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D3.12 Oslo Value Case

Final demonstrator

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Acronyms

Acronyms	Explanation
ABM	Agent-Based Modelling
B2C	Business-to-consumers
Bc1	Base Case 1
Bc2	Base Case 2
CoP	Communities of Practice
CS	Crowdshippers
DCM	Discrete Choice Model
DT	Digital Twin
EDM	Experiment Design Model
E-vans	Electric vans
GDPR	General Data Protection Regulation
KPIs	Key Performance Indicators
LEAD	Low-Emission Adaptive last-mile logistics supporting 'on Demand economy' through digital twins
LL	Living Lab
LSP	Logistics Service Provider
MVP	Minimum Viable Product
NPRA	Norwegian Public Roads Administration
PT	Physical Twin
S1	Scenario 1
S2	Scenario 2
S3	Scenario 3
S4	Scenario 4
SP	Stated Preference
UFT	Urban Freight Transport

Executive Summary

The pilot in Oslo is located in the central area of the city. Oslo is one of Europe's fastest growing cities and is planning to cut CO2 emissions by 95 % by 2030. The LL5 Oslo aims at promoting within city logistics the use of electric propelled vehicles and crowd shipping services with the intent of increasing urban delivery efficiency and reducing negative externalities (emissions and noise). The value case focuses on delivering large items from commercial furniture stores. NIMBER ships these items after consolidating them in a micro-hub. Starting from the micro-hub, bringers distribute goods abiding by end customers' preferences for time windows and flexibility. The main challenge has been to demonstrate the value of these new business models for the whole community (Logistics Service Providers (LSP), operators, suppliers, customers) and make it sustainable beyond the project.

In the case of LL5 Oslo, four "*what-if*" scenarios are designed and tested both in a physical and digital environment to measure the improvement of the new business models (TO BE scenarios) compared to the AS IS scenario. The LL5 Oslo also investigates stakeholders' acceptability of the scenarios using Stated Preference (SP) surveys whose results represent an input for Agent Based Models (ABM) which help predicting the most likely impacts. Hence, LL5 Oslo uses four models in the Digital Twin (i.e., Experiment Design Model (EDM), Discrete Choice Model (DCM), ABM_Molde and Mass GT) to test the solutions envisaged and to estimate their environmental impact.

The description of the final DT representation relies on conceptual diagrams to show detailed design specifications for the innovative last mile solutions envisaged, following the Minimum Viable Product Approach (MVP) which includes the description of the: (1) LL specific models (including ABMs) developed by the LL, (2) other components from the Generic Models Library (Other LLs specific models), (3) configuration of the LL DT to integrate all the models (LL specific ones and the ones from the Generic Models Library). The document describes the validation process and how it followed two separated yet coordinated paths in line with the status of the project activities.

1 Introduction

1.1 Scope and objectives

This deliverable represents an updated and final version of the activities and results presented in D3.11. 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 LL5 Digital Twin and the configuration of the LL5 in the LEAD Digital Twin. This D3.12 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 and policymakers' perspectives. Table 1 illustrates 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 present deliverable addressing LEAD GA	Description
ST3.6.1 Preparation. MVP Specification and Modelling.	Chapter 2. Oslo pilot	This section contains a description of the pilot in Oslo following the MVP approach and conceptual diagrams to detail the stakeholders involved and the interaction (based on agent-based models' concept) for the AS IS and TO BE scenarios.
	Chapter 3.1 Scenarios Modelling and chapter 3.2 and 3.3 with the configuration of the DT and "*What-if*" scenarios	This section contains conceptual diagrams of the AS IS and TO BE scenarios following the MVP approach. It includes detailed descriptions of the specific models developed by the LL and the models configured from the Generic Reference Model Library.
ST3.6.2. Digital Twin Verification.	Chapter 4. KPIs measurements	This Chapter reports the results of the KPIs described in D3.1 baseline measurement.
	Chapter 5. Business value validation and user acceptance	This section describes the verification process for validating the simulation scenarios and validating the KPIs baseline measurements.
ST3.6.3. 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 2.3. Physical pilot activities	This section reports all the agreements and steps for configuring and launching the real-life experiments. Preparation of the experiments.
	Chapter 6. Learning and recommendations	Update of the implementation plan reported in the D3.1 and description of the next steps for finishing the DT.

ST3.6.4 Evaluation/Impact Assessment:	Chapter 3: Simulation environment	This Chapter reports the modelling conditions/ assumptions; the data sources and data ingested used for calculating the baseline KPIs measurements, key results of the simulation exercises and verifying and validating the DT.
	Chapter 2.3. Pilot activities	This section reports the execution and results from the physical pilots to configure the DT
	Chapter 5. Business value validation and user acceptance	This section describes the verification process for validating the simulation scenarios and validating the KPIs baseline measurements
	Chapter 6. Learning and recommendations	This chapter summarises the lessons learned and proposed the outlook for the next steps

1.2 How does this deliverable relate to other deliverables?

This report is based on the results of D1.3 (Innovative Business Models, Governance and Public Private Partnerships), D1.4 (Innovation Agenda: Value case scenarios and validation KPIs), D2.3 (Decision Support Systems and APIs) and D3.1 (Living Labs planning, setup, and management). This report is the updated version of the D3.11 and contributes to the D3.2 and D3.15.

1.3 Structure of the document

- Chapter 1: Introduction
- Chapter 2: The Oslo pilot
- Chapter 3: Simulation environment
- Chapter 4: KPIs measurement
- Chapter 5: Business value validation and user acceptance
- Chapter 6: Learnings and recommendations
- Chapter 7: Summary and outlook

2 The Oslo pilot

2.1 Description

The study area for the Oslo pilot is in both Oslo business area and in the neighbouring cities. Oslo is the capital of Norway and is one of Europe's fastest growing cities. The current plans are to cut the city's CO2 emissions by 95 % by 2030. The City's forthcoming Climate Strategy identifies city logistics as an important policy area for reduced emissions focusing on measures promoting higher load factors and creation of collection centres for zero-emission distributions. More efficient urban freight logistics is core to reach the ambitious CO2 emission reductions. New and innovative urban freight logistics concepts are therefore needed.

The objective of the LL5 Oslo is to: 1) define under which conditions can a shift towards a city logistic scenario based on electric vehicles take place; 2) evaluate the environmental viability of crowdshipping, aiming to mitigate negative externalities related to urban deliveries. In addition, the value case also tests how the use of a Hub can help with the flexibility and optimization of the deliveries. The value case was formulated based in two different base cases. The first used IKEA as the main provider of goods, which supported the decision to focus the Oslo case on the delivery of mainly bulky items (furniture). The second base case, also used in the KPI calculation, focuses on furniture stores and also from shops specializing in one/few product(s), that work with NIMBER in their daily deliveries. The main challenge is to demonstrate the value of these new business models for the whole community (LSP, operators, suppliers, customers) and make it sustainable beyond the end of the project.

2.1.1 Base Case 1 - IKEA

The first step to construct this base case (Bc1) was a small pilot-study at IKEA Slependen, performed by NIMBER in November 2020. It investigated the most popular time windows (14-17h and around 20-21h), to where the orders were delivered, with distribution over days and locations. The pilot also mapped customer's characteristics, preferences, and changes in the use of private cars. The results obtained, supplied valuable information for a set of experiments and contributed to the formulation of the scenarios described in Figure 1. This base case was crucial to orientate the final LL5 experiments. Deliverable 3.11 contains all the information regarding the tests, interviews and detailed information related to Bc1. Additionally, the KPI's measured from Bc1 can be found at Annex 1.

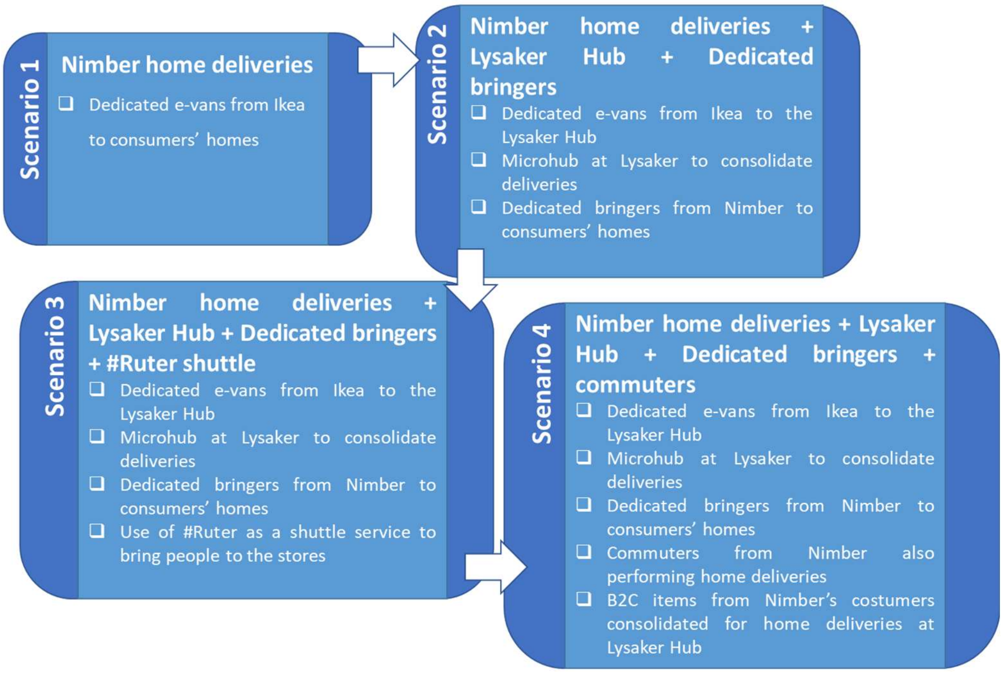

Figure 1. Base Case 1 Scenarios

2.1.2 Base Case 2

Thanks to the lessons learned from Base Case 1, a new base case was designed. In Base Case 2 (Bc2) furniture stores, located close to Slependen, delivering products to consumers' homes (business-to-consumer (B2C) were asked to participate. In essence, Bc2 shares the main characteristics with Bc1 in the sense that larger, furnishing-related B2C items are shipped. NIMBER currently performs these deliveries using electric and diesel vans (Figure 2).

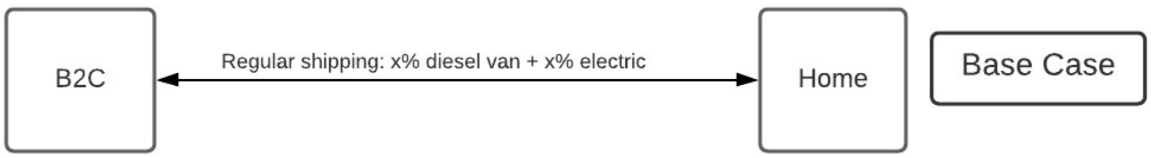

Figure 2. Base Case 2

Therefore, the Oslo Value Case and "*What if*" scenarios were elaborated based on NIMBER current activities, using their historic data and knowledge obtained from the first trial. The value case rests upon the use of a micro-hub located in Fornebu (Oslo) and the "*What if*" scenarios, explained in Figure 3, aim to explore:

- Business model financial viability and benefit from a social/environmental perspective.
- Senders'/Bringers'/Receivers' preferences for alternative delivery services. This is investigated via a Stated Preferences study .
- The interplay between demand and relevant supply design of crowd-shipping services. This is addressed in scenario 3.
- The role of a MicroHub in enhancing bringers' pick-up and drop-off flexibility

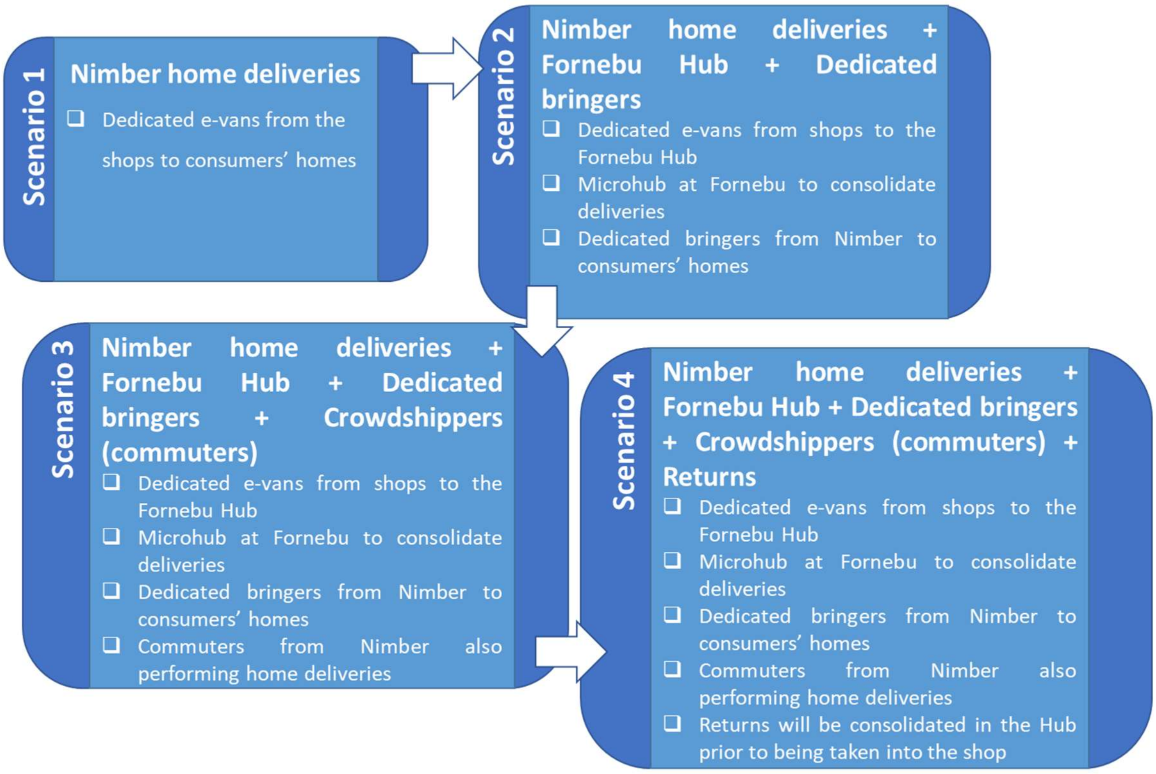

Figure 3. LL5 Oslo "What if" Scenarios

2.2 Agents and interactions

Deliverable 3.1 reports an overview of the LL's main stakeholders' role and resources, in section 8.2. It is replicated here (Table 2), with an additional description of the interactions between them.

Table 2. Description of the LLs stakeholders' roles and resources

Stakeholder	Resources	Description (why, how, when, and how long)	Interactions
Furniture Stores	Freight flows, data	The main store that will provide items for the real-life experiments in all four scenarios. The entire experiment period.	Primarily with NIMBER during the experiments, to 1) supply the experiments with shipments and 2) provide corresponding data.
NIMBER	Bringer services, data	Organise the bringer services, providing dedicated vehicles, agreement with property owner for localization of the MicroHub, provide data on vehicles, bringer times, costs, type of items transported, customer addresses (GDPR regulations will be followed). Supplementary data. The remaining project period.	Primarily with IKEA during experiment 1-4, and with other stores in experiment four, to carry out the practical experiments and with merging corresponding shipment and order data.

NIMBER's bringers	Input to the CoP innovation process	In addition to carrying out crowdshipping services with vehicles, representatives from the bringers will participate in CoP activities. The remaining project period.	Primarily with NIMBER as their employer but also with MOLDE and the other LL members in refining the experiments for future application and evaluating them.
OSLO	Data on traffic flows, coordination with other UL projects	Data on traffic flows, discussions, coordination activities, building of CoP. The entire project period.	Primarily with MOLDE to provide data on traffic flows, discussions under way and evaluation of the experiments. OSLO is heading the EU/MOVE21 project and MOLDE has already met with their coordinator.
INLECOM, DELFT	Model	DT modelling. The remaining project period	Primarily with MOLDE for DT modelling input and data. Integration of models to DT platform by INLECOM.
MOLDE	Running the LL, agent-based modelling	Running of Oslo LL, ABM and DCM	Primarily with NIMBER and OSLO for data and discussions.

Figure 4 illustrates the conceptual AS IS model for LL5, where three agents are involved: *Physical shops* (receives the purchase order, provide the goods), *Consumers* (generate the freight demand and decide on the type of delivery will be used) and *NIMBER*. In this scenario, NIMBER performs the delivery using both dedicated bringers and regular logistics operators. The choice of the type of delivery is taken by Shop owners, directly when using NIMBER'S platform, and based on this, NIMBER performs deliveries as required.

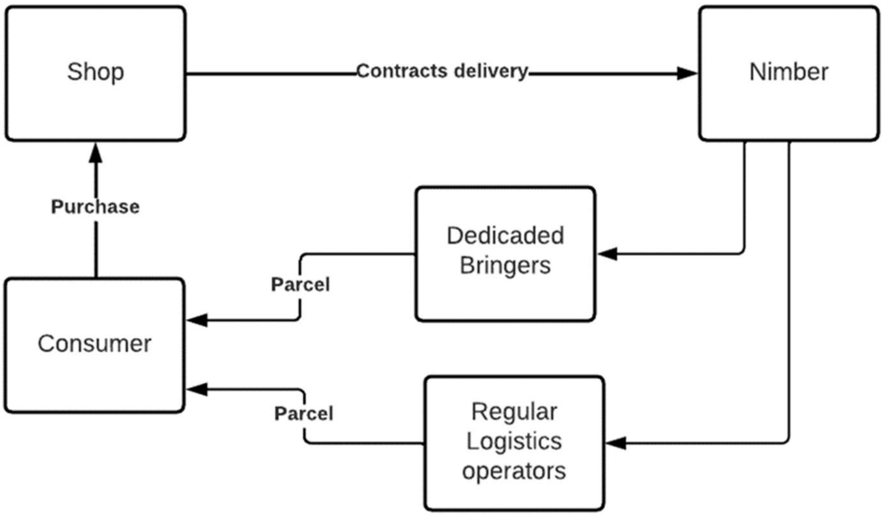

Figure 4. LL5 Oslo – AS IS Scenario

In the TO BE Scenario, shop owners continue choosing the delivery type while in this context all the parcels are consolidated in a MicroHub, closer to Oslo city centre, using dedicated bringers. The dedicated bringers are NIMBER'S employees that will pick-up and fulfil deliveries from the MicroHub using electric vans only. Then, Dedicated Bringers, using the MicroHub will distribute goods to final consumers. The second novelty in the TO BE Scenario includes a new agent, NIMBER'S community of bringers. One of NIMBER'S current service is to connect people or businesses who are going to send a parcel, with people who are going the same way. This is referred to as crowdshipping, where the crowdshippers can use the mode of transport that they prefer. Figure 5 reports the core agents and their interactions in the TO BE Scenario.

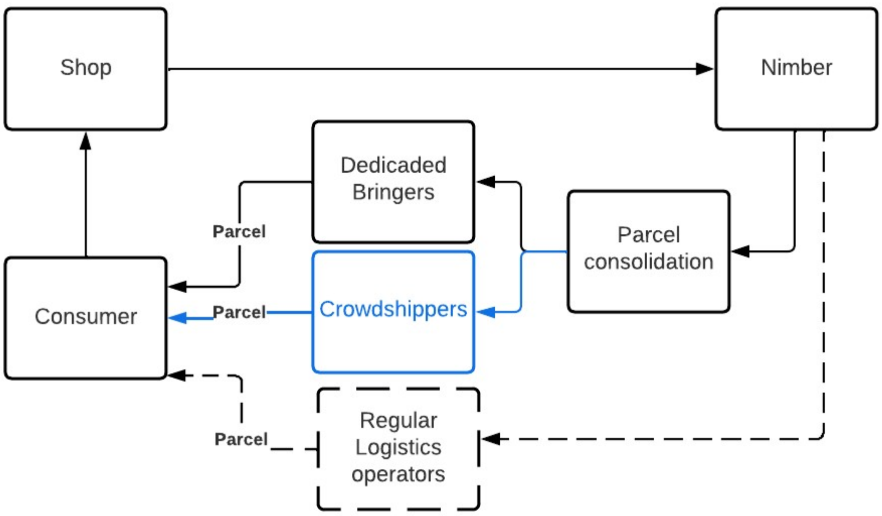

Figure 5. LL5 Oslo - TO BE Scenario

Regarding the actual delivery, for the crowdshippers, a task is created within the crowdshipping platform using some of the deliveries that were formerly performed by regular logistic operators. If the task is not fulfilled, a dedicated bringer will take care of the delivery. As for the dedicated bringers, formal route scheduling is implemented. The crowdshippers can build routes themselves by combining items to several end-customers on the same trip. Concerning the Regular Logistics operators, the process is the same for all trials.

Elaborated from Deliverable D1.4, the list below shows the LL5 stakeholders included in the LL5 CoP.

- Property owners of the location for the micro-hub
- Businesses taking part in the shipment (B2C customers of NIMBER)
- Residents representing areas where NIMBER has regular deliveries.
- Norwegian Public Roads administration (NPRA)
- Regional project coordinator for urban freight projects
- Participants in ongoing urban freight logistics projects
- Researchers taking part in projects dealing with related issues. This includes the Institute of Transport Economics in particular, where we have contact with the EU/H2020 ULaads project.

The LL5 Oslo team has good and frequent contacts with most of the CoP members. NIMBER has a few businesses as customers and their flows will be fed into the shipments. There are regular contacts with NPRA, who is also a part of LEADs Advisory Board. The regional urban freight project ‘Varelevering i Vestkorridoren’ coordinator has been contacted, with a clear interest in contributing to LL5 Oslo. Participants in ongoing urban freight logistics projects such as Bring and researchers dealing with related issues from the Institute of Transport Economics (TØI) have contributed to the validation of the scenarios. One meeting has taken place (web meeting on 27 October 2020) to exchange ideas, experiences, and challenges across related Last Mile Deliveries projects from other cities in Norway. Through Workshop 1 (31 May 2022) the CoP was involved in the evaluation of the experiments and in developing the experiments further, for future reference.

2.3 Pilot activities

2.3.1 Pilot implementation

Figure 6 contains the representation of the “*What if*” scenarios that were planned to be tested both in real life and in the Digital Twin. LL5 managed to test the first three proposed scenarios, obtaining good outcomes. The main challenges of implementing the scenarios started with the MicroHub location. Initially it was planned to use a green mobility hub close to Oslo city centre (and close to one of the main arterial roads (E18) and a bus stop), but this had to change because the scenarios using other than e-vehicles could not be implemented there due to restricted use of conventional fuel. The second attempt was close to Lysaker, 7 km west of downtown Oslo but still conveniently located close to one of the main arterial roads (E18) and to areas where NIMBER’s end customers reside. There was no bus stop close by, but this was of minor to no importance because all scenarios deal with larger furniture that are less suited for being taken through the public transit network. This location had to be abandoned too, because of road construction work that in an unforeseen way affected the experiments. The final location at Fornebu (close to the pre 1998 Oslo main airport) shared many of the same characteristics as the Lysaker location, but it had better facilities for access and egress because it was shared with other hub activities. One challenge though was restricted opening hours, which were in coherence with regular business hours and hence put some challenges on evening deliveries. This was handled through manual adaptations by staff employed at NIMBER's, as described below.

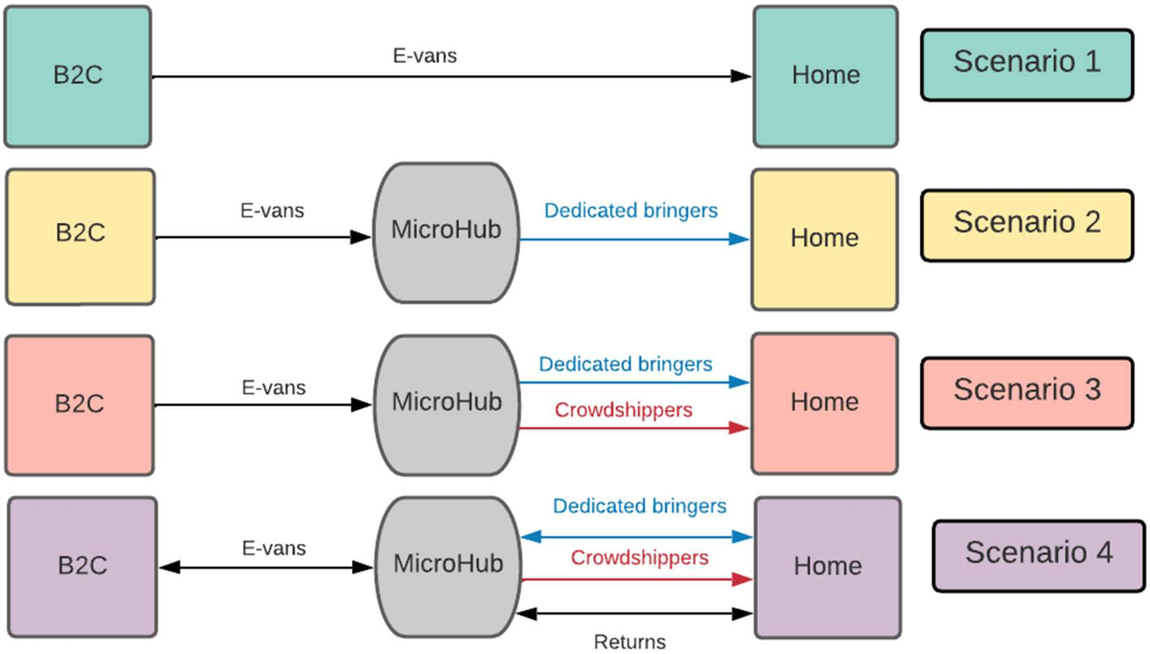

Figure 6. LL5 Oslo Pilot "What-if" Scenarios

Due to the delay with the MicroHub location, the pilot started its operations with Scenario 1 (S1) on September 26th, 2022, and continued until 07th October 2022. Since S1 envisioned the use of only electric vehicles (e-vans), some adjustments were needed in the vehicles (maintenance) and in the operations to make sure all the deliveries were performed following the requested timeframe asked from the shop.

The pilot had to be stopped for 37 days, while the negotiations with the Fornebu Hub were being held. Scenario 2 (S2) started on the 14th of November and lasted until the 16th of December 2022. In this scenario, NIMBER went through an important learning process, together with the partnered shops, to enhance and optimize the pickup process. This will be quite visible when presenting on field measured KPI's in the following chapters.

Scenario 3 (S3) started 27th of December and finished 28th of January. In S3, a main problem was limited access to the Hub for CS. Fornebu hub could only be accessed using card keys, and Nimber could only have a limited number of keys for its employees. Therefore, the pilot test involving CS had to undergo some adjustments. In fact, when the tasks were posted to NIMBER's community accepted, someone from NIMBER had to be physically at the Hub to handle the packages. This entails that the flexibility for CS usage was restricted and not in line with intentions. A total of 43 parcels were delivered using CS, separated between 29 routes.

When implementing Scenario 4 (S4), that foresaw the incorporation of returned products from the consumers, some unforseeble issues, related to low demand, were encountered. In total, around 10 per cent of the freight volumes in Norway are returns. There are no detailed sectorwise data available, but this share is likely to vary among sectors. For the duration of the experiments , only one returned product was handled by NIMBER. Therefore, the LL5 team, together with NIMBER, decided to investigate the market by means of a survey to acquire a clearer vision of the possible opportunities to exploit and constraints to overcome in order to increase demand for returns through CS operations. A total of 14 companies, currently NIMBER's daily customers, answered the questionnaire, with 4 of them working with NIMBER on their returns.

2.3.2 Oslo Living Lab workshops and events.

Oslo Living Lab has organized two workshops with the 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 5 and Deliverable 3.15).

2.3.3 Conferences and Recognitions

LL5 participated in different seminars and conferences, where we were able to disseminate the work done in the Digital Twin, as well as the learnings from the Living Lab approach. Important also to mention that two articles were produced and published. Annex 2 contains detailed information on the activities.

3 Simulation environment

The deliverables (D3.11, 2022) and (D2.2, 2023) introduce a detailed description of the LL5 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.

The objectives of this section in this deliverable are threefold. First, to complement the previous deliverable D3.11 with an explanation of the final refinements needed to compare the sustainability performance of the pilot implementation after introducing the proposed scenarios. Second, to describe the different "*what if*" scenarios that will be simulated with the digital twin. Finally, present the results of the scenarios simulated with the digital twin. In addition, it explains how the LL5 digital twin is integrated in the LEAD platform.

3.1 Digital Twin: Scenario modelling

3.1.1 Description of the LL5 Models

For reproducing the logistics operations of the Oslo real scenarios (Bc2 vs. TO BE) in the Digital Twin, LL5 has taken a unique data input request to the user(s), using a two-step modelling approach that meets Oslo's ambition and that integrates with the LEAD vision and could be extended to other cities. The first step is based on the MASS-GT related modules developed by TU Delft. These are Pa*rcel Generator, Parcel Market, Parcel Tour formation*, and *Network Assignment*. Second step uses two models created by LL5, named *ABM_Molde* and *DCM_Molde* and a tool named *EDM_Molde*. Figure 7 describes the two steps, how they are connected and some of the main inputs/outputs obtained from the models.

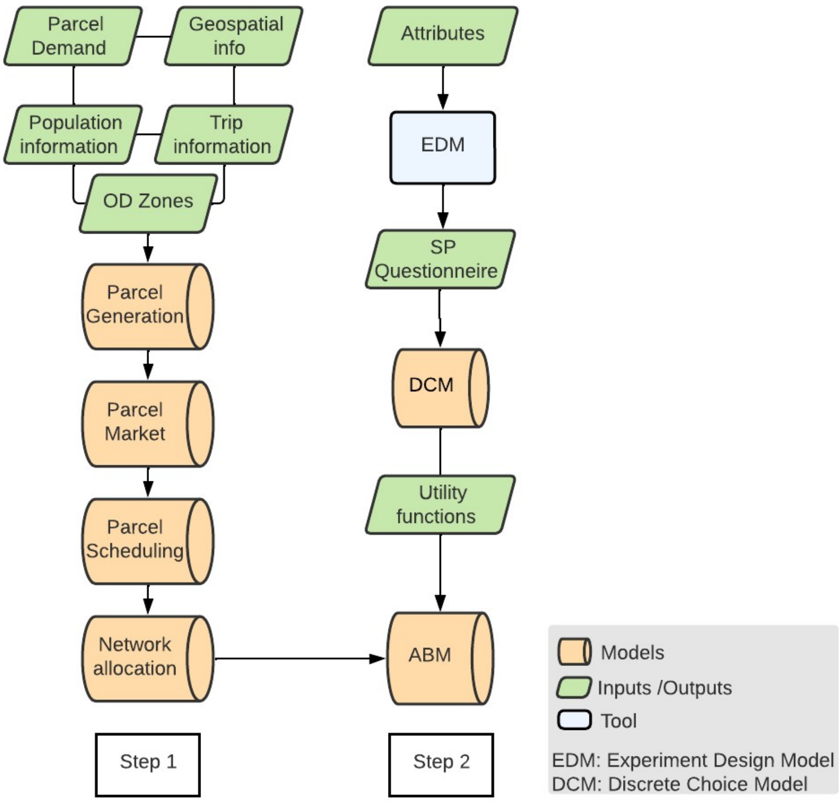

Figure 7. LL5 Oslo Models

3.1.2 Generic models and connectors

Tables 3,4 and 5 below contain an updated summary of the models and connections of the LL5 digital twin pipeline already explained in (D3.11, 2022).

Table 3. Summary of the generic models developed in the framework of LL5.

Model	Description
EDM_Molde	This model represents an analytical tool that provides the building blocks to design the choice experiments included in the SP survey so to acquire the necessary data to be used for DCM. In the LL5 case, a SP survey will be administered. This will help forecasting agents' decisions, by asking respondents to select the most preferred option within a choice set in hypothetical situations given a specific set of conditions created thanks to a specific choice experiment design (CED). In more detail, alternatives, included in a choice set and shown to respondents, represent goods or services that differ from each other based on given attribute levels. CED allows constructing suitable choice tasks by appropriately combining attribute levels. (D2.2, 2022).
DCM_Molde	Analytical tool to model agents' preferences, assess adoption/acceptance/reaction, optimise stimuli selection, and identify compromise solutions. Discrete choice models (DCM) are econometric models aimed at estimating decision-maker's choices among alternative (discrete) options. Both stated preference (SP) and revealed preference (RP) data can be used as inputs. This model will be used to investigate stakeholders' preference heterogeneity to forecast their choice behaviour. (D2.2, 2022).

ABM_Molde	Analytical tool to simulate agents' behaviour in a given environment and perform scenario analysis evaluating transport impacts. In this context, using data characterizing single agents' preferences, such as the utility functions. This approach allows capturing stakeholders' willingness to pay/accept when adopting a new type of delivery (green delivery) and model their preference together with other agents (policy makers and cargo owners) and thus estimate their environmental impact. This will allow forecasting how the engaged stakeholders will act in a specific context. (D2.2, 2022).

Table 4. Summary of the proprietary models integrated into the framework of LL5.

Model	Description
Noise pollution 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 will be used to measure noise KPIs. The model is available on GitHub, and additional information can be found in (D2.2, 2022).
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-equivalent and Air pollution - [PM; NOx; VoC]. More detailed information about the model can be found in (D2.2, 2022).
GHG emission from EV	The methodology proposed for estimating the CO2eq emissions from electric vehicles is associated with the electrical mix characterising electricity production in Norway. 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). More detailed information about the model can be found in (D2.2, 2022).
Parcel Generation – TU Delft	The parcel generation module generates the demand from population values and parameters. The demand is randomly generated and aggregated in zones. As a result, we get a parcel demand per zone, together with the information concerning the carrier that will fulfil the delivery. The parameters needed to feed the models are the average parcel generation rates per household (for B2C and C2C segments) and employee (in the case of B2B). With that data, and assuming uniform generation per household the number of parcels is generated per area. Randomly, those parcels are distributed per courier according to their market share.
Parcel Market – TU Delft	The parcel market has as an objective to define the fulfilment of the parcels to their final destination. The fulfilment of the parcels is the process in which each of the parcels reaches its final destination. The fulfilment can be done via one or more logistic service providers (LSP), including a crowdshipping platform. As a result, parcel origin and destination are broken down into individual trips between connection points by one carrier. The output of this model is a list per LSP on how each parcel is transported from the origin to the destination, including pick up tours.

Parcel Scheduling – TU Delft	The parcel scheduling model receives as an input a list of parcel origin and destination per Logistic Service Providers (LSP) and generates the sequence of stops to fulfil them. The parcel origin and destination are separated depending on if they are consolidated (hub to hub) or delivery to the final customer, allowing each type to have its separate vehicles.
Network allocation – TU Delft	This model acquires the tours (zone stop list) and allocates them to the network. The links between the zones are centroid to centroid and are consistent with the Skim matrices used in other related models. As a result, the links are populated with the delivery vehicles and the routes can be obtained. As an output, a shapefile with the vehicle counts can be obtained.

Table 5. Summary of the LL5 model connectors.

Model	Description
Gen2Market	Connector between the parcel generator and the parcel market models. It adapts the parcel OD output from the parcel generation and details the fulfilment options that can be used in the parcel market.
Market2Sched	Connector that adapts the parcel market model output to the parcel tour formation model. It separates the first and last mile trips and the consolidated tours.
Sched2Netw	Connector that adapts the scheduling model output to feed the network model
Sched2COPERT	Connector that adapts the scheduling model output to feed the COPERT. model
Netw2NOISE	Connector that adapts the outputs of the network model to the Noise emission model.
Sched2ABM	Connector that adapts the outputs of the scheduling model to the ABM model

3.1.3 Data collection and anonymisation

Table 6 reports the data sources that was used in LL5. The data is collected and stored in accordance with the GDPR regulations. In addition, the configuration of the LL5 DT is explained was explained in D3.11. The characteristics of the vehicles used in the modelling and in the pilot are described in Table 7.

Table 6. LL5 Oslo – data sources

Data source	Data type	Description	Dependencies (KPIs, models)
Stated Preference Questionnaire	Static	To obtain the utility functions for the consumers – their preferences regarding the green delivery. Socioeconomic data Environmental preferences.	EDM DCM ABM_Molde
Population data	Historical	City of Oslo population.	Mass-GT
Shapefiles of Oslo City	Static	Geographic data of Oslo city. It contains the shapefiles of the roads and nodes	ABM_Molde Mass-GT
Facility Location – MicroHub and Pick Locations	Historical	Latitude and longitude of the facilities considered for running the scenarios. Open-source map.	ABM_Molde Mass-GT
Vehicle's information	Static	Set of vehicles used for running the scenarios AS IS and TO BE. Provided by NIMBER.	ABM_Molde Mass-GT
Parcel information	Historical	Information of the parcels to be delivered. Provided by NIMBER	ABM_Molde Mass-GT
Services information	Historical	Past deliveries performed by NIMBER for model calibration.	ABM_Molde Mass-GT

Other data

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

COPERT requires the monthly maximum and minimum temperatures as well as the humidity of the city as well as the average peak and off-peak traffic speed and time share.

EVCO2 requires 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.

Table 7. Vehicles information used in the modelling

Features	Maxus Deliver 3 E-Van 1	Maxus Deliver 9 E-Van 2	Maxus Deliver 9 E-Van 3
Engine	Electric	Electric	Electric
Max Payload	830 Kg	1085 Kg	1085 Kg
Range	227 Km	186 Km	186 Km
Cargo Volume	4,8 m^3	9,7 m^3	9,7 m^3
Environmental Class	Euro 6	Euro 6	Euro 6

3.1.4 Definition of the modelling conditions

The model conditions for the base model have not been essentially changed since D3.11. For the different value cases, the model definitions are given in section 3.4 on the mentioned deliverable.

3.2 Digital Twin: verification process

The verification of the KPIs of the DT models was done directly in the pilots, where all the *"what-if"* scenarios where tested. In addition, the verification and validation were done qualitatively by consulting constantly with the logistical party and the municipality. In both workshops (Section 5.1 and 5.2) the DT modelling approach was shown and explained. Specifically, in workshop 2 we presented the LEAD platform tutorial video, together with the main results for LL5 (see section 4). During Workshop 2, a discussion was also held about the scalability of the LL and the validity of the modelling approach and possible scalability for different European projects.

3.3 LL5 Oslo *"What if"* scenarios definition and simulations

This section touches upon the definition of the different scenarios, the models, and the data used in each one of them. It connects to Section 3.1, where the models that are used within this deliverable are defined. In addition, we present the results obtained for each one of the scenarios.

3.3.1 Scenario 1

The goal with scenario 1 (SC1), presented in Figure 8, was to use only E-vans to perform 100% the deliveries that once were done by a mix of Diesel and Electric vans. This scenario aims at answering a basic question: Based on past demand, is it possible to use only E-vans to perform all the furniture deliveries, while maintaining the quality of the service?

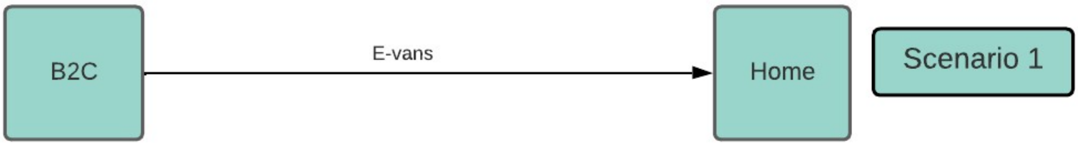

Figure 8. LL5 Oslo – "What-if" scenario 1

SC1 testing was crucial to first, formulate the following "*What-if*" scenarios and, secondly, to understand the importance of having a MicroHub closer to Oslo city centre. For this task, the three vehicles mentioned in Table 7 were used. As for the parcel information, pick-up and delivery location were based in real data from the LSP.

3.3.2 Scenario 2

The goal with scenario 2 (SC2), demonstrated in Figure 9, was to verify the role of a MicroHub in enhancing dedicated bringers' pick-up and drop-off flexibility. The first step to this scenario is the fulfilment of the MicroHub with the parcels from the Shops, using E-van 2 (Table 7) and Nimber's dedicated driver. From the MicroHub, E-van 1 and E-van 3 performed the final deliveries to the consumer's house. In this scenario, the flexibility of the MicroHub, together with the consumer's preference for greener deliveries were measured.

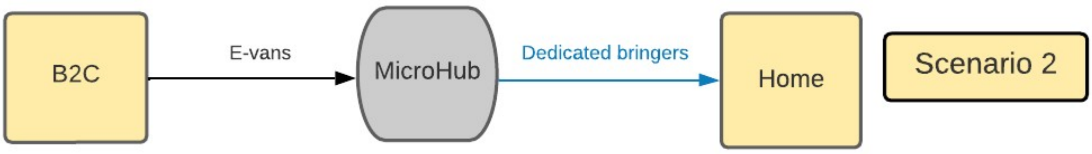

Figure 9. LL5 Oslo – "What-if" scenario 2

The main data used for this scenario were parcel information, pick-up and delivery location, based in real data from Nimber. In addition, a stated preference (SP) survey was performed to understand the consumer's preferences regarding the new green service performed by Nimber. As for the MicroHub, a static location was used, based on a pre-defined contract and decision from Oslo Municipality.

Regarding the survey, which attributes are shown in Figure 10, the consumers' preferences are based on lower price for the delivery, less than 30 minutes of delay in the delivery time window, 2 days to receive the purchase with flexibility to change the delivery time and date. The highest probability of the model is 86,77%, this being the percentage of consumers who accept the proposed green service.

Attributes	Levels
Price for the delivery (kr)	460
	550
	610
Punctuality	Less then 30min
	More then 1hr
Lead Time (days to receive products)	2
	3
	4
CO2 (emissions)	Green
	Yellow
	Red
Flexibility (to change delivery day and time)	Yes
	No

Figure 10. LL5 Oslo – Stated preference attributes for consumers' preference.

3.3.3 Scenario 3

The goal with scenario 3 (Figure 11) was to verify the interplay between demand and relevant supply design of crowdshipping services. In the scenario, the services tested in Scenario 2 were maintained, as well for the data and the parameters, meaning that the Dedicated bringers were still used to perform most of the deliveries and as a backup for the deliveries not fulfilled by the crowdshippers.

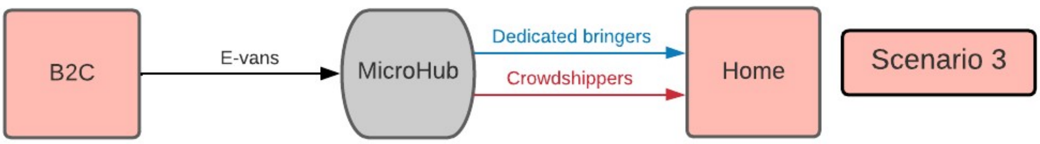

Figure 11. LL5 Oslo – "What-if" scenario 3

The crowdshipping services parameters also followed a stated preference survey (Figure 12), where the attributes measured the willingness of commuters to act as crowdshippers. The highest utility (values highlighted in a green box) was found when higher payments were offered and paid per delivery, also with the possibility of performing the delivery in the evening time. Additionally, the respondents also preferred to select themselves the deliveries.

Attributes	Levels
Remuneration (kr)	150 250 350
Time (hrs)	Morning (07:00-12:00) Afternoon (12:01-17:00) Evening (17:01-22:00)
Frequency (number)	Single delivery Per 5 deliveries Per 10 deliveries
Delivery assignment	Company Self-select
Distance (km)	0-5 5.1-10 10.1-20

Figure 12. LL5 Oslo – Stated Preference attributes used for crowdshippers

3.3.4 Scenario 4

The goal with scenario 4 (Figure 13) was to verify the flexibility that the hub could offer when performing returning products from the consumers to the original shops. The initial plan was to have both Dedicated Bringers and Crowdshippers to perform this task. Additionally, this service was supposed to be performed at the same time as the other services incorporated in Scenario 3.

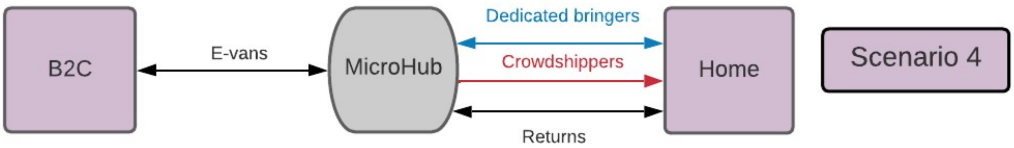

Figure 13. LL5 Oslo – "What-if" Scenario 4

Since this is quite a new service, not performed by Nimber before, a Questionnaire to the Nimber's business customers to understand the market and the possibilities of increasing the demand. Annexe 3 contains the detailed information of the study performed to understand better the returns market in Oslo.

4 KPIs measurements

4.1 LL5 Oslo

The following tables present the calculation and results of the LEAD Living Lab for the “Bc2” (Baseline value) and “TO BE ” scenario (presented in Figure 5), following the calculation methods presented in Annex 1. The data for calculating the KPIs belong from real to the months of November 2022 to January 2023.

Table 8 includes the environmental KPIs. The KPI results are heavily influenced by factors such as, for instance, the number and technology of 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 in the LL5 Scenarios, due to the change of the Diesel vehicle, used previously, to 100% electric vehicles.It is important to mention that the calculation used for the emissions for electric vehicles are optimistic, since we considered Norway using 98% of renewable energy. When this energy use is considered per region, the number may vary between regions, depending on the energy grid and the exchange with the European energy market. In Oslo, this exchange is rather high as compared with e.g. Northern Norway. Nonetheless, reaching the 100% of renewable energy source is a goal for Norway as well as for Europe in the longer run.

Table 8. LEAD Environmental KPIs: LL5 Oslo

KPI	Baseline value	TO BE Scenario	Target	Delta
Energy consumption (kWh/delivery)	124.49	35.4	-20%	-72%
GHG emission ($KgCO_2$/delivery)	11.90	0.052	-20%	-99%
Air quality (gPM2.5/delivery)	0.03	0	-10%	-100%
Air quality (gNO_2/delivery)	18.05	0	-10%	-100%
Air quality (gV_OC/delivery)	1.27	0	-10%	-100%
Noise impact (Δ% population affected)	*Ideally, measuring equipment is needed and a strong control over when and where the vehicles are moving including loading/unloading, is necessary and no such model exist at this level. We have suggested earlier that a qualitative measure is better suited. The Oslo LL micro-hub was located away from residential areas so loading/unloading noise was not an issue. The running noise from electric vehicles (with the same warning signals as well as artificial ICEV noise) is marginally different from ICEV, depending on the vehicle types.* ***We claim that a marginal reduction is likely, due to somewhat lower vehicle noise from inbound e-vans to the micro-hub, a more efficient capacity utilization and no significant increase in the number of shipments****. However, this may not be the case if the scenarios are going to be upscaled and/or if micro-hub locations closer to residential areas are used. In such cases, more comprehensive noise models should be applied.*			

Table 9 includes the social KPIs. Regarding the number of jobs, NIMBER did not hire extra employees to perform the deliveries, but with the use of crowdshippers to perform deliveries there is the potential to generate informal forms of employments, and extra income to the couriers that decide to take part in it. Additionally, the use of MicroHub added flexibility to both crowdshippers and Bringers.

The social KPIs were based on surveys conducted at the Local Workshop held in April 2023 (see Section 5.2). There were 12 participants responded the survey and the main results can be found in Annex 3. Almost all of the KPI's met the target stipulated. The exception is for the KPI "Neighbourhood quality of life", a reason to this is that the MicroHub is not located close to a residential area, therefore no actual improvement was seeing by the workshop participants.

Table 9. LEAD Social KPIs: LL5 Oslo

KPI	Base line	Suggestions from workshop	Score	Target	Delta from target
Quality of jobs	N/A	N/A	N/A	0.5	
Neighbourhoods' quality of life	N/A	N/A	3.4	>= 3.5	-0.1
Users' sustainable behaviour	N/A	No free deliveries	4.3	>= 3.5	+0.8
		Legal restrictions (show cost of delivery, diesel ban on peak hours etc)	3.6	>= 3.5	+0.1
		Gren certification on firms	3.7	>= 3.5	+0.2
Cooperative solutions and incentive measures	N/A	Increase cooperation among retailers on consolidating	3.5	>= 3.5	0
		Cooperation between transports use available capacity	3.5	>= 3.5	0
		Make the authorities fund white label parcel lockers and pick-up points	4.3	>= 3.5	+0.8

Table 10 includes the Economic KPIs. Regarding the KPI about "*congested shipments (congestion 1)*", no significant improvement or change was seeing, since the goal of LL5 was to offer the consumer more flexibility in choosing the time of delivery, and not to diminish the number of shipments transported in congested hours. The same was applied to the KPI "*delivery time*", which was not measured as provisioned initially. This was attributable to the type of products delivered by NIMBER during the pilot, being them mostly high-end furniture. Since these products require more attention and care, due to their size and weight, this KPI had no purpose to be measured. Regarding the KPI *"average delivery cost of the business model",* the final value was calculated by NIMBER, based on their operations (pick-up city, delivery city, vehicle, and type of delivery).

Table 10. LL5 Oslo - LEAD Economic KPIs

KPI	Baseline value	TO BE Scenario	Target	Delta
Average delivery cost of the business model	275	241	-20%	-12%
Congestion 1 (Congested Shipments)	23%	26%	-20%	+8%
Congestion 2 - driving time (min/delivery)	51	34.3	-10%	-33%
Congestion 2 - area occupied by vehicles (m2/day)	201,459	86,952	No change (the mobility hub space needs to be offset by savings elsewhere)	-57%
Financial internal rate of return of the investment conducted	No change (see elaboration below table)			
Delivery time (minutes/delivery)	Not applied to the LL5 (see elaboration below)			
Delivery reliability within the time window	85%	90%	+10%	6%

KPI on Financial rate of return of the investment conducted: It was challenging to locate the micro-hub. After having negotiations with several locations, rented space at the recently established (2022) Fornebu cargo hub outside of Oslo was selected as location for the micro-hub. This turned out to be a better functioning and less costly solution than using a parking lot as location for an *ad hoc* micro-hub. This information emerged through a rather lengthy process for finding a suitable location. In this process it was fundamental to possess a suitably designed container to avoid further delays.

The cost of renting one car parking space amounts to at least around EUR 600/month. This cost is significantly lower in more rural areas. Such a solution is planned to become tested in such an area, but after the LEAD project has ended. NIMBER claims that it is beyond doubt that a micro-hub is more efficient given its options for consolidation and delivery flexibility where deliveries to the hub within business hours and from the hub in the evenings with crowd-shippers are possible. The experiments and the subsequent Workshop 2 indicated that 24/7 accessible, white-labelled hub facilities (warehousing facilities that could include parcel lockers) are better than *ad hoc* outdoor solutions with containers located at parking lots or similar.

The e-cars were not purchased for the LEAD project although the prospects of using them for LEAD purposes made the decision somewhat easier. However, these e-vans are still in an infancy stage with lots of disruptions in their operations. In addition, fast e-charging has become highly expensive because of the energy market situation in Europe. As an illustration, for two months the charging costs per car may amount to EUR 500-750/month which is about the same as the diesel costs would have been for a vehicle with similar capacity. From the rather limited period with testing related to the scenarios, the benefits from more efficient logistics have been outweighed by direct extra costs for the micro-hub and for time used for setting up new procedures and due to a bit more hassle with loading and unloading the smaller e-vans as compared to larger internal combustion engine vehicles (ICEV) with a rear lift. Hence it cannot be claimed any net profits from the tested scenarios in the short run.

However, NIMBER has gained more insight into how to obtain more efficient vehicle operations, partly induced by the limited range of the e-vans, and how to perform more efficient logistics in the longer run, i.e., *post LEAD*. NIMBER's expectations are that approximately 20 per cent cost saving per shipment can be obtained in future operations using these experiences. LEAD have also contributed to knowledge about how to set up related efficient home delivery services in more rural areas using micro-hubs and e-vans. The experiences will also be used in developing business models for deliveries to public sector enterprises, like kindergartens, schools, and nursing homes.

5 Business value validation and user acceptance

The Value case of LL Oslo have had a primary focus on the environmental and economic KPI's, where the outcome showed promising results perhaps particularly for the TO BE scenarios involving crowdshipping, particularly with respect to energy use/emissions, learning effects/optimization and delivery reliability.

5.1 Workshop 1

The first CoP workshop was held on 31st May 2022 at Oslo Municipality/Dept of environmental issues. The main part was to have a discussion on the scenarios and on the digital twin (DT). In addition, other logistics projects in Oslo dealing with home deliveries were presented.

NIMBER presented their platform, matching the need for parcel deliveries with transporters. At the time, NIMBER had done testing with electric vehicles, primarily in the Vestfold region, south of Oslo. Practical issues regarding the scenarios were discussed. The essence of the four scenarios has not changed since the first workshop. At the time, the final location for the MicroHub in Oslo was not yet decided.

Subsequently, the 5 steps for the creation of the DT for Oslo were presented. They consisted of:

- 1: A pilot study done by NIMBER at IKEA. This one was useful albeit we had to use other furnishing companies as NIMBER's shipping customers.
- 2: A supply-side crowd-shipping survey to measure the willingness of people in Oslo to function as crowd-shippers (commuters).
- 3: Measure the base case (AS IS) of the current services performed by NIMBER.
- 4: A survey on end customers' preferences regarding the proposed business model, to gather their preferences for various green delivery designs.
- 5: Analyzing actual data for the same environment and start the modelling process for the Oslo DT.

There was a discussion on limitations, like value added services (assembly at the customer's home etc.). This is relevant for future research, but we did not want to add too much complexity to the last questionnaire for now but rather to make the scenarios work as they are designed. Another constraint that is left for future research, is the introduction of low- or zero emission zones and/or pedestrian zones within the urban area. Issues of upscaling were only shortly discussed because the audience found it a little premature at this stage with no experience from the experiments related to the four scenarios.

5.2 Workshop 2

The second CoP workshop was held on 14th April 2023 at Oslo Municipality/Dept of environmental issues. The main objectives of the workshop were to show the results of LL Oslo's experiments on selected KPIS, to discuss these results, to present the DT framework where we have offered the participants an online session with DT tests when they are ready, and to score some additional social

KPIs. We also provided discussions about upscaling. This is also a part of the LL-specific survey that is distributed among the participants after the workshop.

The main experiences and conclusions from the workshop were that the KPI scores revealed interesting results in the TO-BE scenarios compared with AS-IS. Both transition to e-vans (scenario 1 & 2) and crowdshippers (scenario 3 & 4) revealed learning effects in terms of the bringers being able to optimize the number of shipments to reduce the need for e-charging and to improve capacity utilization. This became evident through reduced emissions. The number of returns (scenario 4) was too low to yield any evidence, so we had to use an alternative approach by using a survey among NIMBER's customers (cargo suppliers), as described above. The customers revealed some doubts about whether NIMBER's current services were suitable for handling returns. This may have something to do with the small number of returns.

The workshop was also designed to stimulate a constructive co-creation process among the participants. In line with this, we arranged a successful group work on two qualitative KPIs, assigning scores to what affects (1) "sustainable behavior" and (2) to how to achieve "cooperation and incentives". Innovative ideas stemmed from the process and gave quite clear solutions. For (1) one should not have "free deliveries", hence the real transport costs should be made clear to the consumers. For (2), open and free access to "white labelled" hubs and parcel lockers was mentioned as means for reducing barriers to entry and to enhance the use of available transport capacity amongst both professional bringers and crowd-shippers. The workshop also validated user acceptance toward the KPI "Neighbourhoods quality of life." Since the hub was not located in a residential area (and therefore there were no real neighbours), we asked the workshop participants to take the role as residents. The result was 3.4 (out of five). Furthermore, the participants were eager to have a digital meeting on the outcome and use of the lead platform.

In short, based on the lessons learned from the evaluation phase, the workshop's impact on LEAD activities will be seen in connection with the results of the ongoing survey among CoP members that has been distributed after Workshop 2. The results from the group work and discussions as such provide valuable insight when we are going to sum up the results from the experiments and the DT simulations. Of particular interest in this respect are the indicated impacts on energy use which will be held against the DT results, as well as the prospects on upscaling that will be derived from the ongoing survey. One clear outcome of the discussions about upscaling was the importance of identifying market failures (like barriers to entry as lack of available infrastructure for hubs and parcel lockers, and coordination issues that prevents exploitation of economies of scale and scope in the distribution network) and to work out a way of circumventing/solving these.

5.3 Conclusion

The results from the social KPI's should be interpreted with some caution. The social KPI's were measured based on the participants in workshop 2. These participants represent a selection of relevant stakeholders in an urban freight supply chain. The participants were selected based on relevance, however, some stakeholder groups are missing, for example local shop owners.

The workshop format was designed to stimulate new ideas, which are central in two of the KPI's, but at the same time it might be that some stakeholders shaped the discussion more than others. An alternative might have been to first perform in-depth interview with each stakeholder and then gather the stakeholders in group discussions.

The KPI "Neighbourhoods quality of life" was also measured at the workshop. The participants at the workshop can be seen as relevant residents; however, it must be stressed that the workshop participants combined do not represent the average resident in Oslo. The workshop participants have a greater knowledge of the benefits and challenges within urban freight and e-commerce, compared to the general resident. We can also assume that the participants as a group is more homogeneous than the Oslo population in terms of socio-economic factors, age, and ethnicity. To let this KPI represent a fairly robust measure would make a stratified sample of different neighbourhoods necessary. These may vary significantly with respect to the built environment (e.g., squared blocks with closed courtyards in contrast to lamella structures with open spaces in between) and with their general exposure to traffic noise and acoustics. Furthermore, the pilots had relatively short duration and a limited number of shipments. The environmental and partly the economic KPIs had individual shipments as units of analysis. Hence, these can be considered as being fairly reliable. Measuring the social KPIs is a bit more complex because they are partly depending on the mass of shipments rather than individual occurrences. The results of the social KPIs should therefore be considered as being more indicative.

The location of the micro-hub used in the LL Oslo experiments were not located close to residential areas. The main reason for some issues connected with limited accessibility for the crowdshippers during night-time was mainly due to workhours for the staff that were employed in connection with controlled access to the hub area. Additionally, this could've influenced in the user acceptance of the crowdshipping business model, since this influence on they work flexibility.

6 Learnings and recommendations

Workshops and group work: From the first workshop, there was a discussion on limitations in the experiments, like value added services (assembly at the customer's home etc.). This is relevant for future research, but we did not want to add too much complexity to the last questionnaire for now but rather to make the scenarios work as they are designed. Another constraint that is left for future research, is the introduction of low- or zero emission zones and/or pedestrian zones within the urban area. Issues of upscaling were only shortly discussed because the audience found it a little premature at this stage with no experience from the experiments related to the four scenarios.

From the second workshop, a groupwork on two qualitative KPIs, assigning scores to what affects (1) "sustainable behavior" and (2) to how to achieve "cooperation and incentives". These gave quite clear results. For (1) one should not have "free deliveries", hence the real transport costs should be made clear to the consumers. For (2), open and free access to "white labelled" hubs and parcel lockers was mentioned as means for reducing barriers to entry and to enhance the use of available transport capacity amongst both professional bringers and crowd-shippers.

KPIs and optimization of flows: The KPI scores revealed interesting results in the TO-BE scenarios compared with AS-IS. Both transition to e-vans (scenario 1 & 2) and crowd-shippers (scenario 3 & 4) revealed learning effects in terms of the bringers being able to optimize the number of shipments to reduce the need for e-charging and to improve capacity utilization. This became evident through reduced emissions. The number of returns (scenario 4) was too low to yield any evidence, so we had to use an alternative approach by using a survey among NIMBER's customers (cargo suppliers), as described above. The cargo owners revealed some doubts about whether NIMBER's current services were suitable for handling returns. This may have something to do with the small number of returns.

Impacts from CoP activities on LEAD's final stage activities: The results from the group work and discussions as such provide valuable insight when we are going to sum up the results from the experiments and the DT simulations. Of particular interest in this respect are the indicated impacts on energy use measured through the KPIs which will be held against the DT results, as well as the prospects on upscaling that will be derived from the ongoing survey.

Important aspects connected to the scenarios: In S1, the main learning was that the use of only e-vans is not feasible for NIMBER'S activities, since the location of the stores (to pick up the parcels) and the destination of the deliveries (consumer's house) are too distant from each other, due to the lower range constraints pertinent to e-vans. For S2-S4, adequate spaces for micro-hubs in densely populated areas are scarce because they compete with other land use purposes. A recommendation is that for future pilots/experiments, such locations should indeed be decided upon as early as possible in the project and, if possible, owners/developers of attractive locations should be included in the project as partners and/or through binding agreements. For upscaling purposes with many such micro-hubs, public sector involvement (the state or the municipality) as a regulator is likely to become necessary to include it as part of state-of-the-art land use planning. For the experiments one should be aware of whether the size of vital commodity flows is below a critical mass to obtain a viable assessment. In LL Oslo's case, the flow of returns in S4 proved to be too thin to provide enough observations. This may however not be the case if the business model in S4 is to be upscaled. One should also have in mind that areas may have specific restrictions linked to them. These could be permitted vehicle types, business hours for operations, noise restrictions etc. For LL Oslo, the first Micro-hub location had detailed restrictions connected to the fuel types that the vehicles were allowed to use. This caused significant delays in finding an adequate alternative. For the final location, limited business hours gave access restrictions that had to be relaxed. A recommendation could be to detail the project in an early stage to such an extent that such restrictions can be identified, and abatement measures taken.

Prospects for upscaling of the experiments: One clear outcome of the discussions about upscaling was the importance of identifying market failures (like barriers to entry as lack of available infrastructure for hubs and parcel lockers, and coordination issues that prevents exploitation of economies of scale and scope in the distribution network) and to work out a way of circumventing/solving these. There was also pointed out by one of the larger logistics operators that regular parcel services may be easier to upscale through established hubs and logistics systems than coordinated freight of larger items in urban areas. One reason for this is that per item such shipments are more area-demanding and it may also entail less standardized/more expensive equipment and vehicles.

Occurrences seen in hindsight: Getting the necessary infrastructure in place as early as possible is a success factor that could save time and create a better flow. In the LL Oslo case, there were severe delays in getting the micro-hub in place. We believe that this could have been solved better in a normal situation with a more seamless way of interacting with different stakeholders. LEAD started immediately after the pandemic outbreak.

The LL Oslo experiments have benefitted from having one dedicated partner to conduct the practical parts of the LL experiments. This has made everything easier to manage, including maintaining control over the experiments and the possibility to adjust procedures while being under way.

Furthermore, one should always get stakeholders that could become important for the project, on board as partners from the beginning. This could make it easier to avoid replanning and rescheduling important activities.

KPIs and scientific quality. The pilots had relatively short duration and a limited number of shipments. The environmental and partly the economic KPIs had individual shipments as units of analysis. Hence, these can be considered as being reliable. Measuring the social KPIs is a bit more complex because they are partly depending on the mass of shipments rather than individual occurrences. The results of the social KPIs should therefore be considered as being more indicative and perhaps the design and selection of these should be carefully assessed in future experiments.

The location of the micro-hub used in the LL Oslo experiments were not located close to residential areas. The main reason for some issues connected with limited accessibility for the crowd-shippers during night-time was mainly due to workhours for the staff that were employed in connection with controlled access to the hub area. The “Neighbourhood quality of life” - KPI could have worked better for this specific location if impacts on residential areas had been an issue.

7 Summary and outlook

The Oslo pilot is in the central area of Oslo, in Norway. Oslo is one of Europe's fastest growing cities and is planning to cut CO2 emissions by 95 % by 2030. The LL5 Oslo aims at shifting city logistics operations from ICE to electric and crowd shipping with the intent of achieving more efficient urban deliveries with less negative externalities (emissions and noise). The value case focuses on delivering large items originating from commercial furniture stores to final customers. These items are consolidated and shipped to a micro-hub by NIMBER. The bringers, then, distribute these items in accordance with end customers' preferences (e.g., time windows and flexibility). The main challenge has been demonstrating the viability of these innovative business models for the whole community (Logistics Service Providers (LSP), operators, suppliers, customers) and make it sustainable beyond the project.

Four scenarios have been tested in a digital environment. This allowed estimating the improvement of the new business models (TO BE scenarios) compared to the AS IS scenario. In addition to the environmental KPIs, stakeholders' acceptability of the scenarios has also been estimated using Stated Preference (SP) surveys. The results constitute inputs for Agent Based Models (ABM) so to forecast their most likely impacts. LL5 Oslo uses four models in the DT to test the new solutions and estimate their impact in the physical environment. The four models are: Experiment Design Model (EDM), Discrete Choice Model (DCM), ABM_Molde and Mass GT.

Conceptual diagrams describe the final DT representation and illustrate the detailed design specifications for the innovative last mile solutions envisaged. These follow the Minimum Viable Product Approach (MVP) which includes the description of the: LL specific models (including ABMs) developed by the LL, other Generic Models Library (Other LLs specific models) components, LL DT configuration to integrate all the models (LL specific and the Generic Models Library ones). the DT is not fully developed yet, in line with the status of project activities. Its validation will take place as soon as the necessary modelling procedures are successfully completed. This document describes the validation process that follows two separated yet coordinated paths.

The LL Oslo value case primarily focuses on environmental and economic KPI's. The outcomes are promising, particularly for the TO BE scenarios involving crowd-shipping. The results are encouraging with respect to energy use/emissions reductions, positive learning effects/optimization and increased delivery reliability. These will be summarized in more detail when comparing them with DT modelling outcomes. Social KPI's have also been measured, with more uncertain results.

The discussions concerning upscaling the experiments to a full-scale system underline the importance of identifying market failures (e.g., barriers to entry, lack of available infrastructure for hubs and parcel lockers, coordination issues preventing exploitation of economies of scale/scope in the distribution network) and circumventing/solving them. One big logistic operator asserted that regular parcel services may be easier to upscale through established hubs and logistics systems than coordinated freight of larger items in urban areas. The motivation is that such shipments are more area-demanding, per item, thus entailing less standardized/more expensive equipment and vehicles.

Annexe 1: IKEA Case (Base Case 1)

LL5 will use a questionnaire to obtain socioeconomic data on consumers, their preferences on the green delivery proposed by NIMBER and to have information on the base case data for the KPI calculation. The questionnaire is the Revealed Preference (Table 9), where the information obtained is related mostly to the AS IS scenario. This questionnaire is being distributed online and the respondent is kept anonymous.

In addition, this questionnaire was also used for the preliminary study of the attributes that influence consumers when choosing a home delivery from stores (block 3). These attributes will then be used for the choice experiment.

Table 11. LL5 Oslo - Revealed preference questionnaire

Block	Theme	Variable	Response type
Block 1	IKEA	Visited IKEA Slependen	Bool
Block 2	Description of the purchase	Frequency of visit	Categorical
		Type of trip	Categorical
		Type of transport mode used on visit	Categorical
		Size of parcel	Categorical
		Type of delivery used	Categorical
		Day of visit	Categorical
		Time of visit	Categorical
Block 3	Home deliveries	Attributes that affect home delivery decision's	Categorical
Block 4	Characterization of the respondent	Age	Categorical
		Income	Categorical
		Gender	Categorical
		Zip code of private home	Categorical

The KPIs are listed in Deliverable D3.1, along with relevant stakeholders, goals, and target values, as shown in Table 10. The data used to calculate the KPI's came from main two sources: NIMBER'S operations (Bringers and Crowdshippers) between December 2020 and December 2021 and, as mentioned previously, from the RP questionnaire (IKEA).

In the LL5 Oslo case, the measurement of the KPIs is structurally difficult given the nature of the project we are trying to implement. In fact, in our case, we are not exactly improving a pre-existing service where the impact of the improvement can easily be calculated so to give an idea of the impact the innovative solution has had. The disruptive innovation is such that comparing its impacts to the pre-existing configuration is not immediate. For instance, in the IKEA case where customers were previously both buying the goods and self-producing the delivery service the innovative solution implies implementing a green home delivery service. Thus, taking “delivery reliability within the time window” as an example, makes it easy to acknowledge that while it is always 100% when somebody is self-producing the service it can only be worse when a third party is performing the task. For this case, to ensure sound comparability, we will use the average value linked to the home delivery service performed by trusted bringers.

Table 12. LL5 Oslo – KPIs and target values

KPI	Calculation Method	Baseline Value		Target
Financial internal rate of return of the investment conducted	Data from operator	Not applied for the baseline scenarios: surveys will be conducted during the pilot testing phase to compare before and after situations.		+4% return per year
Energy consumption*	COPERT Tier 1	Average energy consumption per delivery (MJ/delivery)	125 MJ/delivery	-20%
Air pollution*		Average $PM_{2.5}$ per delivery ($gPM_{2.5}$/delivery	16 $gPM_{2.5}$/delivery	-10% for all components
		Average V_oC per delivery (gVOC/delivery)	200 gVOC/delivery	
		Average NO_2 per delivery (gNO2/delivery)	364 gNO2/delivery	
Noise impact		Will be addressed during the experiment		-10%
GHG emissions*		Average CO_2 per delivery (gCO2/delivery)	291 gCO2/delivery	-20%
Jobs created	Data from operator survey	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations.		+10%
Hours worked	Data from operator/survey	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations.		+10%
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.		Average score up with 0.5
Neighborhood's quality of life	Neighbourhood’s 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.		>= 3.5

KPI	Calculation Method	Baseline Value		Target
Ideas to promote a more sustainable behavior	Sustainable behaviour (local survey involving the CoP)	Not applied: surveys will be conducted during the pilot testing phase to compare before and after situations.		>= 3.5.
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.		>= 3.5.
Average delivery cost of the business model	Data from operator	Agreed not to be disclosed in the deliverable		-20%
Congestion 1 (congested shipments)	Data from operator	shipments during congested hours	28% - Bringers 31% - crowdshippers 23% - IKEA	-20%
Congestion 2 (congestion from vehicles)	Data from operator	average time spent on the road for delivery vehicles	49 minutes (IKEA) 34 minutes – Bringers 33minutes - Crowdshippers	-10%
Urban storage and parking space	Urban storage and parking space	Not applied to the baseline scenario		No change
Shop/retail benefits	Local survey involving Shops/Retails	Not applied to the baseline scenario		Score >=3.5
Delivery time	Data from operator	Average amount of time requires to make a delivery (with attention to flexibility benefits)	01h:22min – Crowdshippers 02h:12min – Bringers 01h:11min - IKEA	-10% and/or flexibility benefits (through surveys with score >=3.5)
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 (%)	85% - Bringers 65% - Crowdshipper IKEA – not applicable	+10%

The calculations for Environmental KPIs (marked with a *) were calculated using only fossil fuel vehicles from the IKEA case, where customers were previously both buying the goods and self-producing the delivery service, because Bringers use only vehicles provided by NIMBER and these vehicles are all electric. The emissions from the electric vehicles from NIMBER were not calculated for the base case scenario and account for a total of 7.717 kilometres. Our intention is to calculate the emissions savings based on the change of the current scenarios given the green home delivery service studied (only electric vehicles). LL5 used Tier 1 emission factor because we could not obtain precise information about consumers' vehicles, since this is confidential information. The consequence of this approach, in the context of the legislative emission requirements for more modern vehicles, is that the Tier 1 emission factors will give somewhat higher emission values than a Tier 2 or 3 methodology for countries whose fleet comprises vehicles that comply with more recent (i.e. Euro 2 / Euro II and later) emission standards (EEA, 2019).The KPI "Average delivery cost of the business model" is being accompanied by the LL5, but the actual value of the NIMBER share will not be disclosed in this deliverable.

Annexe 2: Conference and Recognitions

LL5 participated in different seminars and conferences among which it is worth recalling:

1) XXII Annual SIET (Italian Society of Transport and Logistics Economists) Scientific Meeting, “Transport in a changing world,” University of Roma Tre, Rome, Italy, September 17th, and 18th September 2020. Presentation titled “Digital twins and urban freight transport planning.”
2) E-commerce conference, NTNU Trondheim, Norway 16-17 June 2022. Presentation titled “Sustainability assessment of inter-urban crowd shipping- A case study approach “.
3) XXIV Annual SIET (Italian Society of Transport and Logistics Economists) Scientific Meeting, “Transport, Tourism and Sustainable Development,” University of Insubria, Varese, September 8th, and 9th September 2022. Presentation titled “Public transport crowdshipping: an economic analysis.”
4) Special Session on “Innovations in last mile logistics towards inclusivity, resilience and sustainability” coordinated by both LEAD partners (LL5 and LL3) and Senator Project, held during the TIS Roma 2022 (https://tisroma.aiit.it/).
5) Seminar “City logistics, digital twins, and smart cities. LEAD Oslo Case.,” on the 23rd of November 2022, in the class of *Smart Cities*, at Roma Tre University.
6) Seminar “LEAD Digital Twin: Oslo Case,” on the 18th of April 2023, in the class of *Sustainable Urban Freight Transport,* at Roma Tre University.

Presentation 2) were material from an MSc thesis at Molde University College that examined the environmental sustainability of inter-urban crowd-shipping, using NIMBER’s databases. This is closely related to the core of LEAD. An extended version of the conference paper is currently under review in Research in Transport Economics, Special Issue on e-commerce (see below). There are also two Special issues under way in Research in Transport Economics (RETREC) that will disseminate findings from LEAD or LEAD-related activities. One is about innovations in last mile logistics and the other is about various aspects of e-commerce.

Papers published:

- Lozzi, G., Iannaccone, G., Maltese, I., Gatta, V., Marcucci, E., Lozzi, R. (2022). On-Demand Logistics: Solutions, Barriers, and Enablers. SUSTAINABILITY, 14, 9465. https://doi.org/10.3390/su14159465
- Marcucci, E., Gatta, V., Le Pira, M., Hansson, L., Bråthen, S. (2020). Digital Twins: A Critical Discussion on Their Potential for Supporting Policy-Making and Planning in Urban Logistics. SUSTAINABILITY, 12(24), 10623. https://doi.org/10.3390/su122410623

Annexe 3: Returns Questionnaire

Questionnaire sent to Nimber's partners	
1) How many returns do you have on average each month?	
2) Which types of vehicles are used?	a) Electric van b) Diesel van c) Cargo bikes d) Other. Specify
3) Are you currently using Nimber for return package trips?	3.1) Yes. How many returns did they manage for you in the last 3 months? 3.2) No
4) Have you thought about having them perform this task?	4.1) Yes. Why? a) Lower price b) Eco-friendly services c) Quick response d) Good flexibility e) Other. Specify 4.2) No
5) What are the main constraints for this to happen?	a) Unreliable b) Low-quality c) Punctuality d) Price e) Other. Specify
6) What are the main enablers for this to happen?	a) Price b) Environmental benefits c) Flexibility d) Provide a better consumer experience e) Other. Specify

A total of 14 companies participated in the survey. Of this, 4 of them currently working occasionally with Nimber on their returns and daily on their delivery demands. With the participating companies, there is a demand for approximately 45 returns a month.

The main reason to use Nimber was that they provide an Eco-friendly service (E-vans) and good flexibility. The main reason not to use Nimber was that they offer unreliable transport when dealing with returns. This is due to the type of product (high-end furniture) that needs specialized help to disassemble the parts and assemble the new ones. Additionally, the main enabler for Nimber is to provide a better consumer experience on this specific market.

Annexe 4: KPIs calculation methodologies

Table 13. LEAD Environmental KPIs: LL5 Oslo calculation method,

KPI	Calculation Method	Measurement units
Energy consumption (Fuel Vehicles)	COPERT using the average activity data (number of vehicles, total kilometres, average speed, average low and hi temperature, and average humidity)	Average energy consumption per delivery (MJ/delivery)
GHG emission (Fuel Vehicles)		Average CO_2 per delivery (gCO2/delivery)
Air quality (Fuel Vehicles)		Average $PM_{2.5}$ per delivery ($gPM_{2.5}$/delivery)
		Average NO_2 per delivery (gNO2/delivery)
		Average V_OC per delivery (gVOC/delivery)
Energy consumption (Electric Vehicles)	GHG emission from EV (LEAD methodology)	Average energy consumption per delivery (MJ/delivery)
GHG emission (Electric Vehicles)	GHG emission from EV (LEAD methodology)	Average CO_2 per delivery (gCO2/delivery)

Table 14. LEAD Social KPIs: LL5 Oslo calculation method

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)	Likert scale 1-5.
Users' sustainable behavior	Users' sustainable behaviour (local survey involving the CoP)	Group discussion among participants in workshop 2. Then vote on each solution using a Likert scale 1-5.

KPI	Calculation Method	Measurement units
Cooperative solutions & incentive measures	Cooperative solutions & incentive measures (number of solutions implemented during the pilot development)	Group discussion among participants in workshop 2. Then vote on each solution using a Likert scale 1-5.

Table 15. LEAD Economic KPIs: LL5 Oslo calculation method

KPI	Calculation Method	Baseline scenario value
Average delivery cost of the business model	Data from operator	Annual average cost per delivery (€/delivery) [1]
Congestion 1 (Congested Shipments)	Data from operator	Not applied
Congestion 2 (Congestion from vehicles)[2]	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[3]	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 (%)

[1] *A: sensitive data. We provide and arbitrary value A.*
[2] *Assuming that the vehicle does not influence congestion when properly parked*
[3] *Assuming that the vehicle does not influence congestion when properly parked*