 was obtained.

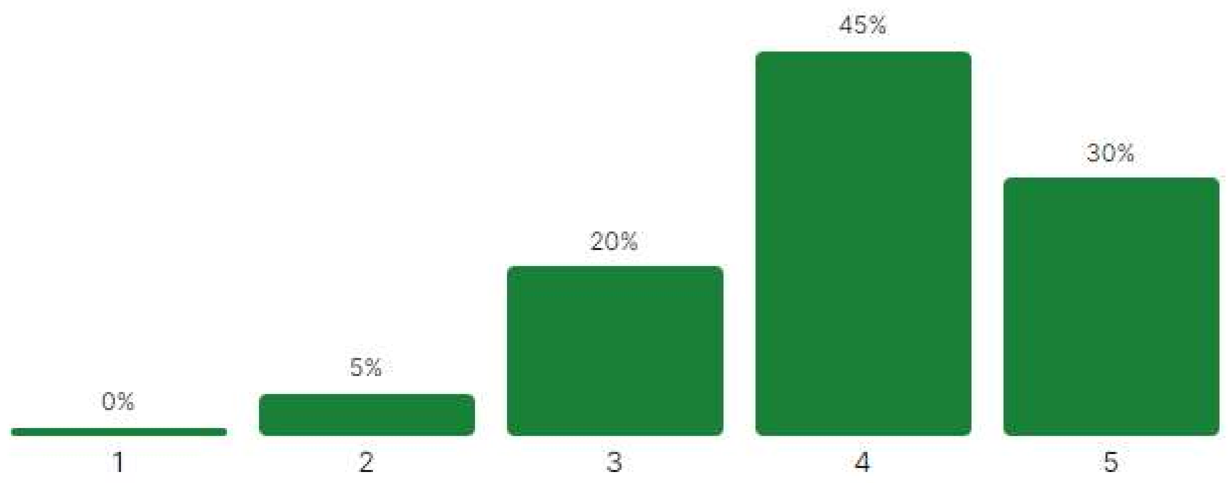

Figure 11 From a non-technical perspective, is the objective sound and understandable? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

Are the results of the digital twin clear and understandable to non-technical people? The question of whether the results of the digital twin are clear and understandable to non-technical people generated varied responses among the participants. Around 50% of the participants understood the results, while the remaining participants found the explanation unclear (see Figure 12). This discrepancy may be attributed to the diverse backgrounds and expertise of the workshop attendees. **The results highlight the need for presenting the information in a more accessible manner**. On average, the participants gave a rating of 3.7, which provides initial insight into how to improve the communication of the results.

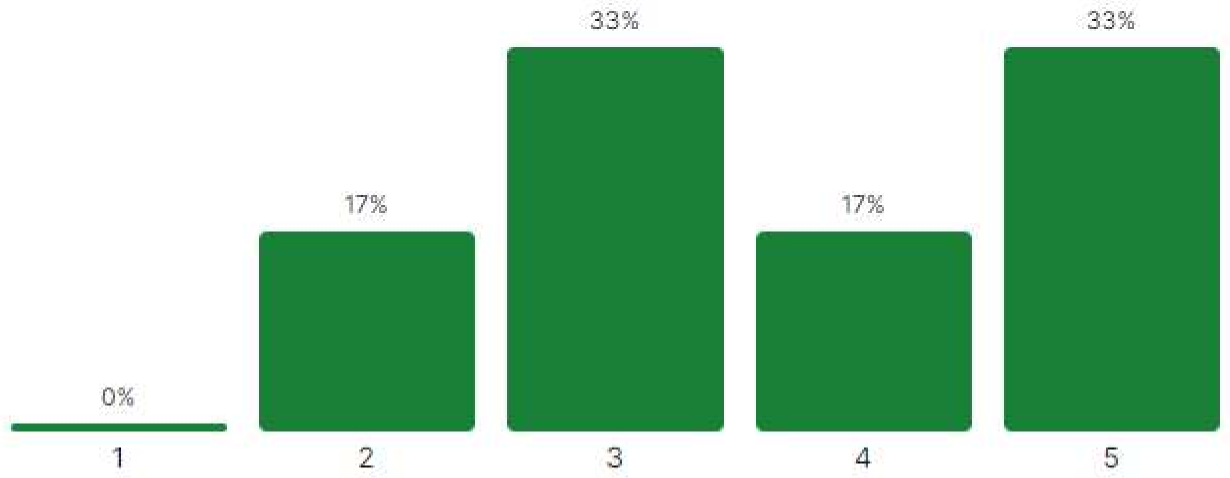

Figure 12 Are the results of the digital twin clear and understandable to non-technical people? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

In your opinion, does the digital twin replicate logistics operations accurately enough? This question aimed to assess whether the participants considered the digital twin to replicate logistics operations accurately. However, the results showed a marked neutral opinion among the participants, with an average rating of 3.5 out of 5. This could suggest that there is room for improvement in terms of the accuracy of the digital twin (see Figure 13). Further investigation may be needed to identify the specific aspects of the digital twin that may require refinement to improve its accuracy. Additionally, feedback from logistics operators and other stakeholders could help identify potential areas for improvement in the simulation model.

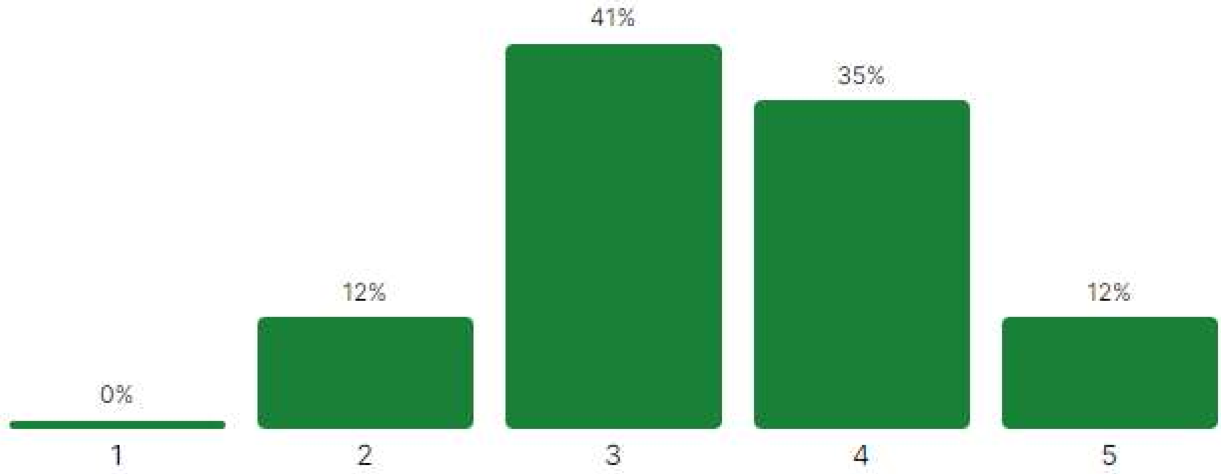

Figure 13 In your opinion, does the digital twin replicate logistics operations accurately enough? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

<u>Does the digital twin include most of the information planners and policymakers need?</u> While the participants generally agreed that the digital twin includes enough information, with an average rating of 3.8, specific details or metrics could be added to enhance decision-making (see Figure 14). To further improve the digital twin, it would be valuable to understand what additional information planners and policymakers would find helpful. Gathering feedback from these stakeholders could help identify areas for improvement and ensure the digital twin provides the most helpful information possible.

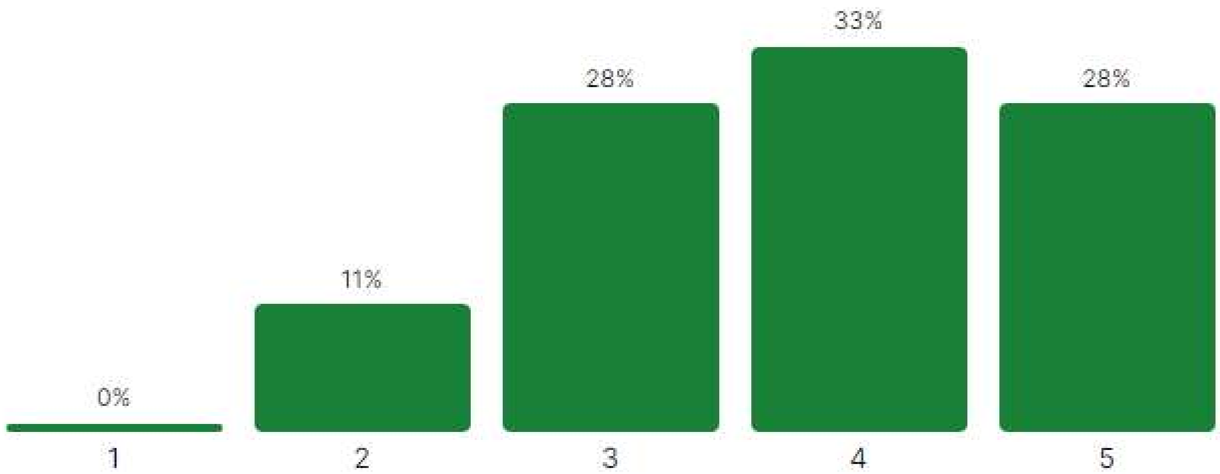

Figure 14 Does the digital twin include most of the information planners and policymakers need? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

<u>*Will the digital twin help planners and logistics companies achieve their goals?*</u> The participant feedback indicates that the digital twin is perceived as a helpful tool for achieving the goals of planners and logistics companies. The average score of 4 suggests that the participants found the digital twin valuable, and 82% had a favourable opinion (see Figure 15). This positive feedback can be attributed to the digital twin's ability to provide data-driven insights that can aid decision-making processes related to logistics operations. However, it is worth noting that some participants expressed neutral or negative opinions, suggesting that there may be areas for improvement. Overall, the digital twin has

the potential to be a useful tool for achieving planners' and logistics companies' goals, but it may require further refinement to address any identified issues

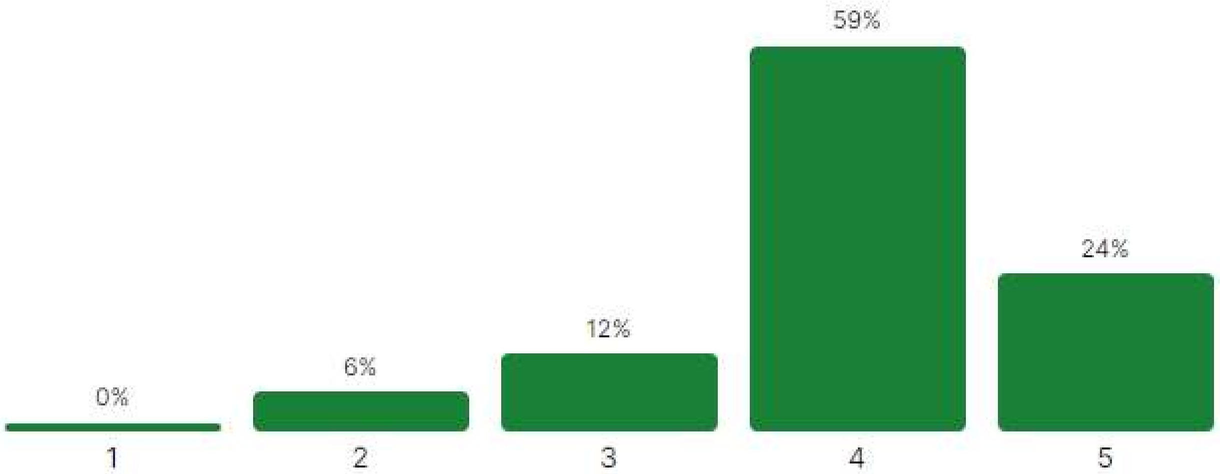

Figure 15 Will the digital twin help planners and logistics companies achieve their goals? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

Indicate what specific issues/aspects you miss in the digital twin. During the workshop, some participants raised issues and aspects they felt were missing in the digital twin. One of the main issues was related to the user interface, which some felt could be improved with better graphical information for decision-making. There were also suggestions for incorporating operational and economic KPIs to track decision-making. Some participants also felt that there could be better cooperation models between stakeholders and the inclusion of other distribution typologies, such as HORECA (Hotel/Restaurant/Café). Additionally, there were suggestions to include a weight variable rather than just volume for emissions issues, visual representation, and the use of lockers. Finally, there were suggestions for better visualization of user results.

Indicate your opinion on the applicability of the digital twin implemented for the Madrid Living Lab consolidation centre to other city areas. In assessing the applicability of the digital twin implemented for the Madrid Living Lab consolidation centre to other city areas, it is clear that the participants consider the idea feasible. Most participants rated the feasibility as very feasible or extremely feasible, indicating that the digital twin's use in other areas is highly possible. This demonstrates the potential for the digital twin's scalability and its ability to contribute to sustainability efforts in other urban areas. The results of this assessment can provide valuable insights for decision-makers and planners considering implementing a digital twin in their cities to improve sustainability and logistics operations.

6.4 LL1 Madrid Living Lab Impact Assessment validation

To validate the impact assessment of the Madrid Living Lab, the results of the KPIs for multiple scenarios were presented in the Final Madrid LL workshop, including the short-term and long-term impact. The KPIs covered various aspects, such as environmental, economic, and social impacts. Policymakers and logistics operators evaluated the presented results to validate the digital twin as a decision support system to enhance the decision-making process. The assessment was crucial in understanding the impact of the pilot implementation and making informed decisions to improve logistics operations in Madrid. Multiple questions were asked to assess the Madrid Pilot. Follow a brief summary of those questions is presented:

Rate the degree of achievement of the results (KPIs) of the Madrid Pilot Urban Consolidation Center compared to the KPI targets set at the beginning of the LEAD project. In the validation session, participants were asked to rate the degree of achievement of the KPIs for the Madrid Pilot Urban Consolidation Center compared to the KPI targets set at the beginning of the LEAD project. The participants' responses showed a positive trend, indicating that Madrid Pilot achieved its KPI targets. The majority of participants (70%) rated the performance as "Very Good," while others rated it as "Good" or "Excellent." Overall, the results show that the Madrid Pilot Urban Consolidation Center has successfully achieved its goals, as outlined in the LEAD project.

Do you consider the medium and long-term impacts of the Urban Consolidation Center strategy presented for Madrid to be realistic? Participants expressed a general agreement on the realism of the medium and long-term impacts resulting from implementing the Urban Consolidation Centre strategy presented for Madrid. The average rating was 4.2, indicating a high confidence level in the feasibility of the proposed approach. This suggests that the Urban Consolidation Centre could potentially serve as a model for similar initiatives in other cities, as it has demonstrated a strong potential to deliver sustainable benefits in the medium to long term.

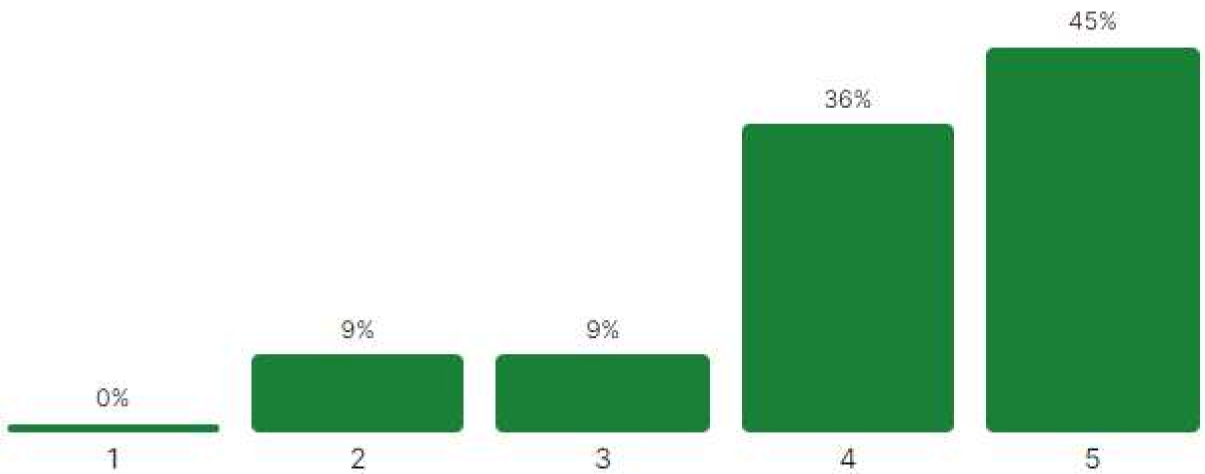

Figure 16 Do you consider the medium and long-term impacts of the Urban Consolidation Center strategy presented for Madrid to be realistic? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

How feasible do you consider the application of the Urban Consolidation Center launched in Madrid on a larger scale in the city (e.g. to all logistics operators, to other districts, etc.)? According to the participant's responses, applying the Urban Consolidation Center on a larger scale in the city is deemed very feasible. This suggests that the success of the Madrid Living Lab pilot project has convinced the participants that a larger-scale implementation is possible and desirable. However, it is essential to note that there may be challenges and considerations unique to scaling up the project that were not addressed in the current pilot. These challenges should be carefully assessed and addressed before attempting to implement the project on a larger scale.

Suppose the Urban Consolidation Center in the Madrid pilot was applied on a larger scale (e.g., other logistics operators, other districts, etc.). Do you think it would positively impact the quality of life of the city's inhabitants? The impact of the Urban Consolidation Center in the Madrid pilot on the quality of life of the city's inhabitants was a concern for the participants. They were asked if implementing this strategy on a larger scale (e.g., other logistics operators, other districts, etc.) would positively impact the quality of life. The question obtained an average grade of 4.5, indicating that participants believe it would positively impact (see Figure 17). This feedback is important for policymakers and stakeholders as they consider implementing similar strategies in other city areas.

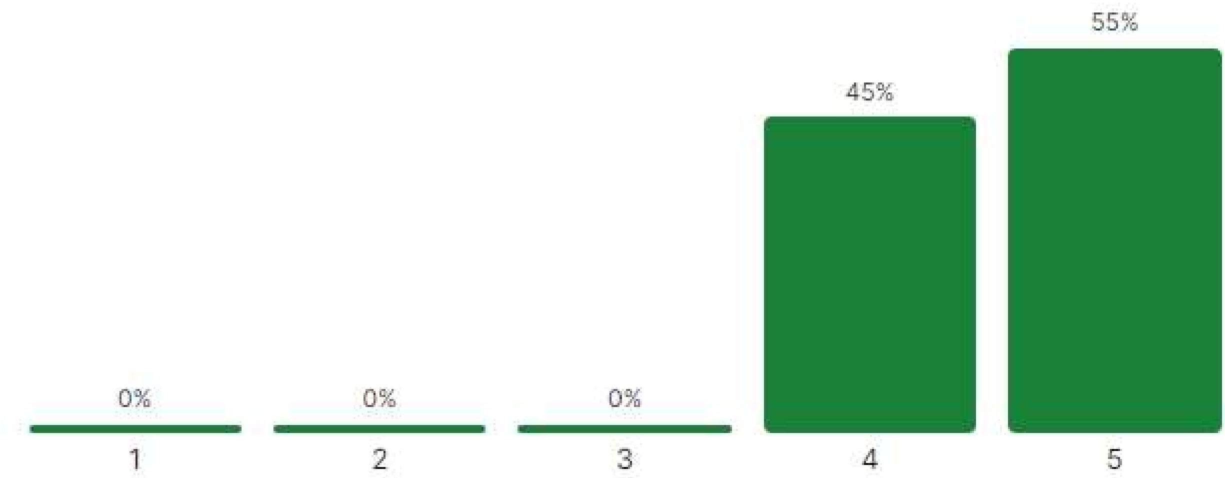

Figure 17 Do you think it would positively impact the quality of life of the city's inhabitants? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

If the Urban Consolidation Center implemented in the Madrid pilot were applied on a larger scale (e.g. to all logistics operators, etc.), do you think it would positively impact the business performance of logistics operators? Based on the responses from the participants, it appears that there is some uncertainty regarding whether the implementation of the Urban Consolidation Center on a larger scale would positively impact the business performance of logistics operators (see Figure 18). The average rating of 3.7 suggests that while some participants believe it could have a positive impact, others may be less convinced. It is important for policymakers and logistics operators to carefully consider the potential impacts of scaling up this strategy, taking into account both the benefits and any potential challenges or drawbacks. Ultimately, a comprehensive analysis should be conducted to determine the most appropriate course of action.

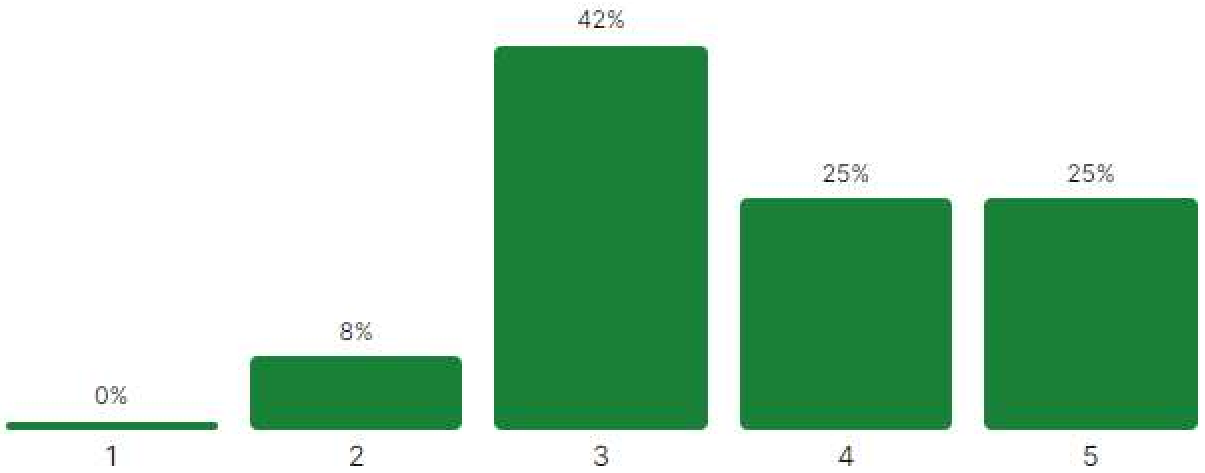

Figure 18 Do you think it would positively impact the business performance of logistics operators? (1. Totally Disagree, 2. Disagree, 3. Neutral, 4. Agree, and 5. Totally Agree)

7 Learnings and recommendations

Overall, considering the whole duration of the project, the main lesson learned is that for the implementation of the real-life pilot it is advisable to start as soon as possible, not only because of the difficulties in finding a suitable space, but also because of the administrative management that makes its use possible, since these are time-consuming procedures.

Another challenge is to match the needs of the local administration with the requirements of the logistics operator, since the business model must be sustainable over time, which implies not only environmental sustainability, but also financial and social sustainability. In this sense, one of the recommendations is to factor in the policies established in the city (regulatory framework, strategies, etc.) to promote this type of activities.

This also applies to the definition of objectives and KPIs, since they must be measurable, without adding unnecessary complexity to the management of the logistics operator, with results that are easily interpretable, and importantly, being useful for the operator in the process of improving its operations.

Although the analysis required many assumptions and is a rough estimation of the environmental impacts of different configurations for the shift of the consumers' preferences to the online channel, the results show that collaborative scenarios do not impact the transport efficiency and emissions while the service quality is improved. This level of collaboration is only possible with synchronous planning. Therefore, manufacturers and other actos across the supply chain may benefit from real-time digital twins to enable collaborative distribution schemes with local businesses.

Regarding the use of the DT, the extensive consultation and exchange with the Community of Practice pointed out that there is room for improvement in terms of the accuracy of the digital twin. Further investigation may be needed to identify the specific aspects of the digital twin that may require refinement to improve its accuracy. Additionally, feedback from logistics operators and other stakeholders could help identify potential areas for improvement in the simulation model user interface, which some felt could be improved with better graphical information to support decision-making.

There were also suggestions for incorporating operational and economic KPIs to track decision-making. Also, the possibility of adding to the DT other distribution typologies, such as HORECA (Hotel/Restaurant/Café) was suggested. Additionally, there were suggestions to include a weight variable rather than just volume for emissions issues, and adding scenarios to explore the use of lockers. Last but not least, there were suggestions for better visualization and visual representation of the simulation results.

Finally, the effective collaboration between public and private entities has been identified as a key strength of this partnership approach.

8 Summary and outlook

The Madrid pilot has run smoothly and without major difficulties. The LL1 promptly defined the modelling activities and data sources to be used in the Madrid Living Lab, including a description of the Pilot following the “minimum viable product” approach and conceptual diagrams to detail the stakeholders involved and the different interactions (based on agent-based models’ concept) for the “BAU” (how it is made today) and “UCC” (how we would like it to be) scenarios.

The specific models developed by the LL and the models configured from the Digital Twin Model Library have been also set, including the verification process for validating the simulation scenarios and KPIs.

The real-life pilot was implemented within the planned timeframe and it has been running since October 6th, 2021, and this fact has allowed to start the “BAU” scenario KPIs measurements to verify and validate the DT.

In brief, starting from the two aforementioned scenarios (“BAU” and “UCC”), the DT applies:

1. A 2-Echelon model developed by ZLC (to consider the UCC step), which uses fixed and semifixed data as input (including facilities, vehicles, and the echelon model configuration data). This model can be easily modified to adapt to potential changes on location, vehicles, etc. The georeferenced information feeds on the most recent area shapefile (Madrid Zona Centro), and calculates a rough-cut freight planning of operations.
2. The next step includes the calculation of vehicle emissions, by using COPERT (EU standard internal combustion engine vehicles under 3.5 ton emissions and energy consumption calculator), feeding from the 2-Echelon model. LEAD uses COPERT to estimate and compare the environmental impacts of implementing different scenarios. This allows to get KPIs to compare with the “do nothing” scenario, such as Energy consumption, GHG emissions, and air pollution (PM; NOx, VoC).
3. Once the previous steps are completed, the LEAD platform presents the user with COPERT and additional KPIs results of the two scenarios, and therefore, the user can choose which one to execute.
4. The user choice feeds the next step, which is the route optimization engine (by using Last Mile Team Digital Platform). This module also uses fixed and semifixed data as input (facilities, vehicles, drivers, work schedule, work breaks and other configuration data. As well as the 2-Echelon model, can be easily modified to adapt to potential changes (location, vehicles). The model performs stop-by-stop detailed route optimization.
5. The outcomes of the previous step finally feed the final models, both to recalculate emissions by using COPERT and the vehicle noise model developed by UPM.
6. The results set includes the vehicles emissions, the vehicle noise calculation and the detailed optimized route information for the selected scenario.

Finally, the development of the LEAD digital twin helped Panasonic to explore technical needs and data arrangements required for leveraging the learnings and outcomes acquired during the development of the last-mile digital twin.

So far, from the perspective and own experience of Madrid Living Lab, the main challenges, encountered in using DT solutions, include:

1. Lack of digitalization in some parts of the last mile supply chain
2. Data sharing mechanisms/Data agreements
3. There is no integration standard. LEAD introduces though a specification for the development of models that make them interoperable, in the sense that more than one models can be combined to simulate complex what-if scenarios.
4. Lack of capabilities (skills). The LEAD MOOC aimed at closing this skills gap of relevant stakeholders.
5. Difficulty/complexity in accessing open data sources

Finally, the modelling of the “UCC” scenario and calculation of activity data has been achieved in the recent months, which results have been included in this deliverable D3.4 (final demonstrator).

In terms of next steps, it is worth to remark that, due to the success of LEAD project and the fruitful cooperation amongst Madrid LL stakeholders, and with the willingness to extend the legacy of LEAD, EMT Madrid, together with Madrid City Council have got involved as partners in a new EU funded project on urban logistics that started last May 1st, 2023. This new project, called UNCHAIN (Urban logistics and plaNning: AntiCipating urban freigHt generAtion and demand including dIgitalisation of urbaN freight) belongs to the Horizon Europe programme and aims to boost the cooperation between public authorities and logistics stakeholders by creating a set of 12 innovative urban logistic services for optimal and flexible urban logistics operation (allocation of urban space), management, planning and policymaking, unleashing the potential that technology and digitalisation can bring to the sustainable urban logistics and moving towards climate-neutral and smart cities. 11 European cities will participate in UNCHAIN activities: Madrid, Berlin and Florence as living labs; Prague, Mechelen, Madeira and Tartu as follower cities, and Brest metropole, Ravenna, Riga and Alba Iulia as peer-cities supporting the early adoption of the results. Also, the well-balanced representation of the urban logistics industry, with DHL, UPS and CityDepot, will ensure large-scale impact and feasibility of the project results.

LEAD experience in Madrid LL has definitely set the ground for a totally new way of approaching urban logistics planning and management in the city.

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Annexe 1: Panasonic

Scenarios configuration

Table 28 shows the statistical analysis of Panasonic. As noticed, the data dispersion is very high. Considering the whole sample of the data the mean is 49 with a standard deviation of 85.

presents the input data for simulating different configurations for the transport network considering that the 100% sales are on the physical store. As noticed, the size orders of Set 1 and Set 2 are completely different, therefore the delivery time was estimated accordingly.

Table 28. Panasonic data statistical analysis.

				Mean	Std
Q4	*Customer 1*	*257*	Set 1	189	64
	Customer 2	*179*			
	Customer 3	*131*			
Q3	*Customer 4*	*11*	Set 2	2	3
	Customer 5	*1*			
	Customer 6	*1*			
Q2	*Customer 7*	*1*			
	Customer 8	*1*			
	Customer 9	*1*			
Q1	*Customer 10*	*1*			
	Customer 11	*1*			
	Customer 12	*1*			
			C1-C12	49	85

List of assumptions

- Need to harmonize the size of the orders for calculating the vehicles based on the capacity available. Panasonic sells a variety of products or stock keeping units in 5 categories: televisions, cameras & camcorders, Home entertainment, home appliances, personal and health care, professional cooking and home phones. The kilograms and volumes vary from each category and even within the same category. From a pragmatic point of view and considering the package of the BAU scenario with CityLogin is the average one, the Panasonic case will assume the size of the orders is the regular package size (Figure 2).
- As there is not data available about the operations as delivery time, vehicles used, facilities or consumers location, the scenarios simulated will consider the vehicles values used for the

scenarios (real and simulated) used in the LL1 Madrid with CityLogin. For the delivery times, they will be adjusted to the mean number of orders of the scenarios

- For the simulations, as there is not data available about the delivery points locations, the 2-echelon model in combination with COPERT and EVCO2 will be used.
- As the 2-echelon considers the average order size and the orders' dispersion is high, the sample of data was divided into two sets. Set 1 contains the customers with the number of orders in Q3 (Customer 1 – Customer 3) and set 2 with Q1, Q2 and Q3 (Table 21).
- For the second category of scenarios (95% B2B + 5% online), we assume the 5% from the B2B belong to Set 1. The result is that 9 orders of 1 package move to set 2. The total number of delivery points will be 18 with a mean of 1.55 (set 2 c in Table 21) orders per delivery point where 9 will be B2B (Set 2 a in Table 21) and 9 B2C (Set 2 b in Table 21).

Simulation results: Category 1 (100% B2B)

Table 29. Panasonic detailed results (simulation 100% B2B).

		Orders	Size	Stop time (h)	Network configuration	Vehicle (echelon 1)	Vehicle (echelon 2)	Number of vehicles (echelon 1)	Number of Vehicles (echelon 2)	Distance 1st Echelon (km)	Distance 2nd Echelon (km)	EC 1st Echelon (MJ)	EC 2nd Echelon (MJ)	CO2 1st Echelon (g)	CO2 2nd Echelon (g)	PM2.5 1st Echelon	PM2.5 2nd Echelon	VOC 1st Echelon	VOC 2nd Echelon	NO2 1st echelon	NO2 2nd echelon
100% B2B	BAU Set 1	3	189	0.5	1 Echelon	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Not applied	4	-	239.34	-	7.6E-04	-	0.0571	-	5.1E-06	-	6.0E-08	-	7.0E-05	-
	BAU Set 2	9	2	0.083	1 Echelon	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Not applied	1	-	62.22	-	2.0E-04	-	0.01505	-	1.3E-06	-	1.6E-08	-	1.8E-05	-
	Set 1 (Diesel Van) +Set 2 (Diesel van)							5		301.56		9.6E-04		0.07215		6.45553E-06		7.59355E-08		8.84818E-05	
100%B2B	UCC Set 1	3	189	0.5	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	4	17	236.17	24.87	0.00046	0	0.02999	0	3.8E-06	0	0.00088	0	2.2E-07	0
	UCC Set 2	9	2	0.083	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	1	1	59.83	5.05	0.00011	0	0.0075	0	9.5E-07		0.00022	0	1.6E-07	0
								5	18	296	29.92	0.00057	0	0.03749	0	4.7E-06	0	0.00109	0	3.8E-07	0
	Set 1(Hybrid van + E-scooter) + Set 2 (Hybrid van + E-scooter)							23		325.92		0.000569237		0.037487461		4.73808E-06		0.001094321		3.80704E-07	
100%B2B	BAU Set 1	3	189	0.5	1 Echelon	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Not applied	4	-	239.34	-	7.6E-04	-	0.0571	-	5.1E-06	-	6.0E-08	-	7.0E-05	-
	UCC Set 2	9	2	0.083	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	1	1	59.83	5.05	0.00011	0	0.0075	0	9.5E-07		0.00022	0	1.6E-07	0
								5	1	299.17	5.05	0.00087	0	0.0646	0	6.1E-06	0	0.00022	0	7E-05	0
	Set 1(Diesel) + Set 2 (Hybrid van + E-scooter)							6		304.22		0.000873847		0.064597492		6.05701E-06		0.000218924		7.01913E-05	

Table 30. Panasonic detailed results (simulation 100% B2B vs 95% B2B + 5% B2C).

		Orders	Size	Stop time (h)	Network configuration	Vehicle (echelon 1)	Vehicle (echelon 2)	Number of vehicles (echelon 1)	Number of Vehicles (echelon 2)	Distance 1st Echelon (km)	Distance 2nd Echelon (km)	EC 1st Echelon (MJ)	EC 2nd Echelon (MJ)	CO2 1st Echelon (g)	CO2 2nd Echelon (g)	PM2.5 1st Echelon	PM2.5 2nd Echelon	NO2 1st echelon	NO2 2nd echelon
95% B2B + 5% B2C	BAU Set 1	3	180	0.5	1 Echelon	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Not applied	4	-	236.17	-	7.7E-04	-	0.05714	-	5.1E-06	-	7.0E-05	-
	UCC Set 2	18	1.6	0.083	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	1	2	59.83	7.929	0.00046	0	0.02999	0	3.8E-06		2.2E-07	0
								5	2	296	7.929	0.00122	0	0.08713	0	8.9E-06	0	7.0E-05	0
	Set 1(Diesel) + Set 2c (Hybrid van + E-scooter) - (24hours delivery| not collaboration)							7		303.929		0.001223942		0.087133054		8.89986E-06		7.02518E-05	
95% B2B + 5% B2C	BAU Set 1	3	189	0.5	1 Echelon	Light Commercial Vehicles,Diesel,N1-III,Euro 6 a/b/c	Not applied	4	-	239.34	-	7.6E-04	-	0.0571	-	5.1E-06	-	7.0E-05	-
	UCC Set 2a	9	2	0.083	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	1	1	59.83	5.05	0.00011	0	0.0075	0	9.5E-07		1.6E-07	0
	UCC Set 2b	9	1	0.083	2 Echelon	Passenger Cars,Petrol Hybrid,Large-SUV-Executive,Euro 6 a/b/c	Three wheeler,Electric, Cargo, Vehicle	0	1	0	5.05	0	0	0	0	0.0E+00		0.0E+00	0
								5	2	299.17	10.1	0.00087	0	0.0646	0	6.1E-06	0	7E-05	0
	Set 1(Diesel) + Set 2 a(Hybrid van + E-scooter) - set 2b (E-scooter)- (same day delivery/ one hour delivery| collaboration)							7		309.27		0.000873847		0.064597492		6.05701E-06		7.01913E-05	

Annexe 2: KPIs calculation methodologies

Table 31. LEAD Environmental KPIs: LL1 Madrid calculation method, (BAU scenario).

KPI	Calculation Method	Measurement units
Energy consumption	COPERT using the average activity data from the month of January 2022 (number of vehicles, total kilometres, average speed) calculated by the route optimization model.	Average energy consumption per delivery (MJ/delivery)
GHG emission		Average CO_2 per delivery (gCO2/delivery)
Air quality		Average $PM_{2.5}$ per delivery ($gPM_{2.5}$/delivery)
		Average NO_2 per delivery (gNO2/delivery)
		Average VoC per delivery (gVOC/delivery)
Noise impact		

Table 32. LEAD Social KPIs: LL1 Madrid calculation method ("UCC" scenario)

KPI	Calculation Method	Measurement units
Jobs created	Data from operator	Number of employees
Quality of the jobs	Quality of the jobs (local survey involving the CoP)	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations.
Neighborhoods quality of life	Neighborhoods quality of life (local survey involving the CoP)	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations
Users sustainable behaviour	Users sustainable behaviour (local survey involving the CoP)	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations

KPI	Calculation Method	Measurement units
Cooperative solutions & incentive measures	Cooperative solutions & incentive measures (number of solutions implemented during the pilot development)	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations

Table 33. LEAD Economic KPIs: LL1 Madrid calculation method ("BAU" and "UCC" scenarios).

KPI	Calculation Method	Baseline scenario value
Average delivery cost of the business model	Data from operator	Annual average cost per delivery (€/delivery) [18]
Congestion 1 (Congested Shipments)	Data from operator	Not applied
Congestion 2 (Congestion from vehicles)[19]	Data from operator	Daily average time spent by vehicles on the road multiplied by the area occupied by vehicles (m^2*/day)
Urban storage and parking space[20]	Data from operator	Urban storage and parking area required depending on the type and ownership of the area (m^2)
Financial internal rate of return of the investment conducted	Data from operator	Not applied in the baseline scenario
Shop/retail benefits (shippers)	Local survey involving Shops/Retails	
Delivery time	Data from operator	Average time required to make a delivery (minutes/delivery)
Delivery reliability within the time window	Data from operator	Daily average percentage of deliveries made on time within the time window and in good conditions (%)

Table 34. LL1 Madrid: CityLogin specific KPIs calculation method ("BAU" and "UCC" scenarios)

[18] A: sensitive data. We provide and arbitrary value A.
[19] Assuming that the vehicle does not influence congestión when propertly parked
[20] Assuming that the vehicle does not influence congestión when propertly parked

KPI	Calculation Method	Baseline scenario value
ETA Accuracy	$\sum_1^n \lvert ATA - ETA^{21} \rvert / n$ Data from the operatorr	Average difference between the ATA and ETA per delivery
Delivery succes rate	$\sum_{i=1}^n \%parcels\ deliver\ in\ time_i / n$ Data from the operator	Average number of parcels devlier in time
Distance per delivery	$\frac{\sum_{i=1}^{\#\ parcels} d_{si} + d_{fi}}{\#\ parcels}$ 22 .Data from the operator	Average distance per delivery

[21] ETA: Expected time of arrival proposed by CityLogin to the consumer. If confirmed CityLogin commits to deliver the parcel within the next hour.
[22] dsi=distance of success deliveries;
dfi=distance of failed deliveries