Data-driven and Dynamic Space and Assets for Physical Internet-led Urban Logistics and Planning

D4.3 Evaluation of impacts at Starring LLs

LSP

29/08/2025

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Abstract

Copenhagen, Ghent, Helsinki, and Thessaloniki serve as the Starring Living Labs within the DISCO project, pioneering the design and testing of sustainable urban logistics measures inspired by the Physical Internet (PI) concept. Within this deliverable D4.3 the implementation process and impact of the DISCO-X measures are evaluated using a KPI-based assessment. Beyond that, the compliance of the measures with existing Sustainable Urban Logistics Plans (SULPs) and SULP guidelines as well as their contributions to the Sustainable Development Goals is reviewed.

The results highlight the effectiveness of measures in reducing environmental impact, improving transport efficiency, optimising land use, and supporting sustainable business models. Specific insights emerged from the tested measures: DISCOCURB revealed behavioral patterns in curbside logistics, DISCOPROXI demonstrated the benefits but also trade-offs of shared microhub concepts, while DISCOSTATE and DISCOBAY underlined the importance of early stakeholder engagement and robust simulation approaches in the context of innovative infrastructure use. The DISCOLLECTION measure fostered valuable partner integration and uncovered further potential of enhanced data management.

Beyond these findings, digital maturity, trust-building through data sharing, and collaborative tool development were identified as key enablers of future logistics systems. A scenario from Thessaloniki illustrates the transformative potential of PI-led logistics, offering substantial environmental, operational, and economic benefits through collaborative and integrated urban logistics solutions.

Summary sheet

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DIMOS THESSALONIKIS	EL	THESSALONIKI

DIETHNIS EKTHESI THESSALONIKI AE	EL	TIF HELEXPO
ACS TACHIDROMIKES IPIRESIES MONOPROSOPI ANONYM	EL	ACS
ROLAN OY	FI	ROLAN
ASOCIACIÓN LOGÍSTICA INNOVADORA DE ARAGÓN	ES	ALIA
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Document history

Version	Date	Organisation	Main area of changes
0.1	28/03/2025	LSP	Definition of ToC
0.2	27/06/2025	COP, GHE, HEL, THESS	Inputs from all Starring LLs
0.3	11/07/2025	LSP	First Draft
0.4	28/07/2025	ITL	Comments on first draft
0.5	28/07/2025	ITL	Final draft for internal peer review
0.6	04/08/2025	ITL, FIT	Comments from Reviewer
0.7	22/08/2025	POLIS	Comments from Reviewer
0.8	26/08/2025	LSP	Final rework with last check from LLs
1.0	29/08/2025	LSP	Submission

List of acronyms

API	Application Programming Interface
BD	Baseline Data
D	Deliverable
EV	Electric Vehicle
FCD	Floating Car Data
GIS	Geographic Information System
GLM	Green Last Mile
IoT	Internet of Things
KPI	Key Performance Indicator
LiDAR	Light Detection and Ranging
LCV	Light Commercial Vehicles
LEZ	Low Emission Zone
LL	Living Lab
LSP	Logistics Service Provider
PI	Physical Internet
IoT	Internet of Things
ITS	Intelligent Transport Systems
SDGs	Sustainable Development Goals
SDP	Smart Data Platform
SLLs	Starring Living Labs
SULP	Sustainable Urban Logistic Plan

SUMP	Sustainable Urban Mobility Plan
ToC	Table of Contents
UAC	Urban Access Control
WP	Work Package
ZEZ	Zero Emission Zone

Executive Summary

Copenhagen, Ghent, Helsinki and Thessaloniki form the Starring Living Labs of DISCO. As pioneers of urban logistics, they significantly contributed to the design and testing of sustainable logistics measures inspired by the concept of Physical Internet. To pave the way to a new generation of PI-led urban logistics, the implementation process and impact of the DISCO-X measures tested by the Living Labs were evaluated, identifying remaining obstacles and demonstrating their feasibility and replicability for subsequent cities.

From a methodological point of view, the indicators defined as part of the project were used to carry out a KPI-based assessment. For this purpose, the so-called DISCO Dashboard was applied, a tool developed within the project for collecting, analysing, and visualising logistics-related data. Furthermore, the compliance of the measures with existing Sustainable Urban Logistics Plans (SULPs) and SULP guidelines was reviewed, and the contribution of the various measures to the Sustainable Development Goals was analysed. The focus here was on examining the effectiveness of the measures regarding central fields of action in urban logistics. These include reducing environmental impact, increasing urban transport efficiency, making better use of land and infrastructure and demonstrating sustainable business models.

The analysis has shown that the DISCO-X measures are major levers for reorganising urban logistics. However, their successful implementation and, above all, their scaling depends on several aspects, which are outlined below.

- The **DISCOCURB** measures implemented in Copenhagen and Helsinki revealed valuable insights regarding user behaviour and patterns with respect to curbside utilisation for logistics operations in defined areas. While the technical setup in both cases showed robustness, the measure did not allow a quantification of traffic flow efficiency or the planning of new loading/unloading zones. To overcome that barrier, Floating Car Data (FCD) was utilised in Helsinki to analyse commercial vehicle stopping patterns. Regarding the integration of real-time data into maps for logistics service providers, it became apparent that the planning process of the operators is not yet harmonised with the potential of real-time data provision.
- **DISCOPROXI** measures were implemented in all four Living Labs with different approaches ranging from simulation work with the use of digital twins to real-world demonstrations. Copenhagen and Helsinki illustrated the potential of multi-functional logistics hubs and zero-emission delivery methods regarding the reduction of CO_2 emissions. While the environmental impact could be decreased significantly, both implementations showed a trade-off between the optimisation of CO_2 emissions and the optimisation of traffic efficiency or operational-related indicators. Ghent Living Lab, on the other hand, demonstrated the potential of an urban access control system in a pilot, increasing traffic flow, delivery density, as well as reducing operational costs, while Thessaloniki rolled out

innovative business models and services for free space use, by adopting smart-contracts within this measure. Whereas the technical solution worked properly, extensive coordination was necessary, and the approval process was long.

- Within a direct link to the above-mentioned measure, Thessaloniki demonstrated the temporary and multipurpose use of infrastructure at the TIF HELEXPO Exhibition Centre as a logistic hub within **DISCOESTATE**. Even though all partners shared a common goal, differences in specific needs (space offerings vs. operational requirements) became apparent and highlighted the need for earlier and more comprehensive stakeholder engagement.
- The **DISCOBAY** measures were implemented in Copenhagen, Ghent and Thessaloniki. Copenhagen worked on two streams on the retrofit of Høje Taastrup terminal. Based on a digital twin simulation, the potential of fleet decarbonisation was illustrated, whereas a stakeholder engagement format revealed cost challenges regarding a potential retrofit. Ghent conducted a comparison between green last-mile delivery options and existing traditional models, showing feasibility from a technical standpoint and great potential regarding the environmental impact. Nevertheless, cost challenges that come with green delivery options became apparent. With the approach to map underused infrastructure, Thessaloniki created an integrated space availability observatory for the city. Again, while the technical system was set up properly, incomplete or inconsistent databases required rigorous data cleaning and iterative testing to ensure accurate simulation outcomes.
- Finally, all Living Labs implemented the **DISCOLLECTION** measure. This measure was in most cases closely linked with other measures serving as a supporting tool to the collection, utilisation, and sharing of (real-time) data with data space technology and infrastructure. It can be stated that the implementation of the measure was valuable for integrating partners into the activities and getting them into the system. However, the potential for optimisation about the integration of different data streams in terms of data quality and consistency became clear to provide even better digital support for the transformation of urban logistics in the future.

Beyond those insights gained from the evaluation of the DISCO measures, the development of digital maturity across the entire process chain, early stakeholder engagement as well as the joint building of trust through data sharing and collaboration can be cited as cornerstones for the development of future logistics systems. Against this background, the scenario example from Thessaloniki illustrates the potential impact of a PI-led logistics system, offering significant environmental benefits, operational efficiency, and economic advantages through collaborative resource utilisation and integrated system optimisation.

1. Introduction

The purpose of this document is to provide a comprehensive evaluation of the measures implemented in the four Starring Living Labs (SLLs) of the DISCO project within Work Package 4. It builds directly on Deliverable D4.2, which documented the context, rationale, and implementation of the measures deployed in Copenhagen, Ghent, Helsinki, and Thessaloniki. While D4.2 focused on what was implemented and why, this deliverable focuses on how these measures were evaluated and what impacts they generated, both locally and in relation to the wider project ambitions of DISCO.

The evaluation was designed to capture the contribution of these measures to Physical Internet–inspired sustainability transitions in urban logistics, where freight flows become more modular, interconnected, and resource efficient through shared assets, collaborative processes, and open data exchange. Urban freight transportation is indispensable for modern supply chains, yet it generates significant negative externalities, including congestion, greenhouse gas emissions, noise, and land-use conflicts. In line with the European Green Deal[1] and the EU Urban Mobility Framework[2], DISCO aims to transform this system by moving away from fragmented, siloed logistics toward a hyperconnected, data driven, and collaborative model.

The SLLs —Copenhagen (DK), Ghent (BE), Helsinki (FI), and Thessaloniki (GR)—demonstrate how these ambitions can be translated into practice. Each city represents a different urban context with its own logistics challenges, governance structures, and stakeholder dynamics. Across these contexts, the SLLs tested and adapted DISCO-X innovations—a modular suite of measures spanning the domains of DISCOCURB, DISCOPROXI, DISCOBAY, DISCOESTATE, and DISCOLLECTION. These measures were designed to tackle pressing challenges in urban freight, such as congestion on main corridors, inefficient curb use, underutilised spaces, and reliance on fossil-fuel-based delivery systems.

The evaluation methodology draws on the Evaluation Dashboard (T4.6.1), the definition of PI-led metrics and the design of the evaluation process (T4.6.2), and the assessment of SULP compliance (T4.6.3). This integrated approach ensures both local relevance and cross-site comparability. In particular, a set of PI-inspired KPIs were defined and used for a quantitative assessment. Moreover, the compliance of the measures with Sustainable Urban Logistics Plans (SULPs) and alignment with

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[1] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[2] https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility_en

SULP ELTIS guidelines[3], and the contributions to selected Sustainable Development Goals (SDGs) were evaluated.

In summary, this deliverable moves from implementation to evaluation, offering both detailed insights for each Living Lab and cross-cutting lessons that connect local innovation to the wider vision of a sustainable, data-driven, and collaborative urban freight system. It demonstrates how evidence-based, stakeholder-informed approaches can unlock hidden assets, optimise urban space, and accelerate the transition toward climate-neutral, liveable cities by 2030.

Chapter 2 outlines the evaluation methodology, including PI-led metrics, data integration, and stakeholder-based approaches. In chapters 3 to 6 the evaluation results for each Living Lab are presented, structured as described above. Chapter 7 synthesises cross-cutting lessons learned, highlighting success factors, barriers, and recommendations for scaling measures in line with PI principles. Eventually, chapter 8 illustrates how the evaluation methodology can be scaled to a fully PI-enabled urban logistics scenario, using Thessaloniki as a case study.

[3] https://urban-mobility-observatory.transport.ec.europa.eu/system/files/2023-11/sustainable_urban_logistics_planning.pdf

2. Evaluation Methodology & Dashboard

The individual elements of the evaluation methodology are presented below. These include the previously mentioned components 'Evaluation Dashboard', 'Definition of the PI-led metrics', as well as the 'PI Compliance to SULP'. In addition, by referring to an ideal-typical evaluation process and by bundling essential building blocks of the evaluation, a framework is formed as an orientation for the stakeholders involved in the evaluation process. The process for this task comprised numerous individual steps in which content was developed, discussed with the representatives of the Living Labs, and revised to fulfil the requirements of the evaluation to be carried out. The following table provides information on these activities over the course of the past months:

Table 1: Overview of activities carried out in the development of the Evaluation Methodology & Dashboard

Sub-Task	Activity	Contributor	Time period	Artefact
4.6.1	Deployment Dashboard	LSP	04.-08.2024	Dashboard
4.6.1	Update KPIs	LSP	06.-09.2024	Dashboard
4.6.2	Definition PI-led metrics	LSP, ITL, FIT, CERTH	05.-08.2024	
4.6.2	Elaboration of methodology	LSP	10.24-02.2025	Evaluation guideline v1
4.6.2	KPI Questionnaire	LSP + LLs	02.2025	Excel Template
4.6.2	KPI Conversion / Weighting	LSP + ITL	02.2025	Excel Table KPI weights
4.6.2	KPI Association	LSP + ITL + LLs	03.-04.2025	pptx Template
4.6.2	Preparation Evaluation Workshops	LSP + LLs	05.-06.25	pptx how-to, Excel with processed Baseline data
4.6.2	Evaluation Workshops	LSP + LLs + ITL + BUAS	06.2025	
4.6.3	SULP Compliance	LSP + LL	05.-06.2025	SULP Compliance Matrix

To present the interdependencies in the best possible way, the following section begins with the description of 'Defining PI-led metrics and evaluation process'.

2.1. Defining PI-led metrics and evaluation process

The overall goal of this subtask is to define the targets, metrics, and procedures for data collection and validation, to set up the overall evaluation concept, including the categorisation and linking of the single evaluation elements, as well as the elaboration of the evaluation process in close collaboration with the Living Labs.

A typical evaluation process can be divided into different phases (see Figure 1). It starts with the definition of the evaluation set-up and goals (phase 1). Building on this, the evaluation concept is developed (phase 2). In the subsequent phase, the actual evaluation is carried out by collecting and analysing information and data (phase 3). Following on from this, the findings are documented and communicated (phase 4) and utilised to improve measures (phase 5).

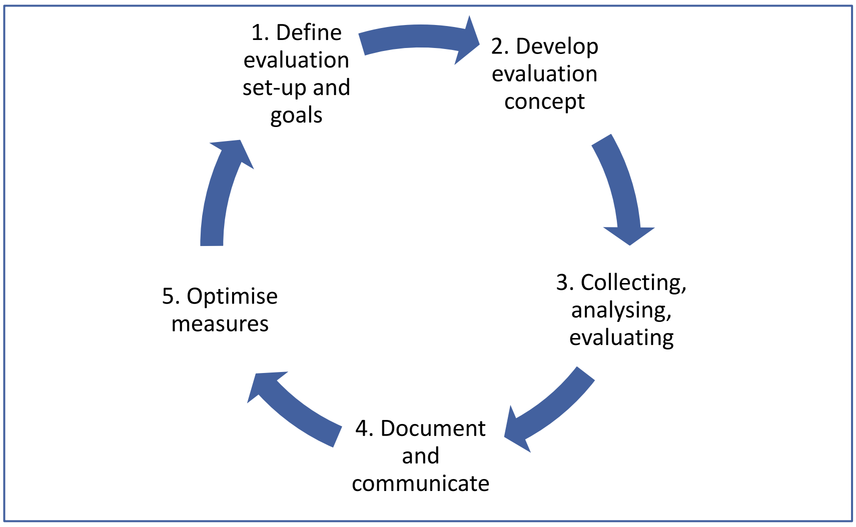


Figure 1: Typical process and phases of a project evaluation (based on: IN_FORM_Leitfaden_Evaluation.pdf)

This process-oriented approach was used as a common thread for the diverse evaluation works. While the activities conducted in the first two phases are part of this chapter, the execution of the evaluation in the four LLs is described separately and is the subject of Chapters 3, 4, 5, and 6.

The work on this task started in May 2024 with the definition of PI-led metrics as well as the elaboration of the methodology. Input for this task was the KPIs defined in Task 4.1, along with the fact sheets for the Living Labs. In a first step, the KPIs were defined by operationalising the indicators included in the Grant Agreement. The underlying idea was to translate and operationalise the concept of the Physical Internet for evaluation purposes. Therefore, the KPIs were specifically designed to reflect core PI principles—such as resource sharing, cooperation and stakeholder engagement, and resource efficiency—as key levers for sustainability transitions.

The KPIs capture both process and impact characteristics, enabling a comprehensive understanding of the potential and challenges of the measures. During this initial phase, the KPIs were reviewed and discussed, and their correlations with the DISCO-X measures and other descriptive and classification features were defined. The 25 KPIs were associated with the SDGs and, in conjunction with them, key priorities for DISCO—such as “no congestion,” “lower CO_2 emissions,” and “efficient use of city space”—were identified. In addition, an association between the five Impact Domains (Shared solutions, Connected logistics, Smart logistics, Urban network management, Agile storage and last-mile distribution) and the KPIs was established. The result was an allocation of the KPIs to the impact domains, as well as an allocation of the KPIs according to their dependency on the achievement of the SDGs at the target level.

A total of 7 SDGs (3, 8, 9, 11, 12, 13, 17) and associated 11 SDG targets (3.9, 8.2, 8.4, 9.1, 9.4, 11.3, 11.6, 11.A, 12.6, 13.2, 17.16) were identified as relevant for the activities within DISCO. Furthermore, a categorisation of the KPIs regarding the SETR dimensions (societal, economic, technical, regulatory), as well as regarding dimensions of energy efficiency gains, was made. This preliminary work was done in line with the development of the DISCO dashboard and served as the basis for the development of the actual evaluation methodology, which is based on several building blocks. To address the various evaluation objectives, an approach consisting of different ‘perspectives’ was developed. These include:

- Clustering and ranking of KPIs regarding the importance from a Living Lab perspective (Living Lab perspective)
- Evaluation based on KPIs with respect to KPI Value Changes before and after implementation (Data-driven perspective)
- Evaluation based on KPIs with respect to a normalised KPI Weighting (Evaluation perspective)
- Evaluation based on KPIs with respect to an integrated metric (System perspective)

Living Lab perspective – Evaluating the importance of KPIs

Within this perspective, the importance of each KPI is ranked by the specific city representatives in clustering the KPIs into four groups in a first step. The first Cluster A includes the most relevant ones, the second Cluster B includes the important ones, the third Cluster C includes the less important ones, and the fourth Cluster D includes the ones that are not applicable. In a second step, a rating of the KPIs within the four clusters regarding their specific rank is conducted. This approach allows a prioritisation of KPIs' respective measurements and serves as input for the later KPI-assessment. The LL leaders were consulted to carry out the clustering and ranking since they have continuously interacted with all the other stakeholders in the LL, including logistic service providers, businesses, citizens, public authorities, and so on. As a consequence, their clustering is informed by the vision, perceptions, and characteristics of different types of stakeholders in the city.

	A	B	C	D	E
1				*Example*	*Example*
2	**KPI Number**	**KPI**	**Description and data format**	**Cluster**	**Rank in Cluster**
3	1	Traffic Flow	Total freight kilometers driven per 10000 inh	B (important)	1
4	2	Distance Travelled	Average distance per delivery	A (very important)	4
5	3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	C (less important)	1
6	4	Delivery time	Average delivery time per route	A (very important)	2
7	5	Delivery Density	Number of deliveries per km	D (not applicable)	0
8	6	Cost per parcel	Cost of delivery per km	C (less important)	3
9	7	Operational Cost per day	Total delivery cost	C (less important)	2
10	8	CO2 Emissions per km	Total kg of CO2 emissions per km	A (very important)	3
11	9	CO2 Emissions per parcel	Total kg of CO2 emissions per parcel	A (very important)	1
12	...	...	...	...	...

Figure 2: Extract from questionnaire to cluster and rank KPIs from a Living Lab perspective

Data-driven perspective – Determining the achievements

The evaluation focuses on the KPIs before and after the Living Lab implementation period. The change in data points per KPI between the first and second survey is compared and displayed as a percentage increase or decrease, by dividing the KPI value of the second survey by the KPI value of the first survey and subtracting 1 from the result.

Value Change KPI$_n$ = $\frac{ValueKPIn(t2)}{ValueKPIn(t1)} - 1$; with n ∈ {1, 2, 3, ...20}

This evaluation step, based on real data, enables an exact measurement of progress in the form of a valid percentage value, e.g. for expert discussions on how to further reduce or improve a value. The KPI Value Change can be calculated for KPIs 1-20. For the KPIs 21-25, which are likely to start at 0, intervals based on the actual values rather than percentages are used.

Evaluation perspective – Evaluation of the achievements

In the next step, the improvements made due to the implemented measures are weighted on a scale from minus 3, meaning significant worsening, to plus 3, significant improvements. This is called a weighted achievement. This assessment allows the KPI changes to be compared across the Living Labs without showing the exact value of the change. In addition, a quick overview of the changes can be obtained in the form of a graphic visualisation, e.g. in the form of a heat map guiding different stakeholders through the relevant discussions. The intervals for the conversion of the percentage values have been set preliminarily and have been validated after the completion of the ex-post measurements. The following figure illustrates the weighing approach by showing some examples with respect to KPIs 1-4.

						Weights				Interval
			Very bad	Bad	Poor	None	Fair	Good	Very good	
Label	Description and data format	Unit	-3	-2	-1	0	1	2	3	
Traffic Flow	Total freight kilometers driven per 10000 inh	km/10000 inh	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%
Distance Travelled	Average distance per delivery	km/del	> +30%	+16-30%	+1-15%	0	-1-(-15)%	-16-(-30)%	< -30%	15%
Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	%	> +30%	+16-30%	+1-15%	0	-1-(-15)%	-16-(-30)%	< -30%	15%
Delivery time	Average delivery time per route	mins	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%
...										

Figure 3: Extract from the weighting table

For KPIs where measurements are lacking, a qualitative judgement can be made. The scale applied is: -3: Very bad, -2: Bad, -1: Poor, 0: None, 1: Fair, 2: Good, 3: Very Good.

System perspective – Contextualising results

As a result of the three previous steps (perspectives), a specific KPI Value for each of the 25 KPIs can be derived. This value can be seen as an integrated metric combining the input from the LLs regarding the importance of the KPIs and the achievement made due to the implementation of a measure.

KPI_n Value = $WeightKPIn\ (-3 \ldots +3) \cdot ClusterWeightKPIn\ (0 \ldots +3)$;
with Cluster A = 3 points, Cluster B = 2 points, Cluster C = 1 points, Cluster D = 0 points.

The resulting standardised and weighted KPIs allow for a comparison across dimensions within the LL, as they clearly show what are the biggest achievements and weaknesses of each measure based on the needs and objectives of the LL. The KPI value can range from -9 (very poor) to +9 (very good).

Compliance with SULPs and SULP guidelines

In addition to the four perspectives described above, a module for assessing SULP compliance has been integrated. This is provided for two different types of SULP compliance assessment.

- Alternative 1: A SULP in the city already exists or is currently under development
- Alternative 2: There is not yet a plan or associated activities that enable the utilisation of targets

In the first case, the existing objectives from the SULP can be used, and the measures of a Living Lab can be compared regarding their compliance. In addition to this comparison, a compliance check is also carried out using already formulated guidelines. In the second case, where no SULP or related activities are available, the compliance check is based solely on these guidelines.

For this purpose, we utilised the SULP Guidelines from the European Local Transport Information Service (ELTIS). The Guidelines address important goals and aspects within the "Socio-economic," "Commercial," "Operational," and "Technical" dimensions. With the help of this structure, the DISCO-X measures are checked for compliance with the formulated guidelines. For doing this, we have used the following scale:

- 3 = High compliance – no need for adaptation,
- 2 = Medium compliance – short-time adaptation,
- 1 = Low compliance – long-time adaptation.

The findings from this assessment can be used to optimise measures for higher compliance or to introduce further measures.

Evaluation Workshops and Association of KPIs to DISCO-X measures

To prepare for the evaluation of the DISCO-X measures in the Living Labs, individual evaluation workshops with the Living Labs were conducted. In this context, an already predefined association of the KPIs to the different DISCO-X measures per Living Lab was verified and discussed with the Living Lab leaders with respect to the data availability.

2.2. Evaluation Dashboard

The Evaluation Dashboard was developed in August 2024, using data and formulas previously compiled by ITL. A key requirement was to balance a sophisticated interactive tool for evaluation with a clear and user-friendly interface. While alternative application development tools were considered, they were deemed less likely to achieve the desired ease of use. Hence, Microsoft Excel was selected as the development platform due to its broad accessibility and practical utility. The main page of this multi-sheet Excel file contains hyperlinks to navigate throughout the tool.

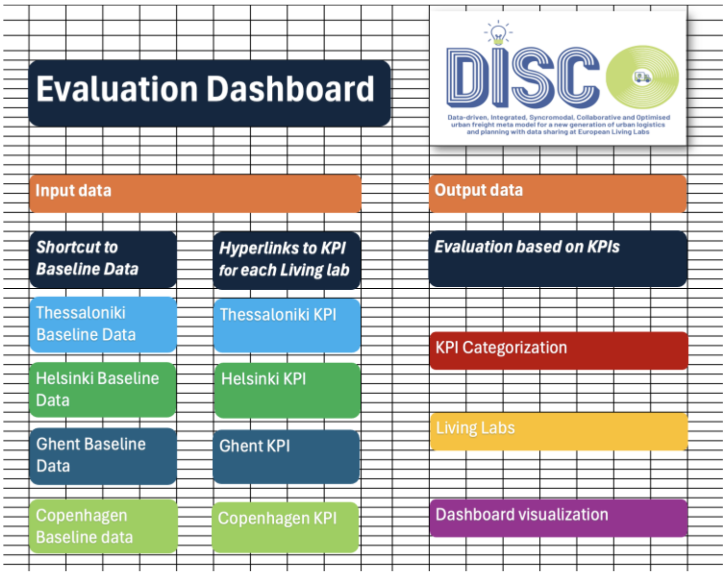


Figure 4: Main page of the Evaluation Dashboard

For each Living Lab, there are two dedicated sheets:

- A Baseline Data sheet.
- A Key Performance Indicators (KPIs) sheet.

Data from these individual lab sheets is evaluated and visualised in separate evaluation sheets, which are designed to facilitate analysis and cross-lab comparisons, for example, by using Pivot Tables.

The evaluation dashboard plays an important role in the evaluation process and can provide important support in all the above-mentioned phases of the evaluation process (see Figure 1). From support in the definition of objectives, through the categorisation or classification of indicators, to the optimisation of measures. However, the tool is designed to support the following objectives, which essentially address phase 3 ‘Collecting, analysing, evaluating’:

- Interface for collecting and providing data in a comparable way,
- Association and clustering of KPIs regarding relevant categories,

- Processing and analysing of data input from the Living Labs,
- Visualisation of indicator changes and impact of the implemented measures.

The four objectives and the associated work on the dashboard are described in more detail below.

From Input Data to Output Data

The figure below illustrates the calculation method for KPIs. Each KPI is derived from a unique set of Baseline Data points using a predetermined formula. For instance, KPI 9 is calculated using a specific formula that pulls values from cells D3, D4, D5, and D6 in the DISCOCURB sheet. This calculation occurs in the background, with the final value displayed in the corresponding KPI sheet. A key feature of this system is its dynamic nature; any updates made to the Baseline Data will automatically and instantly recalculate the relevant KPI.

Baseline Data

	Description baseline data	Unit
1	The population of the city during the last year	Inhs
2	Total number of freight vehicles operating in the pilot area daily	vehs
3	Average freight kilometres per day per vehicle in the pilot area	km/vehs
4	Weighted average of eq.CO2 emissions per km of vehicles in the pilot area	kgCO2/km
5	Average number of deliveries per vehicle at each day within the pilot area	dels/vehs
6	Average number of parcels per delivery at each day within the pilot area	parc/del
7	Number of freight/commercial EV vehicles operating daily in the pilot area	vehs
8	Number of cargo bikes operating daily in the pilot area	vehs
9	Percentage of companies operating with cargo bikes in the city	-
10	Percentage of deliveries performed with cargo bikes	%
11	...	

KPIs

N.	Label	Description and data format	Unit
1	Traffic Flow	Total freight kilometers driven per 10000 inh	km/10000 inhs
2	Distance Travelled	Average distance per delivery	km/del
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	%
4	Delivery time	Average delivery time per route	mins
5	Delivery Density	Number of deliveries per km	del/km
6	Cost per parcel	Cost of delivery per km	€/km
7	Operational Cost per day	Total delivery cost	€
8	CO2 Emissions per km	Total kg of CO2 emissions per km	eCO2/km
9	**CO2 Emissions per parcel**	Total kg of CO2 emissions per parcel	eCO2/parcel
10	EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	%
11	Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	-

KPI 9 = ('Baseline DISCOCURB'!D4 * 'Baseline DISCOCURB'!D3) / ('Baseline DISCOCURB'!D5 * 'Baseline DISCOCURB'!D6)

Figure 5: From Baseline Data to KPI - Example KPI 9: CO_2 Emissions/parcel

Analyse and evaluate based on categorisations

To analyse and evaluate data or visualise results, the dashboard uses various linking and clustering approaches as well as **categorisations**. Those are:

- DISCO-X measures
- 7 Sustainability Development Goals (3,8,9,11,12,13,17) on target level
- the 5 impact domains of DISCO
- SETR dimensions (societal, economic, technical, regulatory)
- dimensions of energy efficiency gains

Normalisation from the weighting approach

In addition to the categories listed above, information from the Living Labs on the importance of the KPIs is processed and combined with the weighting approach.

To enable a more nuanced evaluation, the Evaluation Dashboard normalises KPIs through a system of clustering and weighting. This method generates a final score that reflects both the importance and the performance of each KPI. First, each Living Lab assigns an "importance" rating to their KPIs, based on a framework developed by Lindholmen Science Park and ITL. The ratings are converted to a numerical score:

- “Very Important”: 3 points,
- “Important”: 2 points,
- “Less Important”: 1 point,
- “Not Applicable”: 0 points.

Secondly, a weight is assigned based on the KPI's percentage change from the value of the KPI before implementation to after the implementation. This performance is exemplified below in one of the KPIs, “Traffic flow”, as follows:

- Improvement of > 20%: 3 points,
- Improvement of 11% - 20%: 2 points,
- Improvement of 1% - 10%: 1 point,
- a change of -1% - (-10%): -1 points,
- a change of -11% - (-20%): -2,
- a change of > 20%: -3 points.

Calculating the KPI value

Finally, the clustering score is multiplied by the weighting to produce a single, comprehensive value for each KPI, providing a clearer quantitative or qualitative assessment. The figure below shows an example of how a KPI value is calculated. In the example, we give the KPI value change a rating between -3 and 3 based on the percentage of change. The weight is multiplied by the rating of the clustering, and the KPI is assigned a quantitative value. By multiplying the clustering with the weight, the KPI value is normalised. This allows a comparison across KPIs in the evaluation process.

N.	Label	Cluster A (very important, 3), Cluster B (important, 2), Cluster C (less important, 1), Cluster D (not applicable, 0).	Value before implementation	Value after implementation	KPI Value Change in %	Weight
1	Traffic Flow	2	4.85	5.31	10%	-1
2	Distance Travelled	1	0.33	1.52	354%	-3
3	Failed Deliveries	2	0.35	1.00	186%	-3

Helsinki DISCOPROXI – KPI Value
-2
-3
-6

Figure 6: Determination of KPI Value (Example DISCOPROXI - Helsinki Living Lab)

Visualisation for the purpose of action

In Figure 7, we have an example from one of the Living Labs, Helsinki. The visualisation shows a couple of KPIs values after the implementation. The scale of the rating ranges from -9 to +9. The figure distinctly visualises the value of several KPIs, for example, KPI 10, EV adoption rate, or KPI 1, Traffic flow. The value after the implementation is a positive value of 6 for KPI 10, and the KPI value for KPI 1, after the implementation, is a negative 2. While the KPI value 6 for KPI 10 is seen as a great improvement, the result for KPI 2 is seen as a decline.

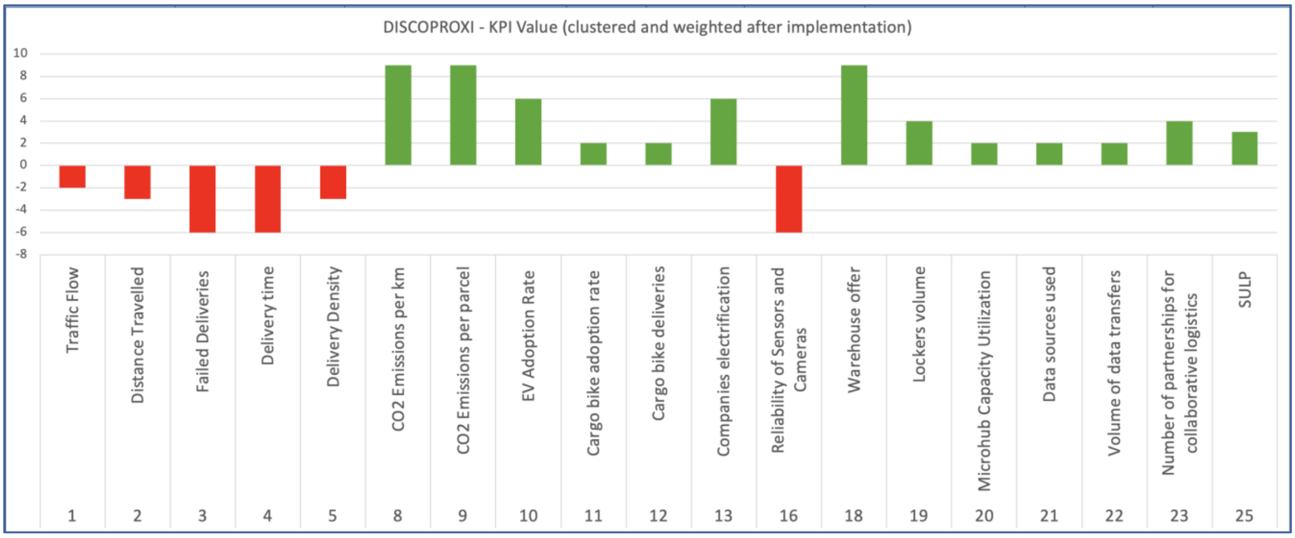
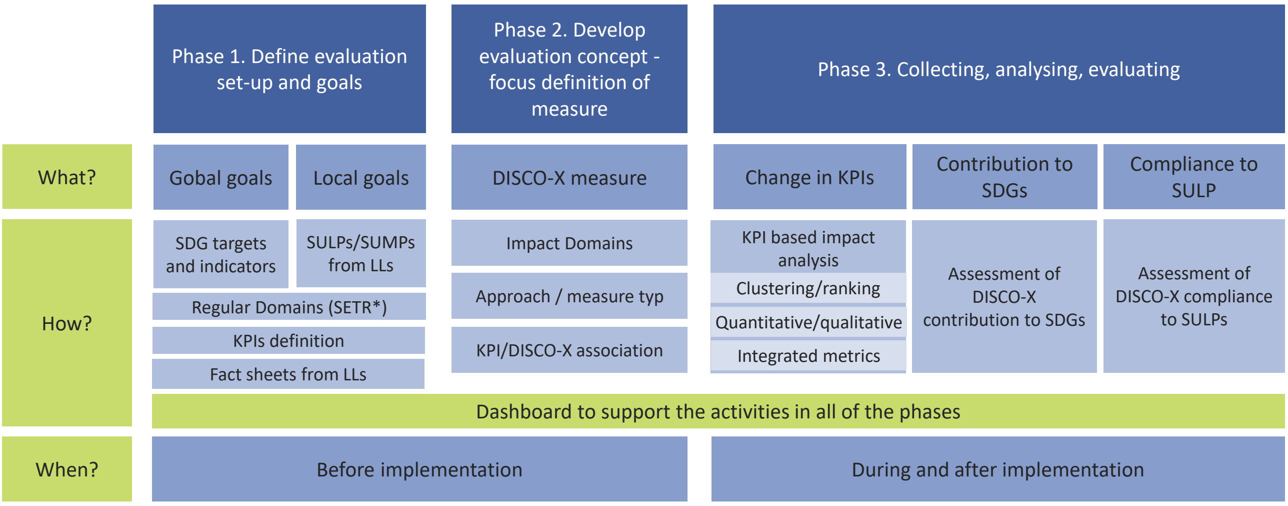


Figure 7: Visualisation of KPI Value (Example DISCOPROXI - Helsinki Living Lab)

2.3. Guide to Evaluation for Living Labs – The Evaluation Framework

As a summary and tool to support future evaluation work, such as the Twinning Living Labs, the findings have been summarised in the following framework. This comprises the first three phases of a typical evaluation process and contains the essential elements and content of the evaluation, from the definition of objectives at the global and local levels, through the definition and categorisation of measures, to the approaches used in the execution of the evaluation.



**SETR = societal, economic, technical, regulatory*

Figure 8: Evaluation Framework (Phase 1-3)

Questions that support the application of the framework are, for example:

Phase 1:

- Are there already existing sustainable urban logistics plans (SULPs) or can those be developed in the context of the project?
- Which basic categories should be considered and can be used for defining the set-up and goals with respect to a holistic approach (e.g., societal, economic, technical, regulatory)?
- Which indicators can be used to assess the implementation and determine the impact of measures? How can these be classified in relation to the project setting (e.g., through assignment to Impact Domains, Regular Domains or SDGs)?
- Which indicators reflect the local goals of reducing congestion and emissions, increasing efficiency by deploying the Physical Internet paradigm in urban logistics?
- Has the most important information regarding the planned measures been prepared in a structured manner, and is it available to the stakeholders involved?

Phase 2:

- What is the primary Impact Domain of a DISCO-X measure: Shared solutions, Connected logistics, Smart logistics, Urban network management, Agile storage and last-mile distribution?
- What are the characteristics of the individual DISCO-X measures? (e.g., can it be classified as a physical measure, a digital measure, or a measure focusing on business activities?)
- Is an assignment of DISCO-X measures to KPIs possible, and is quantitative/qualitative data or information available?

3. Undertaking the Evaluation in the Starring LLs – Copenhagen

3.1. Short Summary Copenhagen LL Report (D4.2)

Copenhagen Living Lab consists of DISCOCURB, DISCOPROXI, DISCOLLECTION, and DISCOBAY. The overall purpose of the DISCO measures is to discover how to become carbon-neutral by 2025. In that pursuit, Copenhagen has introduced several logistics strategies designed to reduce emissions and improve urban liveability. DISCO supports this by introducing an innovative, data driven approach to city planning and traffic management with the DISCO-X measures.

DISCOCURB focuses on developing a dynamic space management and urban planning tool to optimise curbside use. A user-friendly booking platform, smart signage at the location, sensors, and an integrated platform are made for testing the technology at two delivery sites relevant to Tivoli.
DISCOPROXI aims to develop a sustainable business model for an open consolidation hub, encouraging more couriers to utilise shared logistics facilities. The initiative aims to lay the groundwork for an updated SULP by developing a viable business model for an open consolidation hub and investigating the financial and legal conditions necessary for establishing shared logistics infrastructure. A key focus is encouraging more couriers to use shared microhubs.

DISCOBAY involves retrofitting the Høje Taastrup terminal to function as a peri-urban and neighbourhood multimodal hub that supports zero-emission freight deliveries. In parallel with work involving local stakeholders, activities focused on calculating the potential impact of a physical retrofit with a Digital Twin.

DISCOLLECTION seeks to establish a real-time transport data collection model by engaging private logistics and e-commerce companies, and to engage the local industrial community in shaping the new SULP. The project adopts a Digital Twin approach for urban logistics, allowing for the simulation and analysis of logistics movements and patterns across different scales within the city.

The development and experimental implementation of these measures have contributed to improving the overall understanding of the urban logistics context in Copenhagen. The operational data provided by the 11 operators involved in this initiative was processed to extract information specific to logistics practices. This data provides insight into the intensity of demand based on various parameters such as freight type and vehicle size.

The inherent complexity of these activities and their multi-actor dimension is also highlighted by these analyses. Modelling work using digital twins made it possible to project future situations and measure their impacts. Specific work has been carried out on policies relating to traffic restrictions for combustion engine vehicles, the consolidation of flows, and the staggering of delivery times. The results support the measurement of the quantitative impacts on the evolution of fleets, their motorisation, and all externalities (traffic, energy, CO_2).

3.2. Evaluation set-up and preliminary remarks

As described above, Copenhagen worked on the introduction of a total of four DISCO-X measures. To gain a better understanding of the following evaluation results, the table below illustrates the characteristics of the respective measures.

Table 2: DISCO-X characteristics Copenhagen

	DISCOCURB	DISCOPROXI	DISCOBAY	DISCOLLECTION
Impact Domain	Agil storage and last mile distribution	Connected Logistics	Connected Logistics	Connected Logistics
Typology	Digital	Business	Physical	Digital
Implementation approach	Proof-of-concept	Simulation	Stakeholder Engagement + Simulation	Simulation
Supporting Technology	Narrow-band IoT sensors, booking app	Digital Twin	Digital Twin	Digital Twin
Focus area	Tivoli (inner city)	Medieval city and environmental zone	Høje Taastrup terminal	Medieval city and environmental zone
Partners	Coding the Curbs (Start-up) and City of Copenhagen	11 logistic operators	Various stakeholder	11 logistic operators
Data sources used	Sensor data (occupancy) and booking data (app)	11 data samples from logistic providers	Traffic counting, secondary data regarding CO_2	11 data samples from logistic providers
Evaluation approach	Mainly qualitative	Quantitative with focus on CO_2 Emission	Quantitative with focus on CO_2 Emission	Quantitative with focus on CO_2 Emission
Addressed KPIs	1, 4, 6-9, 15-17, 21, 22, 23, 25	2, 8, 21, 22, 23, 25	8, 18, 20, 21, 22, 23, 25	8, 21, 22, 23, 25

3.3. Assessment of KPI importance

The overall goal of becoming the first carbon-neutral city in the world requires new solutions and the commitment of all parties involved. A balance must be struck between climate targets and the use of emission-free, efficient logistics solutions. This endeavour is also evident in the assessment of the KPIs in terms of their importance from the city's perspective. Strategic KPIs are, therefore, the "reduction of CO_2 Emissions per km", the "number of partnerships for collaborative logistics", or the development of a "Sustainable Urban Logistics Plan (SULP)". Since a new plan has not yet been adopted, it becomes even more important. The developed recommendations for SULP 2025 within the DISCO project will be discussed in more detail in chapter 3.4.2. The following figure shows the overall assessment of the KPI importance according to the Cluster defined in chapter 2.

KPI Numb	KPI	Description and data format	Cluster	Rank in Cluster
4	Delivery time	Average delivery time per route	A (very important)	5
8	CO2 Emissions per km	Total kg of CO2 emissions per km	A (very important)	3
2	Distance Travelled	Average distance per delivery	A (very important)	4
22	Data Utilization	Number of new/enhanced services utilizing old/new data collected	A (very important)	6
23	Number of partnerships for collaborative logistics	Number private-private and -or public-private partnerships for last mile deliveries	A (very important)	2
25	SULP	Number of locally politically approved SULP or freight logistics plan	A (very important)	1
9	CO2 Emissions per parcel	Total kg of CO2 emissions per parcel	B (important)	3
1	Traffic Flow	Total freight kilometers driven per 10000 inh	B (important)	4
7	Operational Cost per day	Total delivery cost	B (important)	2
5	Delivery Density	Number of deliveries per km	B (important)	5
10	EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	B (important)	1
21	Data sources used	Number of data sources or platforms that are connected to the data space	B (important)	6
24	Investment plans	Number of investment logistics plans of local private entities operating in Urban logistics	B (important)	7
15	Space Utilization Efficiency	Average occupancy of parking spaces	B (important)	11
16	Reliability of Sensors and Cameras	Average time that sensors were not working properly	B (important)	8
17	Transport infra offer	Average offered space of a transport infrastracture to be used as (shared) space for logistics operations	B (important)	10
18	Warehouse offer	Average offered space of a warehouses be used as (shared) space for logistics operations	B (important)	9
6	Cost per parcel	Cost of delivery per km	C (less important)	1
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	D (not applicable)	
11	Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	D (not applicable)	
12	Cargo bike deliveries	Percentage of the total deliveries performed by cargo bikes	D (not applicable)	
13	Companies electrification	Percentage of companies that operate with cargo bikes	D (not applicable)	
14	Parking fines	Parking fines per 10000 inh	D (not applicable)	
19	Lockers volume	Percentage of freight volume delivered through lockers	D (not applicable)	
20	Microhub Capacity Utilization	Average utilization rate of a parcel locker	D (not applicable)	

Figure 9: Clustering and ranking of KPIs Copenhagen

As the measures in the Living Lab of Copenhagen are not addressing the success rate of deliveries or the use of electric cargo bikes (only in a simulation context) those KPIs were rated "not applicable".

3.4. Evaluation of DISCO-X measures

In the following, the four DISCO-X measures implemented in the Copenhagen Living Lab are evaluated on three different levels. In a first step, a KPI assessment based on the 25 KPIs defined in DISCO is carried out (operational level). This assessment uses the methodology described in chapter 2.1, considering the different perspectives. From a data point of view, qualitative and quantitative information before and after implementation is used. Following up on this, their compliance with the ELTIS SULP Guidelines is reviewed and aligned with the developed SULP recommendations 2025 (local level). In a final step, their contribution to the SDGs at the target level is assessed (global level).

3.4.1. KPI-Assessment

The four DISCO-X measures implemented in the Copenhagen Living Lab are evaluated based on the 25 KPIs. As not all KPIs were applicable and in some cases quantitative data was not included in all measures, an assessment is made both quantitatively and qualitatively. A distinction must also be made between the respective implementation approaches. While DISCOCURB represents a proof of concept in a real setting, DISCOPROXI and DISCOLLECTION are based on a simulation using the

Digital Twin. DISCOBAY can be understood as a hybrid approach, which is divided into two streams - a simulation and a stakeholder-based approach regarding the real retrofitting of Høje Taastrup terminal.

DISCOCURB

The DISCOCURB measure was implemented in Tivoli Gardens, a central location in Copenhagen. With millions of annual visitors and nearly 100 restaurant facilities Tivoli Gardens is facing serious challenges to managing deliveries. The lack of a system to organise delivery schedules has caused conflicts over limited parking spaces for trucks. Besides that, in September 2024 the construction at Tietgensgade shifted the main delivery entrance to the side street H.C. Anderson Boulevard. This situation created a unique opportunity to pilot a smarter solution in collaboration with Coding the Curbs (start-up company). The overall goal of the pilot was to test the implementation of a Smart Zone solution to optimise logistics operations. Within the measure, there were two main aspects addressed:

- **Analyse Usage Patterns:** Gather insights on delivery patterns, booking behaviours, occupancy rates, and instances of violations or no-shows;
- **Understand User Experience:** Evaluate how logistics providers interact with the Smart Zone booking system and its practicality in daily delivery operations.

The pilot used temporary infrastructure to address congestion, logistical inefficiencies, and environmental impact during peak seasons and upcoming construction at the delivery site, serving as a model for broader citywide applications. There were two implementation periods (late September – beginning of November and mid-November – Christmas 2024) for two smart zones. To collect data, 3 sensors per smart zone were installed. Besides the sensors, a booking app was developed to collect and analyse data from the users. The setup provided valuable insights into user patterns and user experience with respect to the digital booking system. For example, based on the sensor data the type of vehicle parked on the Smart Zone could be determined. Contrary to expectations, 83% of all delivery activities are carried out using either cars or small trucks. In terms of booking duration, 60% of users completed their deliveries within 15 minutes, while almost 18% reserved the space for more than an hour. This shows the varying unloading requirements, with a clear preference for short time slots. In addition, ongoing communication with Tivoli management helped gather user feedback to evaluate the user experience and understand how logistics service providers interacted with the Smart Zone booking system and how practical it was in daily operations. The feedback received was reported as positive.[4]

Due to the early-stage proof-of-concept set-up with a clear focus on the two mentioned aspects, no quantitative data with a direct link to the 25 DISCO KPIs was collected. To provide a KPI-based

[4] Further lessons learned can be viewed in D4.2.

assessment of the measure, a qualitative assessment was made in the context of the evaluation workshop with the Living Lab representatives held on 19 June 2025. In the following, the results of the assessment are described:

Regarding KPI 1, “Traffic Flow”, it was stated that the measure has a major effect on the reduction of traffic jams. This was mainly because of the construction work conducted at that time in the area since one lane of the road, including a loading/unloading bay, was taken away by the construction company. Concerning KPI 4 “Delivery time”, a positive effect due to time savings resulting from an optimised planning with the help of the app, limiting waiting times, is assumed.

For KPI “Cost per parcel” as well as for KPI 7 “Operational costs per day”, a slight positive effect was hypothesised because of (small) time savings within the overall logistics process. KPI 8 “CO_2 Emissions per km” and KPI 9 “CO_2 Emissions per parcel” are also associated with a slight positive effect. The emission reduction results from the optimised situation on-site. Due to the guaranteed slot during unloading, the drivers immediately find their parking spot, which reduces the time until the motor is switched off.

For the KPI 15 “Space Utilisation Efficiency” (transferred to the smart zone concept) and KPI 17 “Transport infra offer”, the measure provides small improvements. Especially the use as (shared) space for logistics operations was tested within the pilot with positive resonance. With respect to KPI 16, “Reliability of Sensors and Cameras”, full utilisation can be confirmed since the sensors were running for 100 percent of the time. For the KPIs 21, 22, and 23, slight to medium positive effects were derived.

The particular situation created by the construction works brought some distortions about the expected effects. Nonetheless, this evaluation shows that positive effects in the areas of traffic flow, delivery costs, CO_2 reduction, as well as land use are associated with the measure.

Table 3: KPI Assessment DISCOCURB Copenhagen[5]

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
1 - Traffic Flow	B					3	6
4 - Delivery time	A					2	6
6 - Cost per parcel	C					1	1
7 - Operational Cost per day	B					1	2
8- CO_2 Emissions per km	A					1	3
9 - CO_2 Em. per parcel	B					1	2
15 - Space Utilisation Efficiency	B					1	2
16 - Reliability of Sensors and Cameras	B					3	6
17 - Transport infra offer	B	0	83,2 sqm	formula not appl.	1		2
21 - Data sources used	B	0	1	formula not appl.	1		2
22 - Data Utilisation	A	0	1	formula not appl.	1		3
23 - Number of partnerships for collaborative logistics	A	0	1	formula not appl.	1		3

DISCOPROXI

The objective of the measure was to achieve a 25% increase in courier participation in shared microhubs, leading to improved last-mile delivery efficiency and reduced vehicle trips into the city centre. This intervention is expected to lower CO_2 emissions per km by optimising route efficiency, reducing the number of delivery vehicles required, and shifting freight movements to more sustainable modes. From a geographical standpoint, the consolidation hub simulation differentiates

[5] The KPI Value can range from -9 (very poor) to +9 (very good). The colour coding is based on this scale. While a very dark colour represents a very poor rating (red) or a very good rating (green), a lighter tone indicates a weakening of this rating, either in a negative or positive sense.

between the two scenarios, "Medieval City" and "Environmental Zone", and was based on the following "multi-functional logistics hub" assumptions:

- All deliveries in the Medieval City are made by cargo bikes,
- Parcels are delivered by motor vehicles at the hub before 10:00 am,
- Cargo bikes start their operations at 10:30 (capacity 20 parcels per bike),
- Motor vehicles keep circulating in the Medieval city,
- Other areas are delivered smoothly.

For the simulation, different baseline data were used. The following figure illustrates BD 2: "Total number of freight vehicles operating in the pilot area daily". Beside that information regarding the "Average freight kilometres per day per vehicle in the pilot area" (BD 3), the "Weighted average of eq.CO_2 emissions per km of vehicles in the pilot area" (BD 4) as well as the "Average number of deliveries per vehicle at each day within the pilot area" (BD 5) was utilised.[6]

Multi-functional logistics hub: Medieval City results

Fleets composition

Medieval City average day		Baseline	Hub operational	Evolution
	Trucks thermic	297	59	-80%
	Trucks electric	3	1	
	Vans thermic	1 045	207	
	Vans electric	55	11	
	TOTAL	**1 400**	**278**	

Environmental indicators

Medieval City *Annual values*		Baseline situation	(*) Hub operationaL	Evolution (%)
Distance [1000 km]	Trucks thermic	1 693	846	107%
	Trucks electric	17	51	
	Vans thermic	6 333	5 066	
	Vans electric	333	3 000	
	TOTAL DISTANCE	**8 376**	**8 964**	
Emissions [tCO2eq]	Trucks thermic	1 676	838	73%
	Trucks electric	5	14	
	Vans thermic	1 393	1 115	
	Vans electric	32	288	
	TOTAL EMISSIONS	**3 106**	**2 255**	

Multi-functional logistics hub: Env.Zone results

Fleets composition

Env.Zone average day		Baseline	Hub operational	Evolution
	Trucks thermic	10 785	10 785	112%
	Trucks electric	109	109	
	Vans thermic	76 048	86 694	
	Vans electric	4 003	4 563	
	TOTAL	**90 944**	**102 151**	

Environmental indicators

Env.Zone *Annual values*		Baseline situation	(*) Hub operationaL	Evolution (%)
Distance [1000 km]	Trucks thermic	30 738	30 430	97%
	Trucks electric	310	342	
	Vans thermic	230 424	184 340	
	Vans electric	12 128	50 936	
	TOTAL DISTANCE	**273 600**	**266 047**	
Emissions [tCO2eq]	Trucks thermic	30 430	30 126	92%
	Trucks electric	87	96	
	Vans thermic	50 693	40 555	
	Vans electric	1 164	4 890	
	TOTAL EMISSIONS	**82 375**	**75 666**	

Figure 10: Simulation results DISCOPROXI Copenhagen

[6] BD 3 increases from 17 km to 41 km for vans and from 16 to 101 km for trucks in the Medieval City scenario while the distances for the Environmental Zone scenario show only a change for the vans (from 8 km to 7 km) while the distance for the trucks remained at 8 km. BD 4 decreases by 32,3% from 0,371 kgCO_2/km to 0,251 kgCO_2/km (Medieval City) and by 5,65% from 0,301 kgCO_2/km to 0,284 kgCO_2/km (Environmental Zone). BD 5 increases from 7 to 36 (Medieval City) and decreases from 26.7 to 24.3 (Environmental Zone).

The simulation results for the **Medieval City (MV)** show a significant effect of -27% CO_2 emission reduction on an annual basis. Regarding the distance travelled, an increase of +7% is detected. A greater CO_2 reduction is not achieved, although the fleet size is cut down by 80%. This is mainly because a smaller number of vehicles have to cover more kilometres. The **Environmental Zone (EZ)** simulation results in an increase of the fleet size of +12%. The distance travelled, on the other hand, decreases by 3%. For the CO_2 emissions, a reduction of 8% is calculated, mainly resulting from fewer kilometres driven by conventional vans. If these findings are then transferred to the evaluation logic developed, further insights can be derived. The following table shows the KPIs changes for the Medieval City Scenario and the Environmental Scenario compared to the baseline.

Table 4: KPI Assessment DISCOPROXI Copenhagen

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
2 - Distance Travelled km / del.	A	MV: 1,2	MV: 1,1	-7%	1		3
		EZ: 8,9	EZ: 9,3	+4,85%	-1		-3
8 - CO_2 Emissions per km	A	MV: 519,4	MV: 69,78	-86,57%	3		9
		EZ: 27.374	EZ: 29.011	+5.98%	-1		-3

With respect to the initial goals of this measure, the simulation results show mixed effects. Although emissions can be reduced by lowering the delivery routes of conventional vehicles, the distances travelled across the entire fleet only change marginally. From a traffic standpoint, the results do not indicate an increase in operational efficiency or reduced vehicle trips. Positive effects are seen in the Medieval City through the widespread use of cargo bikes. For establishing a long-term solution within the city, a clear understanding of economic benefits is crucial. Here economic simulations using high quality data are essential. On the other hand, regulatory stability and clarity from the public sector is needed to build a foundation for a successful transformation of the business model towards shared infrastructure.[7]

DISCOBAY

The Copenhagen Living Lab in Høje Taastrup explored the impact of upcoming regulations, such as Zero Emission Zones, on various small, independent companies in a grocery wholesaler area and the goods transportation from peri-urban areas to the city centre for greener last-mile deliveries. It examines the need for physical infrastructure to support the green transition for the independent companies renting space at the wholesaler. This is achieved through collaboration with local

[7] Further lessons learned can be viewed in D4.2.

stakeholders, including the municipality and a charging infrastructure provider, who is already present in the area of the transportation centre. The case is unique due to the presence of several independent small businesses selling groceries, fruits, and vegetables to restaurants and cafés, particularly in Copenhagen. Different delivery models coexist, where either sellers deliver to buyers or buyers visit the wholesaler directly. Since retrofitting the Høje Taastrup terminal aims to function as a peri-urban and neighbourhood multimodal hub that supports zero-emission freight deliveries, the defined goal for this measure was:

- Facilitate the adoption of electric cargo bikes for last-mile logistics while ensuring seamless integration with regional freight networks, with a 40% reduction in CO_2 emissions from freight movements, achieved by increasing the share of goods delivered via zero-emission vehicles and optimising freight distribution to reduce unnecessary travel distance.

The Measure involved various stakeholders and was divided into two tracks:

- The simulation of the retrofit in the digital twin and
- The implementation of the retrofit

Supported by data from a traffic count, a digital twin for electric vehicle (EV) fleet scenarios, considering factors such as energy demand, charging time, and the number of recharging points required, was set up. On this basis, three different scenarios were calculated, measuring changes in the CO_2eq balance for journeys connected to the platform as a function of changes in the proportion of EVs in the fleet.

Table 5: Scenarios and baseline data DISCOBAY Copenhagen

Scenarios:	BD used for the simulation:

• Baseline: 100% thermic vehicles
• Scenario 1: 30% EV, 70% thermic
• Scenario 2: 60% EV, 40% thermic
• Scenario 3: 100% EV
	• BD 2: Total number of freight vehicles operating in the pilot area daily: 1000
	• BD 3: Average freight kilometres per day per vehicle in the pilot area: 90
	• BD 4: Weighted average of eq.CO_2 emissions per km of vehicles in the pilot area[8]:
	  • Baseline Scenario: 0,990 kgCO_2/km
	  • Scenario 1: 0,777 kgCO_2/km
	  • Scenario 2: 0,564 kgCO_2/km
	  • Scenario 3: 0,280 kgCO_2/km
	• BD 5: Average number of deliveries per vehicle at each day within the pilot area: 10,7

As the simulation has a lifecycle perspective regarding the CO_2 emissions, there is even in scenario 3 (pure electric delivery) a considerable amount of CO_2 emissions over the lifetime. Nevertheless, scenario 3 indicates a reduction of CO_2 emissions by more than 70%. To reach the set goal of 40%

[8] As reference the life-cycle GHG emissions of 12-t rigid trucks driven in the EU in 2021 to 2040 was used: https://theicct.org/wp-content/uploads/2023/02/Lifecycle-assessment-EU-HDVs_final2.pdf

reduction in CO_2 emissions from freight movements, an electric vehicle share of close to 60% within the fleet must be met from a lifecycle perspective.

Table 6: KPI Assessment DISCOBAY Copenhagen

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
2 - Distance Travelled km / del.	A	8,41	8,41	0	0		0
5 - Delivery Density (numb. del / km)	B	0,12	0,12	0	0		0
8 - CO_2 Emissions per km	A	990	S1: 777 S2: 564 S3: 280	S1: -21,52% S2: -43,03% S3: -71,72%	S1: 1 S2: 3 S3: 3		S1: 6 S2: 9 S3: 9

Regarding a potential implementation of the retrofit the simulation work indicates positive environmental impact. Nevertheless, the relatively high financial requirements that would come with the redesign pose a major challenge for the stakeholders. Especially for the high number of small and medium-sized enterprises, the switch to more sustainable modes of transport is associated with higher costs. Besides the need for new vehicles, the charging infrastructure also requires investment into the terminal. To solve this situation regulatory or market-driven incentives are needed to in order to foster the transition to this kind of sustainable logistics solution.

Since there was no space made more available during the implementation except from the outside space in the outbound flow for the retrofit (adjustment for physical charging infrastructure) future activities could also concentrate on how parts of the in total 220,000 sqm area can be designed to integrate the diverse set of small and medium sized companies allowing a concept for a real shared hub for green logistics. Regarding the evaluation of the KPIs linked to “Warehouse offer (18) or “Microhub capacity utilisation” (20), no assessment was possible even if an association to those KPIs clearly exists. Nevertheless, the concept under discussion indicated great opportunities to retrofit the terminal in a way that it meets future requirements.

DISCOLLECTION

The overall goal of this measure was to establish a real-time transport data collection model by engaging private logistics and e-commerce companies. Copenhagen set out the goal to collect and analyse transport data covering at least 80% of logistics operators in the city, enabling informed decision-making and predictive analytics for traffic management.

DISCOLLECTION (as well as DISCOPROXI and DISCOBAY) contain a simulation approach using the digital twin. In total eleven samples of operational data were used. They were provided by 11 logistics operators working in the Copenhagen area. This data underwent a series of processing steps to ensure it was properly anonymised and compiled to produce accurate information on logistics patterns while preserving business confidentiality. The processed data was grouped according to the logistics activities considered (parcels, food, and beverage). All the sources used contributed to the completion of the work.

Although the measure is seen as simulation work from a technical point of view, numerous partners and associated data sources were utilised. In conjunction with the cluster categorisation already presented, this results in a high to very high KPI Value (combination of cluster rating with weighting factor). This is a valuable achievement that illustrates the city's endeavours to make data usable and to break new ground together with a wide range of partners.

Table 7: KPI Assessment DISCOLLECTION Copenhagen – Data and partnerships

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
21 - Data sources used	B	0	11	formula not appl.	3		6
22 - Data Utilisation	A	0	11	formula not appl.	3		9
23 - Number of partnerships for collaborative logistics	A	0	11	formula not appl.	3		9

With respect to the overall goal of the measure to establish a real-time transport data collection model it must be said that the implementation process illustrated clear barriers (see also D4.2). One the one hand there is a need for significant investment and time resources to build a realistic and reliable model due to extensive parameterisation and calibration work. On the other hand, trust among potential participants to share data is necessary. Both barriers must continue to be addressed in the future to move from a static to a dynamic data sharing model and thus exploit further potential.

Based on the data collected, different use case scenarios were simulated. In the following, the simulation work regarding the use case “Zero-Emission Zones, which restrict access for non-electric vehicles” is evaluated based on the following assumptions:

- All vehicles stopping at least once in the ZEZ are converted to electric vehicles
- Vehicles not stopping in the ZEZ remain thermic but need to detour around the zone

The simulation for the **Medieval City** shows a sharp decline of -56% regarding the fleet size. Regarding the CO_2 emission, the effect is identical with a reduction of -56%.
For the **Environmental Zone,** a slight increase of +2% regarding the fleet size and a decrease of -20% regarding the CO_2 emissions was calculated.

Zero Emission Zone: Medieval City results

Fleets composition

Medieval City average day		Baseline	ZEZ	Evolution
TOTAL	Trucks	300	132	-56%
	Vans	1 100	484	
	TOTAL	1 400	616	

Environmental indicators

Medieval City *Annual values*		Baseline situation	(*) Hub operationaL	Evolution (%)
Distance	Trucks	16	16	
daily	Vans	17	17	
Emissions	Trucks thermic	1 676	737	44%
[tCO2eq]	Trucks electric	5	2	
	Vans thermic	1 393	613	
	Vans electric	32	14	
	TOTAL EMISSIONS	3 106	1 367	

Zero Emission Zone: Env.Zone results

Fleets composition

Env.Zone average day		Baseline	ZEZ	Evolution
TOTAL	Trucks	10 894	11 112	102%
	Vans	80 050	81 651	
	TOTAL	90 944	92 763	

Environmental indicators

Env.Zone *Annual values*		Baseline situation	(*) Hub operationaL	Evolution (%)
Distance	Trucks	8	8	
daily	Vans	8	8	
Emissions	Trucks thermic	30 430	24 344	80%
[tCO2eq]	Trucks electric	87	70	
	Vans thermic	50 693	40 555	
	Vans electric	1 164	931	
	TOTAL EMISSIONS	82 375	65.900	

Figure 11: Simulation results DISCOLLECTION Copenhagen

In the case of Copenhagen, the simulation of the Zero Emission Zone indicates large potential for the city to cut down emissions drastically. Nevertheless, a differentiation must be made regarding the geographical extension of the positive effects since the environmental Zone profits to a smaller extent. The assumption that vehicles that are not stopping in the ZEZ remain thermic but need to detour around the zone might lead to additional traffic volume. It is therefore advisable to use the knowledge gained to develop concepts for a potential implementation of a Zero Emission zone that minimises the weaknesses identified.

Table 8: KPI Assessment DISCOLLECTION Copenhagen – ZEZ simulation

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
8- CO_2 Emissions per km	A	MV: 517,7	MV: 125,7	-75,7%	3		9
		EZ: 27.366	EZ: 22.977	-16,0%	1		3

3.4.2. Compliance to SULPs

As mentioned in Chapter 3.3, Copenhagen has not yet adopted a new SULP. The current SULP was developed in 2009 and requires an update to align with both the forthcoming Climate Strategy 2035[9] and the broader European requirement for Sustainable Urban Mobility Plans (SUMP). Because of this the city is in the process of updating the plan and has already drawn up recommendations for a SULP 2025 in May 2025. It is worth mentioning that findings from the implementation of the DISCO-X measures in Living Lab Copenhagen have feed into the development of those SULP recommendations. The recommendations include aspects like:

- Close dovetailing of the updated SULP with a new SUMP (scheduled for political adoption by 2027),
- Need for a coordinated logistics strategy—integrating truck corridors, reloading hubs, and cargo bike delivery—can enhance efficiency and sustainability across all urban freight activities,
- Integration with Climate Goals, Stakeholder Engagement, and Partnership Development,
- New approaches for Infrastructure Forecasting, Planning, and Development,
- Regulatory Framework Implementation (e.g., regarding ZEZs),
- Technology and Innovation Adoption (utilise Intelligent Transport Systems (ITS) and smart curbside management solutions,
- Urban Mobility Integration (e.g., develop multifunctional urban spaces),
- Regional Cooperation and Knowledge Sharing.

Many of those aspects are well aligned with the targets[10] highlighted in the Grant Agreement (see page 17) with respect to "urban freight efficient land use for servicing and delivery planning". While the DISCOCURB measure contributes to a more efficient and flexible land use, DISCOPROXI and DISCOBAY illustrate the potential of zero-emission transport solutions and microhub concepts. DISCOPROXI on the other hand addresses the aspect of dynamic data exchange among various stakeholders.

With respect to the compliance to SULP assessment based on the ELTIS guidelines the following illustration shows the result of the evaluation. Selected aspects are discussed in more detail hereafter.

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[9] The city is in the final phase of drafting a new Climate Strategy 2035, which reflects updated scientific understanding and adopts a more holistic approach—incorporating both territorial and consumption-based emissions targets.

[10] The targets are (shortened): 1. Reduce social costs; 2. Promote compactness in supply chains; 3. Alleviate supply chain externalities; 4. Find optimal zero-emission solutions; 5. Engage stakeholders and delineate data sharing governance.

Mobility Governance: Services and measures	SULP guidelines		DISCO X			
			DISCOCURB	DISCOPROXI	DISCOBAY	DISCOLLECTION
	Socio-economic	Reducing traffic impacts in the inner city	1	2		3
		Increasing livability of urban environment	1	2	2	3
		Enhancing local economic development			1	
	Commercial	Generate benefits on competetiveness and business	1		1	
		Optimise logistics operation	1	1		1
		Reduce costs, improve knowledge of delivery cost	1		1	1
	Operational	Improved city access regulation	1			2
		Support adoption/use of sustainable vehicles		3	3	3
		Measures supporting transportation operators market			1	
	Technical	Systems to optimise fleet delivery operation	3	3		
		Systems to optimise logistics operation	3	3		
		Improved integration of logistics in urban mobility	3	3	1	
	State of compliance of technology, service and business model will be scored according to the following general criteria:		1,7	2,4	1,4	2,2
	3 = High compliance - no need for adaptation					
	2 = Medium compliance - short time adaptation					
	1 = Low compliance - long time adaptation					

Figure 12: PI compliance to SULP-Guidelines Copenhagen

Socio-economic perspective

From this perspective, it can be said that all measures contribute positively. Nevertheless, there are some aspects that must be taken into consideration. For DISCOCURB, for example, the compliance was rated quite low because some of the positive effects that result from the measure implementation are linked to the very special situation on site (construction work). For DISCOPROXI and DISCOLLECTION, medium to high compliance was stated. However, the findings from the simulation work show that there are complex interactions between these individual guidelines that influence each other. The microhub concept from DISCOPROXI can be cited as an example: for residents in the Medieval City, it brings a significant increase in quality of life through reduced motorised delivery traffic. However, other residents living in close-by neighbourhoods might be affected by more traffic.

Commercial perspective

From this perspective, there is again only a low compliance for the DISCOCURB, which is in line with the only minor effects detected within the qualitative KPI-assessment of that measure. For DISCOPROXI and DISCOLLECTION, there is a low compliance with the commercial criteria that comes mainly from the character of those measures. For example, the addressed use cases (microhub or ZEZ) lead to a significant reduction in CO_2 emissions in a later implementation, but the focus is not directly on optimising logistics processes. DISCOBAY might generate benefits on competitiveness and business, but first, there must be a switch to electric vehicles and the establishment of the necessary charging infrastructure.

Operational perspective

A high level of compliance with the guideline supports the adoption/use of sustainable vehicles, which is assessed for three of the measures. Besides that, the measure DISCOLLECTION contributes to the guideline “Improved city access regulation” as this measure would have a direct impact on traffic and logistics regulations in defined areas of the city.

Technical perspective

From this perspective, DISCOCURB and DISCOPROXI have been rated as highly compliant with the technical guidelines. For DISCOCURB, the functioning technical set-up and used technologies within the measure implementation were given as a reason, indicating that the tested and demonstrated solution could be used in a later extension of the approach across the city. DISCOPROXI, on the other hand, is not because the measure is a system to optimise fleet or logistics operations, but more because the measure will require an adaptive technical system from the operators that cope with the regulations set by the measure.

Regarding the evaluation of KPI 25, Copenhagen receives a weighting of “1”, meaning that there is a new SULP under development with status “drafted”.

Table 9: KPI 25 - SULP Evaluation Copenhagen

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
25 - SULP	A	1	1	Formula not appl.	1		3

3.4.3. Contribution to SDGs

In the following, the contribution of the DISCO-X measures to the Sustainable Development Goals (SDGs) is evaluated. To be able to make a sufficiently precise statement here, the use of the target level of the SDGs is chosen. The association of KPIs to SDGs, as well as the association of KPIs to DISCO-X measures, serve as input for the assessment. In correlation with the 7 SDGs that are addressed by the DISCO activities, 11 SDG targets were identified and compared with the four measures implemented in the Copenhagen Living Lab. The scale used is green = Direct contribution, light green = indirect contribution, no colour = no contribution. In addition, comments were made to clarify the contribution of the respective measure.

Table 10: Contribution to SDGs Copenhagen

SDG target	DISCO-X			
	DISCOCURB Addr. KPIs: 1, 4, 6-9, 15-17, 21, 22, 23, 25	DISCOPROXI Addr. KPIs: 2, 8, 21, 22, 23, 25	DISCOBAY Addr. KPIs: 8, 18, 20, 21, 22, 23, 25	DISCOLLECTION Addr. KPIs: 8, 21, 22, 23, 25
3.9: Reduce the amount of deaths produced by dangerous chemicals and the pollution of the air, water and soil (…) Ass. KPIs: 1, 2, 3, 5, 8-13	Contribution due to expected minor reduction of CO_2	Clear contribution if hub use case implemented	Clear contribution if measure is implemented	Clear contribution if ZEZ use case is implemented
8.2: Achieve higher levels of economic productivity (…) Ass. KPIs: 6, 7, 24, 25	Contribution due to expected minor time savings			
9.1: Develop quality, reliable, sustainable and resilient infrastructure (…) Ass. KPIs: 1, 5, 15, 17, 18, 20			Infrastructural retrofit of the area	
9.4: (…) upgrade infrastructure and retrofit industries to make them sustainable (…) Ass. KPIs: 17-20	Contribution due implementation of sensor technology		Infrastructural retrofit of the area	
11.6: (…) reduce the adverse per capita environmental impact of cities (…) Ass. KPIs: 8-13	Contribution due to expected minor reduction of CO_2	Clear contribution if hub use case implemented	Clear contribution if measure is implemented	Clear contribution if ZEZ use case is implemented
11.A: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning Ass. KPIs: 24, 25			The measure contributes to this target with the concept of the retrofit linking areas for green logistics	
13.2: Integrate climate change measures into national policies, strategies and planning Ass. KPIs: 25	Contribution due to work on SULP 2025	Contribution due to work on SULP 2025	Contribution due to work on SULP 2025	Contribution due to work on SULP 2025
17.16: Enhance the Global Partnership for Sustainable Development (…) Ass. KPIs: 23		In line with achievement of the measure to integrate partner	Stakeholder approach contributes to this target	In line with achievement of the measure to integrate partner

4. Undertaking the Evaluation in the Starring LLs – Ghent

4.1. Short Summary Ghent LL Report (D4.2)

Ghent's DISCO-X initiatives aim to improve logistics sustainability and efficiency, tackling issues like emissions and congestion. These measures directly support the city's "Plan Stedelijke Logistiek," which provides the strategic framework for cleaner and more efficient urban freight.

The DISCOPROXI measure aimed to develop an Urban Access Control (UAC) system that integrates Ghent's vehicle access regulations (e.g., emission zones, time windows) directly into logistics planning software. The goal was to automatically check routes, flag risks, and promote greener alternatives. In practice, the system proved highly effective, improving safety by flagging an average of 11 potential risks per route.

The DISCOBAY initiative aimed to reduce traffic and emissions by exploring a multimodal model that combined waterway transport (barges) with last-mile cargo bike deliveries. A public demonstration successfully proved the technical feasibility of this barge-to-bike concept. In addition, a comparison between green last-mile delivery options and existing traditional models was conducted. The comparative calculations show great potential for green delivery options regarding, for example, the reduction of CO_2 emissions. While a sustainable business model for general goods is not yet established, the trial highlighted significant potential for specific use cases, particularly construction logistics.

The final measure, DISCOLLECTION, aimed to provide the data infrastructure backbone for the other initiatives by creating a unified data space. The objective was to standardise and securely share logistics information, connecting the city's data portal with various software providers to eliminate inefficient one-to-one integrations. This was successfully achieved with the creation of a proof-of-concept data space that later expanded to other Flemish cities. It effectively demonstrated the value and scalability of a decentralised model by drastically reducing the number of individual connections required between stakeholders.

Overall, Ghent's initiatives demonstrated a holistic approach to urban logistics, effectively combining digital tools, innovative physical transport models, and foundational data infrastructure. The project proved that data-driven systems can immediately enhance safety and unlock significant environmental benefits, while also validating new multimodal concepts. By building a scalable data-sharing model, Ghent has not only improved its own operations but has also created a replicable framework for other cities aiming to build more sustainable freight ecosystems.

4.2. Evaluation set-up and preliminary remarks

Within the Ghent Living Lab, three measures were implemented. As a starting point for the following discussion of the evaluation results, a summary of the most important characteristics of the measures implemented in the Living Lab is given.

Table 11: DISCO-X characteristics Ghent

	DISCOPROXI	DISCOBAY	DISCOLLECTION
Impact Domain	Connected logistics	Shared solutions	Smart logistics
Typology	Digital	Business	Digital
Implementation approach	Implementation of the Urban Access Control (UAC) system	Real-world test of multimodal delivery process	Sharing urban access and logistics information via Data Space
Technology	UAC API	None	Smart Data Platform (SDP)
Focus area	Inner City of Ghent	Logistics chain from the district outside the inner city to the city centre	no geographical area
Partners	IT company (Be-mobile), Transport management system provider (Dropon), logistic operators (Bicobel and Foodbag)	retailers and logistics companies (OHB consortium), stakeholders from the logistics service provider (LSP) ecosystem	Traffic management system provider (Geosparc), cities Leuven and Hasselt
Data sources used / integrated	Data from logistic operators	None	Data from two additional cities and one industry partner
Evaluation approach	Quantitative	Mainly qualitative	Quantitative
Addressed KPIs	1, 2, 3, 5-9, 21-23, 25	23, 25	21, 22, 23, 25

4.3. Assessment of KPI importance

The assessment of the KPI importance conducted by the city representatives illustrates their endeavour to enhance efficiency, safety, and the ecological impact of logistics traffic with the measures implemented in the Living Lab. The KPI's that are heavily linked to these fields are rated more important than others. In addition to this, also aspects regarding data supply, (e.g., in what way the Urban Access Control (UAC) and/or the test partners could provide correct and complete data) were taken into consideration.

KPI Numl	KPI	Description and data format	Cluster	Rank in Cluster
1	Traffic Flow	Total freight kilometers driven per 10000 inh	A (very important)	1
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	A (very important)	2
21	Data sources used	Number of data sources or platforms that are connected to the data space	A (very important)	3
22	Data Utilization	Number of new/enhanced services utilizing old/new data collected	A (very important)	5
23	Number of partnerships for collaborative logistics	Number private-private and -or public-private partnerships for last mile deliveries	A (very important)	4
4	Delivery time	Average delivery time per route	B (important)	3
7	Operational Cost per day	Total delivery cost	B (important)	1
8	CO2 Emissions per km	Total kg of CO2 emissions per km	B (important)	2
2	Distance Travelled	Average distance per delivery	B (important)	4
5	Delivery Density	Number of deliveries per km	B (important)	5
9	CO2 Emissions per parcel	Total kg of CO2 emissions per parcel	B (important)	6
6	Cost per parcel	Cost of delivery per km	C (less important)	1
10	EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	C (less important)	5
11	Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	C (less important)	4
12	Cargo bike deliveries	Percentage of the total deliveries performed by cargo bikes	C (less important)	3
25	SULP	Number of locally politically approved SULP or freight logistics plan	C (less important)	2
13	Companies electrification	Percentage of companies that operate with cargo bikes	D (not applicable)	
14	Parking fines	Parking fines per 10000 inh	D (not applicable)	
15	Space Utilization Efficiency	Average occupancy of parking spaces	D (not applicable)	
16	Reliability of Sensors and Cameras	Average time that sensors were not working properly	D (not applicable)	
17	Transport infra offer	Average offered space of a transport infrastracture to be used as (shared) space for logistics operations	D (not applicable)	
18	Warehouse offer	Average offered space of a warehouses be used as (shared) space for logistics operations	D (not applicable)	
19	Lockers volume	Percentage of freight volume delivered through lockers	D (not applicable)	
20	Microhub Capacity Utilization	Average utilization rate of a parcel locker	D (not applicable)	
24	Investment plans	Number of investment logistics plans of local private entities operating in Urban logistics	D (not applicable)	

Figure 13: Clustering and ranking of KPIs Ghent

4.4. Evaluation of DISCO-X measures

In the following, the three DISCO-X measures implemented in the Ghent Living Lab are evaluated on three different levels. In a first step, a KPI assessment based on the 25 KPIs defined in DISCO is carried out (operational level). The assessment uses the methodology described in chapter 2.1, which considers the different perspectives. From a data point of view, qualitative and quantitative information before and after implementation is used. Following up on this, their compliance with the ELTIS SULP Guidelines is reviewed and aligned with the existing SULP (local level). In a final step, their contribution to the SDGs at the target level is assessed (global level).

4.4.1. KPI-Assessment

The three DISCO-X measures implemented in the Ghent Living Lab are evaluated using the KPIs defined as DISCO before and after implementation. The methodology described in Chapter 2.1 is used, considering the different perspectives. In a first step the quantitative results of DISCOPROXI are presented in detail. Following this the DISCOBAY evaluation results are discussed from a more qualitative perspective. Since there is no quantitative data available, the discussion is based on the experiences gained within the preparation and demonstration of a use case. Finally, the DISCOLLECTION measure is evaluated.

DISCOPROXI

The overall goal of this measure was to develop and demonstrate the functionality of an Urban Access Control (UAC) system to enhance logistics efficiency, safety, and sustainability. This was done by integrating digitised Urban Vehicle Access Regulations (UVARs) via a developed API into a logistics planning tool from a Transport management system provider. With this set-up, relevant access regulations could be directly displayed in the Transport management system interface for the use of logistics service providers (LSPs). Within the implementation phase, two logistic operators tested the solution physically. Lessons learned from D4.2 illustrate that the UAC system has a positive effect on safety and logistics planning with respect to stress reduction. Its implementation has not only revealed numerous sources of risk to road safety but also showed the complexity of urban deliveries and the stress placed on drivers.

Regarding the calculation of the KPIs before and after the implementation, some of the baseline data used is presented to make the changes more comprehensible.

- BD 2: Total number of freight vehicles operating in the pilot area daily declines from 1,63 to 1,3
- BD 3: Average freight kilometres per day per vehicle in the pilot area declines from 15,8 to 12,0
- BD 4: Weighted average of eq.CO_2 emissions per km of vehicles in the pilot area stay constant at 0,18 kgCO_2/km
- BD 5: Average number of deliveries per vehicle on each day within the pilot area decreases from 11,0 to 7,45
- BD 6: Average number of parcels per delivery on each day within the pilot area increases from 9,15 to 11,60

Based on this data, the KPI results show positive effects with respect to traffic efficiency, cost, and CO_2 reductions. Nevertheless, it must be stated that some effects are not exclusively attributable to the UAC.

Table 12: KPI Assessment DISCOPROXI Ghent

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
1 - Traffic Flow	A	0.96	0.58	-39.7%	3		9
2 - Distance Travelled km / del.	B	1.44	1.61	+11.8%	-1		-2
3 - Failed Deliveries	A	1.0%	0.0%	-100.00%	3		9
5 - Delivery Density	B	6.37	7.20	+13%	2		4
6 - Cost per parcel	C	1.63	1.29	-20.86	3		3
7- Operational Cost per day	B	4225,19	1739,12	-58,84%	3		6
8- CO_2 Emissions per km	B	0.30	0.23	-21.98%	3		6
9 - CO_2 Emissions per parcel	B	0.028	0.025	-10.7	2		4

The achievement regarding KPI "Traffic flow", which is based on the total freight kilometres driven in relation to the population, results from a combination of fewer freight vehicles operating in the pilot area daily and a lower average freight kilometres driven per day per vehicle in the pilot area. The low number of vehicles that were used in the pilot hardly allows any further analyses with respect to the vehicle fleet.

The increase in the KPI "Distance travelled per delivery" is linked with a decrease in the average number of deliveries per vehicle on each day within the pilot area.
The positive cost effects for KPI 6 "Cost per parcel" and KPI 7 "Operational cost per day" are a combination of the changes seen in the baseline data 2, 3, 5, and 6. The extent of the effect of the introduction of the UAC in comparison to influences emanating from logistics operators cannot be clearly determined. Changes in the pooling strategy or the delivery schedule for example might heavily affect the result.

The positive CO_2 emission effect for KPI 8 "Total CO_2 Em. per km" results from the decrease in the fleet size, whereas the positive effect for KPI 9 "CO_2 Emissions per parcel" is a result of the changes in the baseline data 2, 3, 5, and 6. Interestingly, the reduction is only achieved by changing these factors and not, as perhaps assumed, by reducing the consumption of the fleet vehicles. This is because the composition of the fleet was not changed and consisted solely of conventional vehicles. If electric vehicles were now integrated into the fleet, the CO_2 savings would be even higher.

Another interesting insight can be given in combining the "city perspective" with the "evaluation perspective": In the first evaluation step the clustering and ranking of KPIs regarding their importance the Living Lab responsible classified the KPIs "Traffic Flow", "Failed Deliveries", "Data sources used" as well as "Data Utilisation" and "Number of partnerships" as most important. This is logical as both DISCOPROXI and DISCOLLECTION focus on the integration of partners and the use of data to achieve added value in terms of transport efficiency and other factors. If the cluster ranking is now combined with the achieved results, the derived KPI Value for those five KPIs is at the maximum (see Tables 11 and 12). This shows that the Living Lab representatives have a good understanding of the indicators and possible impacts of the measures.

DISCOBAY

The overall aim of the DISCOBAY project was to demonstrate the integration of multimodal green logistics for the last mile by combining inland waterway transport with cargo bike deliveries in the city of Ghent. The aim of the measure was to help reduce urban congestion and emissions while increasing the efficiency of last-mile delivery. As part of the measure, a collaboration between partners located both in the city centre and outside the city was needed to establish the logistics chains. Within the measure, dedicated work on practical aspects like route optimisation, timing, and cargo handling procedures to ensure the model's viability was elaborated.

In addition, a comparison between green last-mile delivery options and existing traditional models was conducted. The comparative calculations, also taking into consideration use cases for waterway logistics, show great potential for green delivery options regarding the reduction of CO_2 emissions, but also challenges on the cost side. In the following, some results based on a data sample of 388 trips are shown.

- Nearly 65% of the trips could be performed by Green Last Mile (GLM),
- Average 494g CO_2 savings per trip, or 1235 kg in total,
- 10% could be performed at the same or lower price,
- On average, it costs the operator 4.14 euros per trip to outsource to a GLM.

The real-world testing of the concept took place during the Open Day on April 2025 in Ghent. This limited showcase did not provide reliable quantitative data for the evaluation purpose. Nevertheless, it can be stated that the successful demonstration indicated potential to reduce urban congestion and CO_2 emissions as well as to optimise last-mile delivery.
To gain more knowledge about the effects outlined, further work should follow. This could be, for example, an exchange of experiences with other cities on this topic, the review of available research findings related to this kind of delivery, or an expansion of practical trials in the field.

Table 13: KPI Assessment DISCOBAY Ghent

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
23 - Number of partnerships for collaborative logistics	A	0	4	formula not appl.	3		9

DISCOLLECTION

In the following an assessment of decentral data and collaboration aspects is conducted. From this perspective DISCOLLECTION is closely interlinked with DISCOPROXI. When it comes to the data collection, sharing and utilisation, they both use a common data space. Also, the number of partnerships for collaborative logistics are intertwined. For these reasons the analysis incorporates the data for KPI 21, 22 and 23 of both measures.

The results show a great achievement in mobilising partnerships with various logistics partners and stakeholder within the Ghent ecosystem. Beside that the two cities Leuven and Hasselt were added to the data space during the implementation of the DISCOLLECTION measure which offers the opportunity to generate more services and new use cases from the data pool but is also an important aspect of the mutual learning process and a basis to consider other cities beyond Ghent. In the following, the results for the KPIs 21, 22 and 23 are summarised and presented in a tabular.

Table 14: KPI Assessment DISCOLLECTION (including DISCOPROXI data) Ghent

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
21 - Data sources used	A	0	4	Formula not appl.	3		9
22 - Data Utilisation	A	0	10	Formula not appl.	3		9
23 - Number of partnerships for collaborative logistics	A	0	7	Formula not appl.	3		9

Beside this positive evaluation based on the KPIs, it must be noted that there are similar obstacles to those identified by Copenhagen when it comes to resources needed to build the corresponding data infrastructure or the added value and business cases that come with collaborative data sharing approaches. To enable applications based on real-time data, the digital coverage of many cities must be significantly increased. The example of Ghent clearly showed that a great deal of manual work is still required at present to structure and digitise datasets before an implementation. To overcome this hurdle both the data culture to support more advanced processes like data collection and analytics as well as the cities data infrastructures to fully leverage the potential of digital tools and data driven decision-making must change (see also D4.2).

4.4.2. Compliance to SULPs

In 2023 the "Plan Stedelijke Logistiek" of Ghent was approved[11]. It was enhanced by the DISCO project since data sets to support traffic safety in school environments[12] or loading and unloading zones[13] were built up for the open data platform. Furthermore, the Plan includes a variety of other aspects that are well aligned with the DISCO measures implemented in the Living Lab of Ghent and are also in line with the ELTIS SULP guidelines. Some examples are:

- Data collection and data management,
- Partnerships in Research & Development,
- Logistics sector stakeholder development,
- Knowledge sharing with other cities,
- Modal shift bicycle logistics, light electric freight vehicles, and part mobility,

[11] Urban Logistics Plan Ghent (Stedelijke Logistiek): 20230921_DOC_Stad Gent Plan stedelijke logistiek.pdf
[12] https://data.stad.gent/explore/dataset/schooltoegangen-gent/table
[13] https://data.stad.gent/explore/dataset/laad-en-losplaatsen-gent/table

- Zero-emission zone for logistics flows.

Regarding the compliance with SULP assessment, the following results are presented:

Mobility Governance: Services and measures	SULP guidelines		DISCO X		
			DISCOPROXI	DISCOBAY	DISCOLLECTION
	Socio-economic	Reducing traffic impacts in the historical centre	3	3	1
		Increasing livability of urban environment	2	2	1
		Enhancing local economic development	1	2	2
	Commercial	Generate benefits on competetiveness and business	3	1	3
		Optimise logistics operation	3	2	2
		Reduce costs, improve knowledge of delivery cost	3	1	2
	Operational	Improved city access regulation	3	1	2
		Support adoption/use of sustainable vehicles	2	3	1
		Measures supporting transportation operators market	2	3	3
	Technical	Systems to optimise fleet delivery operation	3	2	1
		Systems to optimise logistics operation	3	3	2
		Improved integration of logistics in urban mobility	3	2	2
	State of compliance of technology, service and business model will be scored according to the following general criteria:		2,6	2,1	1,8
	3 = High compliance - no need for adaptation				
	2 = Medium compliance - short time adaptation				
	1 = Low compliance - long time adaptation				

Figure 14: PI compliance to SULP-Guidelines Ghent

Socio-economic perspective

From this perspective, especially the DISCOPROXI, but also the DISCOBAY measure, is compliant with the guidelines. Regarding the guideline “Reduce traffic in historical centre”, the “Urban Access Control” developed in DISCOPROXI enables cities to directly integrate data concerning school zones, time windows, and car-free zones/streets into the logistics planning tools. As a result, logistics planners can optimise their routes and avoid busy and dangerous areas, resulting in fewer vehicles in the historical city centres.

Commercial perspective

With respect to the guideline “Generate benefits on competitiveness & business”, the DISCOLLECTION measure “Smart Data Platform” increased the scalability of cities and logistics stakeholders to share information with each other. As this ecosystem of connected stakeholders increases, the added value of its data sharing capabilities also increases (e.g., more transparency on urban access rules increases the efficiency of a delivery route). To motivate even more players to share data, the economic benefits of such data platforms should be made clear to move from a purely competitive perspective to greater collaboration.

Operational perspective

From an operational perspective, the DISCOBAY measure has strong compliance with some of the guidelines. As part of the DISCOBAY scope, strategic impact assessments were performed on the deliveries driven during the DISCOPROXI Living Lab period. This assessment compared the time, emissions, and cost of the driven deliveries with a list of local, green last-mile alternative transport options (among which was a theoretical waterway transport option). The resulting comparison helps planners outsource their future deliveries to more sustainable last-mile alternatives.

Technical perspective

From this perspective, especially the DISCOPROXI measure has a strong compliance with the guidelines. This is because the developed technical system, consisting of the different elements (App, API, Data space connection, etc.), is directly aiming at optimising fleet delivery and logistics operations as well as improving the integration of logistics in urban mobility.

Regarding the evaluation of KPI 25, Ghent receives a weighting of "3", meaning that there is already a SULP with status "approved". Since the KPI 25 SULP was rated as a C cluster KPI, the resulting KPI Value is 3.

Table 15: KPI 25 - SULP Evaluation Ghent

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
25 - SULP	C	1	1	Formula not appl.	3		3

4.4.3. Contribution to SDGs

In this step the contribution of the DISCO-X measures to the Sustainable Development Goals (SDGs) is evaluated. To be able to make a sufficiently precise statement here, the use of the target level of the SDGs is chosen. The association of KPIs to SDGs as well as the association of KPIs to DISCO-X measures serve as input for the assessment. In correlation with the 7 SDGs that are addressed by the DISCO activities, 11 SDG targets were identified and compared with the four measures implemented in the Ghent Living Lab. The scale used is green = Direct contribution, light green = indirect contribution, no colour = no contribution. In addition, comments were made to clarify the contribution of the respective measure.

Table 16: Contribution to SDGs Ghent

SDG target	DISCO-X		
	DISCOPROXI Addr. KPIs: 1, 2, 3, 5-9, 21-23, 25	DISCOBAY Addr. KPIs: 23, 25	DISCOLLECTION Addr. KPIs: 21, 22, 23, 25
3.9: Reduce the amount of deaths produced by dangerous chemicals and the pollution of the air, water and soil (…) Ass. KPIs: 1, 2, 3, 5, 8-13	Contribution due to CO_2 reduction	In line but impact not assessed	Measure supports this but more from a meta level
8.2: Achieve higher levels of economic productivity (…) Ass. KPIs: 6, 7, 24, 25	Contribution due to optimising traffic flow and cost savings	In line but impact not assessed	Measure supports this but more from a meta level
9.4: (…) upgrade infrastructure and retrofit industries to make them sustainable (…) Ass. KPIs: 17-20			Measure supports retrofit and scalability of cities onboarding on the dataspace
11.6: (…) reduce the adverse per capita environmental impact of cities (…) Ass. KPIs: 8-13	Contribution due to CO_2 reduction	In line but impact not assessed	
11.A: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning Ass. KPIs: 24, 25		In line but impact not assessed	
12.6: Encourage companies (…) to adopt sustainable practices and to integrate sustainability information into their reporting cycle Ass. KPIs: 13, 23	Measure supports this but more indirect	Companies are nudged to opt for more sustainable delivery options	
13.2: Integrate climate change measures into national policies, strategies and planning Ass. KPIs: 25	This measure is aligned with the SULP	This measure is aligned with the SULP, but impact not assessed	This measure is aligned with the SULP
17.16: Enhance the Global Partnership for Sustainable Development (…) Ass. KPIs: 23	In line with achievement of the measure to integrate partner	In line with the approach to build-up new partnerships for logistics chains	In line with achievement of the measure to integrate partner

5. Undertaking the Evaluation in the Starring LLs – Helsinki

5.1. Short Summary Helsinki LL Report (D4.2)

Helsinki's geographical location on a peninsula and its heavy freight traffic from the ports create major logistical challenges that conflict with the city's goals of carbon neutrality and livability. To address this, Helsinki's Living Lab implemented three measures under the DISCO project, guided by the 2020 City Logistics Action Plan. This plan provides a strategic framework and emphasises the need for better data and development, especially for managing loading zones.

In Helsinki LL, three DISCOCURB measures were tested. First, Floating Car Data were purchased and analysed to define optimal locations for new loading zones and provide sound recommendations for logistics planning. Second, movable sensors for real-time monitoring of loading zones were deployed and used for analysing patterns of use and misuse. Moreover, the real-time data was integrated into the Tietorahti map service, used by professional drivers for planning routes. Third, a simulation of a Low Emission Zone was conducted using the collected data, showing a large CO_2 reduction potential.

The DISCOPROXI initiative focused on creating physical nodes for more sustainable last-mile deliveries. After permit challenges required a change of plans, a single, larger multi-actor microhub was established in a shopping center, alongside a test of a "mobile microhub" concept. While the pilot successfully achieved zero tailpipe emissions, it also revealed a conflict where other metrics like traffic flow and delivery success were negatively impacted. These negative effects were directly caused by the longer delivery times and smaller volumes characteristic of delivery robots and cargo bikes.

DISCOLLECTION measure aimed to build the supporting data infrastructure by integrating DISCOCURB's monitoring data into the Urban Freight Dataspace. The goal was to showcase how sharing standardised data could improve city planning. This was achieved successfully, supporting the foundation of Helsinki's future Digital Twin for Mobility and marking the first time urban logistics data was added to the Helsinki Mobility Data Catalogue.

Ultimately, Helsinki's Living Lab demonstrated remarkable adaptability, successfully turning complex urban challenges into valuable, data-driven solutions. The project delivered not just successful pilots but also a tangible legacy of practical tools and crucial insights that empower the city to manage its logistics more intelligently. By laying the foundational groundwork for its Digital Twin and proving the value of a collaborative, multi-faceted approach, Helsinki continues its way to shape the future of sustainable and efficient urban logistics.

5.2. Evaluation set-up and preliminary remarks

Helsinki implemented the DISCOCURB, DISCOPROXI, and DISCOLLECTION measures within the Living Lab. As a basis for the discussion of the evaluation results, a compact summary of the most important characteristics of the measures is given.

Table 17: DISCO-X characteristics Helsinki

	DISCOCURB	DISCOPROXI	DISCOLLECTION
Impact Domain	Agile storage and last-mile distribution	Urban network management	Smart logistics
Typology	Digital	Business	Digital
Implementation approach	1. flexible, battery-based monitoring system for loading zones 2. Loading zone planning tool (FCD) 3. LEZ Emission Simulation	multi-actor microhub & mobile microhub concept, connecting EV fleets and cargo bikes by A2B	Integrating real-time curbside monitoring data from the DISCOCURB to the Urban Freight Data-space and incorporation into the Helsinki Mobility Data Catalog
Technology	1. Camera-based and LiDAR-based 2. FCD 3. Visual analytics platform	Sensor to collect multi-modal traffic data (Telraam); Smart pick-up locker via platform (LMAD), Delivery robots	Urban Freight Dataspace platform
Focus area	Various sites in the city	Ruoholahti shopping center (microhub)	Loading locations
Partners	1. Ramboll Finland, Technolution AB, and Flow Analytics 2. Vianova (FCD) 3. Light commercial dataset and collected LSP data	LSPs, city departments, universities, traffic admins, retailers and residents (planning); A2B, DHL Express, DB Schenker, LMAD, Rolan, (implementation)	IMEC
Data sources used	Sensor data from the monitoring system, Floating Car Data (FCD), infrastructure and demographic data	pedestrian, cycle, LSP data and vehicle traffic data	collected data from the loading zone measure (not real time) + add. open data sets
Evaluation approach	Qualitative and quantitative	Quantitative and qualitative (res. survey)	Qualitative and quantitative
Addressed KPIs	8, 14, 16, 23, 25	1-5, 8-13, 16, 18-20, 23 25, 26 (added)	21, 22, 25

5.3. Assessment of KPI importance

The Helsinki Living Lab, especially in the context of DISCOPROXI, aimed to improve the level of logistics services, increase cooperation and collaboration among stakeholders. Moreover, a clear goal to cut CO_2 emissions was set. This endeavour is reflected in the clustering and ranking of the KPIs from the Living Lab perspective. To illustrate the need for an indicator expressing the satisfaction of residents towards logistics innovations, an additional KPI 26 "Resident satisfaction", was introduced and measured by the Living Lab.

KPI Numl	KPI	Description and data format	Cluster	Rank in Cluster
26	Resident satisfaction (added)	Percentage of recipients who see logistics services sufficient (e.g. Microhub services)	A (very important)	2
8	CO2 Emissions per km	Total kg of CO2 emissions per km	A (very important)	1
9	CO2 Emissions per parcel	Total kg of CO2 emissions per parcel	A (very important)	3
18	Warehouse offer	Average offered space of a warehouses be used as (shared) space for logistics operations	A (very important)	4
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	B (important)	9
12	Cargo bike deliveries	Percentage of the total deliveries performed by cargo bikes	B (important)	1
16	Reliability of Sensors and Cameras	Average time that sensors were not working properly	B (important)	7
11	Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	B (important)	2
4	Delivery time	Average delivery time per route.	B (important)	5
23	Number of partnerships for collaborative logistics	Number private-private and -or public-private partnerships for last mile deliveries	B (important)	4
10	EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	B (important)	3
21	Data sources used	Number of data sources or platforms that are connected to the data space	B (important)	11
19	Lockers volume	Percentage of freight volume delivered through lockers	B (important)	8
25	SULP	Number of locally politically approved SULP or freight logistics plan	B (important)	10
1	Traffic Flow	Total freight kilometers driven per 10000 inh	B (important)	6
20	Microhub Capacity Utilization	Average utilization rate of a parcel locker	B (important)	7
13	Companies electrification	Percentage of companies that operate with cargo bikes	B (important)	1
2	Distance Travelled	Average distance per delivery	C (less important)	2
22	Data Utilization	Number of new/enhanced services utilizing old/new data collected	C (less important)	1
14	Parking fines	Parking fines per 10000 inh	C (less important)	3
5	Delivery Density	Number of deliveries per km	C (less important)	4
15	Space Utilization Efficiency	Average occupancy of parking spaces, vehicles per hour	D (not applicable)	5
17	Transport infra offer	Average offered space of a transport infrastracture to be used as (shared) space for logistics operations	D (not applicable)	1
24	Investment plans	Number of investment logistics plans of local private entities operating in Urban logistics	D (not applicable)	2
6	Cost per parcel	Cost of delivery per km	D (not applicable)	3
7	Operational Cost per day	Total delivery cost	D (not applicable)	4

Figure 15: Clustering and ranking of KPIs Helsinki

5.4. Evaluation of DISCO-X measures

In the following, the DISCO-X measures implemented in the Helsinki Living Lab are evaluated on three different levels. In a first step, a KPI assessment based on the 25 KPIs defined in DISCO is carried out (operational level). This assessment uses the methodology described in chapter 2.1, considering the different perspectives. From a data point of view, qualitative and quantitative information before and after implementation is used. Following up on this, their compliance with the ELTIS SULP Guidelines is reviewed and aligned with the existing Action Plan for City Logistics (local level). In a final step, their contribution to the SDGs at the target level is assessed (global level).

5.4.1. KPI-Assessment

In the following, the three DISCO-X measures implemented in the Helsinki Living Lab are evaluated using the KPIs defined in DISCO before and after implementation. The methodology described in chapter 2.1 is used, considering the different perspectives. In a first step the assessment of the DISCOCURB measures is conducted. In a second step, the DISCOPROXI evaluation results are presented and discussed. Finally, the DISCOLLECTION measure is addressed with focus on data sources and data utilisation.

DISCOCURB

The DISCOCURB evaluation addresses mainly the implementation process of sensors, the simulation of the LEZ as well as the partnerships established for collaborative logistics. The evaluation regarding data collection and sharing (KPI 21 and KPI 22) is part of the DISCOLLECTION measure.

The flexible, battery-based monitoring system for loading zones showed robustness with respect to the sensors used (both camera- as well as LiDAR-based). None of the sensors were down within the implementation period. Regarding the Tietorahti Map service tool based on real-time monitoring with sensors, a survey was conducted among LSP drivers, indicating that the real-time occupancy visualisation generally contributes to making delivery operations smoother. Nevertheless, since the route planning takes place days before the actual delivery, a gap between the requirements of the LSP and the functionality of the service was identified. Out of the companies that completed the survey, approximately 50% found the service useful during delivery operations.

The LEZ simulation, on the other hand, provided valuable insight regarding the LEZ CO_2 emission potential. Since the simulation work was based on a rich data pool including an LCV origin-destination dataset from Bridgestone[14] as well as data from a survey for local LSP (in total 15,000 individual trips were considered), the results are classified as highly valid, showing a potential to reduce CO_2 emissions in the inner city by -307tCO_2e.

Besides that, valuable partnerships for collaborative logistics have been established while working on the implementation of both measures. Unfortunately, no quantitative analysis was made with a focus on the effects on traffic flow, delivery density, or cost aspects. This circumstance does not allow for an evaluation with the goal of improving the freight efficiency in Helsinki.

[14] https://datasolutions.bridgestone-emia.com/vehicle-data/

Table 18: KPI Assessment DISCOCURB Helsinki

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
8 - CO2 Emissions per km [15]	A	307tCO_2e	0	307tCO_2e (maximum reduction potential)	3		9
14 - Parking fines	C	16,3	16.3	0%	-		
16 - Reliability of Sensors and Cameras	B	0	0	0%	3		6
23 - Number of partnerships for collaborative logistics	B	0	4	formula not appl.	3		6

DISCOPROXI

The overall aim of the DISCOPROXI measure was to demonstrate a multifunctional, multi-actor microhub in the urban environment, reducing CO_2 emissions by integrating emission-free delivery methods such as cargo bikes and delivery robots. In addition, more efficient and connected urban logistics operations and viable business and operational models for microhubs, advancing long-term solutions for sustainable last-mile delivery, were the focus.

Regarding the fleet characteristics, data from one provider was made available. This provider used a pool of 14 vehicles, covering electric vehicles, gas-powered vans, and regular vans before the implementation. In the 2025 pilot, only electric vehicles (18) were used. In addition, two delivery robots and three electric cargo bikes were integrated. This combination resulted in zero emissions during the utilisation phase of the fleet (coming from 0,2 kgCO_2/km; BD4: Weighted average of eq.CO_2 emissions per km of vehicles in the pilot area).

As a result of switching to cargo bikes and delivery robots, KPIs related to traffic efficiency changed negatively. The “Distance travelled per delivery” or the “Delivery time per route”, for example, increased by more than a factor of 3.5 in both cases. The biggest negative change is seen in the “Delivery Density”, which stands for the number of deliveries per km, with a decline of around 90%. A look at the baseline data reveals the underlying effects. BD5: “Average number of deliveries per vehicle at each day within the pilot area” decreases from 70 to 10. BD 6: “Average number of parcels

[15] Since the calculations were based on different data sets no values for BD 2: “Total number of freight vehicles operating in the pilot area daily“ and BD 4: “Weighted average of eq.CO2 emissions per km of vehicles in the pilot area” could be determined. Because auf this KPI 8 describes the estimated “Total CO_2 produced within the low-emission zone based on all trips in one year” instead of the “Total CO_2 emissions of the fleet per kilometre”.

per delivery on each day within the pilot area" decreases from 3.6 to 1.6. Both indicators are influencing the Delivery Density to a large extent.

From a technical standpoint, the reliability of sensors and cameras was rated very low based on the quantitative data supplied. In fact, it must be said that, from a set of eight sensors, only one sensor malfunctioned during the pilot. Regarding KPI 19 "Lockers Volume", the quantitative data describes the percentage of freight volume delivered through lockers available in the delivery robots, since the microhub itself did not have lockers. The delivery robots contribute to this indicator; however, the effect is classified as low, which is due to the small number of two robots in the pilot.

Besides the known list of 25 KPIs, Helsinki added a new indicator describing the "Percentage of recipients who see logistics services sufficient (e.g., microhub services). Based on two surveys before and after the implementation, the residents' agreement regarding this criterion was assessed. The results show an increase of +9% linked to the measure activities, although it must be said that the previous value was already very high at over 89%.

In summary, the KPI evaluation shows clearly that there is a conflict of objectives in the optimisation of the various areas. While there are great achievements regarding the CO_2 emission reduction or adoption rate of electric vehicles in the cargo fleet, other indicators like traffic flow, distance travelled, or failed deliveries are affected negatively. Those negative effects are directly linked to the integration of delivery robots and cargo bikes into the delivery fleet since they are characterised by longer average delivery times and smaller delivery volumes.

Table 19: KPI Assessment DISCOPROXI Helsinki

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
1 - Traffic Flow	B	4.85	5.31	+9%	-1		-2
2 - Distance Travelled km / del.	C	0.33	1,52	+361	-3		-3
3 - Failed Deliveries	B	0.35	1	+186%	-3		-6
4 - Delivery time	B	33	158	+379%	-3		-6
5 - Delivery Density	C	10.79	1.05	-90%	-3		-3
8- CO_2 Emissions per km	A	2.80	0.00	-100%	3		9
9 - CO_2 Emissions per parcel	A	0.0186	0.00	-100%	0.007		9
10 - EV Adoption Rate	B	4.4	18	+309%	3		6
11 - Cargo bike adoption rate	B	0	3	formula not appl.	1		2

12 - Cargo bike deliveries	B	0%	13%	formula not appl.	1		2
13- Companies electrification	B	0.0%	50.0%	formula not appl.	3		6
16 - Reliability of Sensors and Cameras	B	0	43200	formula not appl.	-3		-6
18 - Warehouse offer	A	0	250	formula not appl.	3		9
19 - Lockers volume	B	0	4	formula not appl.	2		4
20 - Microhub Capacity Utilisation	B	0%	1%	formula not appl.	1		2
23 - Number of partnerships for collaborative logistics	B	0	2	formula not appl.	2		4
26 - residents satisfaction	A	89.4%	97.8	+9.4%	1		3

From an evaluation perspective, future initiatives should aim to minimise the negative effects of switching to zero emissions logistics methods. For this purpose, further data from the operations of the logistics operators would be valuable to gain an even better understanding of their operations and requirements. Building on this, solution concepts should be developed together with representatives of the city and the operators. In connection to this, lessons learned from D4.2 showed that the task of location planning is crucial for a later success of the microhub. While Helsinki used a bottom-up approach with participating companies' discussions arose regarding a suitable location that is serving everyone. To overcome this challenge a future location identification could be more strategic and data-based taking into consideration factors like traffic, infrastructure, and the city's preferences, followed by an open call for companies with similar interests and parcel flows. In addition, there are also still some open issues regarding the optimal configuration of the operator model. While a single-operator model has been shown to be more profitable and efficient from an economic perspective, it may result in compromises in terms of flexibility and the use of multiple areas.[16]

[16] More lessons learned and recommendations for actions can be found in the Microhub Concept Report: Lessons learned from the Microhub pilot collected in a Concept report - Forum Virium Helsinki

DISCOLLECTION

The DISCOLLECTION measure focusses on the process of collecting and sharing data and takes into consideration the result from DISCOCURB and DISCOLLECTION. Overall, it can be said that significant progress has been made in relation to both KPI 21 and KPI 22 within the framework of the measures.

During the DISCOCURB measure sensor data from the monitoring system, the Floating Car Data (FCD), and additional infrastructure data was generated and utilised for service development and enhancement. While there were 7 different data sources added on the city's data aggregation platform 10 sources we used for the development and enhancement of services required for measures implementation. Within the DISCOPROXI measure on the other hand one more data source was added to the platform and four sources were used for service development.

Table 20: KPI Assessment DISCOLLECTION Helsinki

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
21 - Data sources used	B	0	8	formula not appl.	3		6
22 - Data Utilisation	C	0	14	formula not appl.	3		3

5.4.2. Compliance to SULPs

In the following, the compliance of the three DISCO-X measures implemented in the Living Lab is assessed regarding their compliance with the ELTIS SULP guidelines. As with the other Living Labs, the four perspectives “socio-economic”, “commercial”, “operational”, as well as “technical” are used as a structuring element.

Helsinki follows an Action plan for City Logistics[17] that is well aligned with the carbon neutrality goals of the city, aiming for a carbon-neutral Helsinki by 2035.[18] In addition, a development program for Loading Zone infrastructure is currently being developed and will be finished by the end of 2025. In the SULP compliance assessment, information linked to those documents (already existing and still under development) is also included.

Socio-economic perspective

From this perspective, especially the DISCOCURB measure has a high compliance rating. For example, the measure contributes to a high extent to the guideline "Decreasing traffic impacts in the historical centre". The FCD loading zone analysis and recommendations for new loading zones

[17] Action plan for City Logistics of Helsinki: Helsingin citylogistiikan toimenpideohjelman päivittäminen
[18] The Carbon-neutral Helsinki 2035 Action Plan: Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf

support planning of new zones, which decrease traffic impacts by increasing the loading infrastructure in the city centre. In addition, the real-time monitoring of loading zones and Tietorahti connection provided data to support route planning of drivers, hence decreasing unnecessary driving in the city centre. With respect to the Action Plan for City Logistic, "The development of loading zone infrastructure" is one focus point (3) of the plan.

When it comes to "Increasing Liveability of Urban Environment", DISCOPROXI has a strong compliance rating. The developed microhub and the mobile microhub concept enabled companies to adopt cargo bikes and delivery robots, thus decreasing the number of vans needed in the delivery operations. This, in turn, decreases the number of vans conducting delivery operations/parking in the residential areas, which increases the liveability of the urban areas. The development of microhubs is again a focal point (11) in the Helsinki Action Plan for Citylogistics.

Commercial perspective

Regarding the commercial compliance, again DISCOCURB has received high ratings. This is mainly because the concept has a high potential to generate competitiveness and business, and to optimise logistics operations. Nevertheless, since no quantitative data were provided to assess such effects, this rating must stand the test of time. Also, DISCOPROXI was rated with good compliance, although the KPI assessment showed a gap between sustainability and operational efficiency. The effects identified point to longer delivery times and therefore higher costs, which requires the concept to be optimised.

Operational perspective

From the operational side, DISCOPROXI complies with the support adoption/use of sustainable vehicles. In addition, DISCOCURB as well as DISCOLLECTION are in line with "supporting transportation operators' market" due to the data that is collected, shared, and utilised for the development of logistics services and the optimisation of operators' processes.

Technical perspective

Within the DISCOCURB measure, the loading zone monitoring and Tietorahti integration both produced new real-time occupancy data and integrated it into the system utilised by professional drivers. This enabled the drivers to use real-time occupancy data in their route planning. This helped the drivers to optimise their delivery operations. Regarding DISCOPROXI was rated highly compliant about optimising fleet delivery and logistics operations. As mentioned, the positive achievements of the measure must be considered together with the negative effects regarding the efficiency of the delivery process.

Mobility Governance: Services and measures	SULP guidelines		DISCO X DISCOCURB	DISCOPROXI	DISCOLLECTION
	Socio-economic	Reducing traffic impacts in the historical centre	3	2	3
		Increasing livability of urban environment	3	3	3
		Enhancing local economic development	3	1	1
	Commercial	Generate benefits on competetiveness and business	3	2	1
		Optimise logistics operation	3	3	3
		Reduce costs, improve knowledge of delivery cost	3	1	3
	Operational	Improved city access regulation	x	x	x
		Support adoption/use of sustainable vehicles	1	3	1
		Measures supporting transportation operators market	3	2	3
	Technical	Systems to optimise fleet delivery operation	3	3	1
		Systems to optimise logistics operation	3	3	1
		Improved integration of logistics in urban mobility	3	1	1
	State of compliance of technology, service and business model will be scored according to the following general criteria:		2,8	2,2	1,9
	3 = High compliance - no need for adaptation				
	2 = Medium compliance - short time adaptation				
	1 = Low compliance - long time adaptation				

Figure 16: PI compliance to SULP-Guidelines Helsinki

Regarding the evaluation of KPI 25, Helsinki receives a weighting of “3”, meaning that there is already a Plan with status “approved”. Since the KPI 25 SULP was rated as a B cluster KPI, the resulting KPI Value is 6.

Table 21: KPI 25 - SULP Evaluation Helsinki

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
25 - SULP	B	1	1	Formula not appl.	3		6

5.4.3. Contribution to SDGs

In this step, the contribution of the DISCO-X measures to the Sustainable Development Goals (SDGs) is evaluated. To be able to make a sufficiently precise statement here, the use of the target level of the SDGs is chosen. The association of KPIs to SDGs as well as the association of KPIs to DISCO-X measures, serve as input for the assessment. In correlation with the 7 SDGs that are addressed by the DISCO activities, 11 SDG targets were identified and compared with the four measures implemented in the Helsinki Living Lab. The scale used is green = Direct contribution, light green = indirect contribution, no colour = no contribution. In addition, comments were made to clarify the contribution of the respective measure.

Table 22: Contribution to SDGs Helsinki

SDG target	DISCO-X		
	DISCOCURB Addr. KPIs: 8, 14, 16, 23, 25	DISCOPROXI Addr. KPIs: 1-5, 8-13, 16, 18-20, 23, 25, 26 (added)	DISCOLLECTION Addr. KPIs: 21, 22, 25
3.9: Reduce the amount of deaths produced by dangerous chemicals and the pollution of the air, water and soil (…) Ass. KPIs: 1, 2, 3, 5, 8-13	Contribution if LEZ concept is rolled out	Contribution due to CO_2 reduction	
8.2: Achieve higher levels of economic productivity (…) Ass. KPIs: 6, 7, 24, 25	Measure contributes to a more efficient logistics process		Measure contributes indirectly due to data utilisation
8.4: Improve (…) global resource efficiency in con-sumption and production (…) Ass. KPIs: 1, 2, 5, 10		Contribution due to CO_2 reduction and switching to sustainable modes of delivery	
9.1: Develop quality, reliable, sustainable and resilient infrastructure (…) Ass. KPIs: 1, 5, 15, 17, 18, 20	Contribution due to robust sensor infrastructure and other technologies utilised		
9.4: (…) upgrade infrastructure and retrofit industries to make them sustainable (…) Ass. KPIs: 17-20	Contribution due to robust sensor infrastructure and other technologies utilised		Measure contributes due to building up digital infrastructure capabilities
11.3: (…) enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management (…) Ass. KPIs: 11, 19, 20	Measure contributes to sustainable urbanisation due to data-driven approach	Microhub concept contributes to sustainable urbanisation and includes residents needs	
11.A: Support positive economic, social and environmental links between urban,	Measure allows for new approaches in		

peri-urban and rural areas by strengthening national and regional development planning Ass. KPIs: 24, 25	development planning due to extensive data utilisation		
12.6: Encourage companies (…) to adopt sustainable practices and to integrate sustainability information into their reporting cycle Ass. KPIs: 13, 23		Contributing due to clear focus on reducing CO_2 emissions to zero with the partners	Contribution due to Urban Freight Dataspace
13.2: Integrate climate change measures into national policies, strategies and planning Ass. KPIs: 25	Serves as input for development program for Loading Zone infrastructure	Direct link to Action plan for City Logistics	Serves as input for development program for Loading Zone infrastructure
17.16: Enhance the Global Partnership for Sustainable Development (…) Ass. KPIs: 23		Contribution due to building up new collaborative logistics concepts	Measure contributes through utilisation and sharing of data and experiences

6. Undertaking the Evaluation in the Starring LLs – Thessaloniki

6.1. Short Summary Thessaloniki LL Report (D4.2)

The Thessaloniki Living Lab aimed to address the city's sustainability goals for a CO_2-neutral future by 2030 through measures designed to reduce delivery vehicle traffic, ease congestion, and improve urban quality of life. The core strategy was to develop a new, cooperative business model integrating urban freight data with spatial planning, leveraging underutilised spaces and assets to create a more efficient, Physical Internet-inspired logistics ecosystem. Four measures were deployed to achieve this.

The DISCOPROXI measure tackled the uncontrolled growth of private smart lockers by demonstrating the value of a shared, regulated network. By creating a dynamic database of all existing lockers and using a facility location tool, a compelling, evidence-based case was presented to the Municipality, which led to the approval and installation of pilot lockers in public spaces. The measure also enhanced the WareM&O platform (a legacy Warehouse as a Service platform developed by HIT/CERTH) with blockchain-enabled smart contracts to facilitate transparent and secure agreements for temporary logistics space.

DISCOESTATE focused on repurposing underutilised buildings at the TIF HELEXPO Exhibition Centre into a multipurpose logistics hub. A major achievement was the relocation of ACS Courier's main depot from the congested historical center to the TIF HELEXPO premises, an agreement formalised through the WareM&O platform. This was supplemented by infrastructure upgrades, including RFID systems and cameras, to ensure seamless 24/7 logistics operations.

The DISCOBAY measure created an integrated space availability observatory by mapping underused transport infrastructure near the city center, including assets from the port and railway operator (GaiaOSE). These potential "freight hotels" were integrated into the city's dataspace. A simulation platform was developed to test consolidation scenarios, demonstrating that a shared operations model could reduce total van kilometers significantly and, thus, cut emissions.

Finally, DISCOLLECTION is the measure where Thessaloniki made proof of the concept of a local Urban Freight Dataspace[19] to serve as the digital backbone for evidence-based planning. The platform successfully integrated data from all other Thessaloniki measures, city systems like GIS, and extensive stakeholder surveys. This provided municipal planners with interactive dashboards

[19] https://uldthess.imet.gr/

and a holistic view of freight dynamics, leading to the approval of a new loading/unloading time regulation for the city.

Together, the Thessaloniki measures provided a compelling proof of concept for an integrated approach where digital platforms and data analytics directly enable transformative physical changes and policy advancements, laying a strong foundation for the city's Sustainable Urban Logistics Plan (SULP).

6.2. Evaluation set-up and preliminary remarks

In the Thessaloniki Living Lab, four distinct DISCO-X measures were implemented to address the city's urban logistics challenges. The following table provides a compact summary of the characteristics of each of these measures.

Table 23: DISCO-X characteristics Thessaloniki

	DISCOPROXI	DISCOSTATE	DISCOBAY	DISCOLLECTION
Impact Domain	Agile storage and last-mile distribution	Agile storage and last-mile distribution	Urban network management	Smart logistics
Typology	Business	Physical	Digital	Digital
Implementation approach	Real-world pilot and proof of concept	Real-world pilot	Simulation and GIS Mapping	Proof of concept and data integration
Supporting Technology	Blockchain, Facility location tool	WareM&O Platform, RFID-based entry systems	Simulation platform, GIS mapping tools	Urban Freight Dataspace, Interactive Dashboards, Voronoi diagrams
Focus area	Public spaces in Thessaloniki	TIF HELEXPO & historical city center	Peri-urban area of Thessaloniki's historical center	Thessaloniki's historical and central area
Partners	CERTH/HIT, Municipality of Thessaloniki, ACS Courier, TIF-HELEXPO	CERTH/HIT, Municipality of Thessaloniki, TIF HELEXPO, ACS Courier, FM Logistic	CERTH/HIT, Municipality of Thessaloniki, TIF HELEXPO, ACS, GaiaOSE	CERTH/HIT, Municipality of Thessaloniki, ACS Courier, TIF-HELEXPO, Local Thessaloniki Chamber of Commerce & Industry
Data sources used	User questionnaires, ACS' courier deliveries data,	Building Management System (BMS) data, Warehouse	GIS data, real operational data from logistics operators for	Freight surveys, recorded vehicle classification data, real operational

	demand pattern analysis	Management System (WMS) data, real-time occupancy data	simulation calibration, ACS' data	data from logistics operators from Surveys and Open Days events
Evaluation approach	Holistic assessment based on real-world data and simulations	Holistic assessment based on real-world data and simulations	Holistic assessment based on real-world data and simulations	Holistic assessment based on real-world data and simulations
Addressed KPIs	1,2, 4, 7, 8, 17, 18, 24, 25	1, 4, 8, 25	1,16, 21, 22, 23, 25	1, 2, 3, 4, 5, 6, 7, 8, 9, 19, 20, 23, 24, 25

6.3. Assessment of KPI importance

Thessaloniki's main goal is to build a solid foundation for its future Sustainable Urban Logistics Plan, and the KPI assessment reflects this exact practical approach. Rather than focusing on a single area, the pilot tested a mix of new and legacy Physical Internet-driven solutions to see how they work in the real world. This meant prioritising indicators that could measure the actual performance of our new shared assets, like the public smart lockers and the repurposed logistics hub at TIF-HELEXPO. At the same time, we needed to track how our new data-sharing tools, like the Urban Freight Dataspace, were helping to improve collaboration and decision-making among our local partners.

KPI Numl	KPI	Description and data format	Cluster	Rank in Cluster
2	Distance Travelled	Average distance per delivery	A (very important)	5
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	A (very important)	3
4	Delivery time	Average delivery time per route	A (very important)	7
5	Delivery Density	Number of deliveries per km	A (very important)	6
7	Operational Cost per day	Total delivery cost	A (very important)	8
19	Lockers volume	Percentage of freight volume delivered through lockers	A (very important)	1
20	Microhub Capacity Utilization	Average utilization rate of a parcel locker	A (very important)	2
22	Data Utilization	Number of new/enhanced services utilizing old/new data collected	A (very important)	4
8	CO2 Emissions per km	Total kg of CO2 emissions per km	B (important)	5
9	CO2 Emissions per parcel	Total kg of CO2 emissions per parcel	B (important)	4
17	Transport infra offer	Average offered space of a transport infrastracture to be used as (shared) space for logistics operations	B (important)	2
21	Data sources used	Number of data sources or platforms that are connected to the data space	B (important)	1
23	Number of partnerships for collaborative logistics	Number private-private and -or public-private partnerships for last mile deliveries	B (important)	3
1	Traffic Flow	Total freight kilometers driven per 10000 inh	C (less important)	5
6	Cost per parcel	Cost of delivery per km	C (less important)	3
16	Reliability of Sensors and Cameras	Average time that sensors were not working properly	C (less important)	2
18	Warehouse offer	Average offered space of a warehouses be used as (shared) space for logistics operations	C (less important)	1
24	Investment plans	Number of investment logistics plans of local private entities operating in Urban logistics	C (less important)	4
25	SULP	Number of locally politically approved SULP or freight logistics plan	C (less important)	6
10	EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	D (not applicable)	
11	Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	D (not applicable)	
12	Cargo bike deliveries	Percentage of the total deliveries performed by cargo bikes	D (not applicable)	
13	Companies electrification	Percentage of companies that operate with cargo bikes	D (not applicable)	
14	Parking fines	Parking fines per 10000 inh	D (not applicable)	
15	Space Utilization Efficiency	Average occupancy of parking spaces	D (not applicable)	

Figure 17: Clustering and ranking of KPIs Thessaloniki

6.4. Evaluation of DISCO-X measures

In the following, the four DISCO-X measures implemented in the Thessaloniki Living Lab are evaluated on three different levels. In a first step, a KPI assessment based on the 25 KPIs defined in DISCO is carried out (operational level). This assessment uses the methodology described in Chapter

2.1, considering the different perspectives. From a data point of view, qualitative and quantitative information before and after implementation is used. Following up on this, their compliance with the ELTIS SULP Guidelines is reviewed and aligned with existing or developing SULPS or action plans where available (local level). In a final step, their contribution to the SDGs at the target level is assessed (global level).

6.4.1. KPI-Assessment

The impact assessment for the Thessaloniki Living Lab employs a unique methodological approach that distinguishes it from other evaluations. While many assessments analyse individual measures in isolation, which is a suitable method when solutions are independent or deployed in different areas, Thessaloniki's quantitative KPI assessment was performed holistically. This means that while each of the four measures was assessed qualitatively, their combined impact was evaluated as a single, integrated system. This systemic approach was essential because the Thessaloniki measures were designed to be deeply interconnected and synergistic; the physical changes from shared lockers (DISCOPROXI) and the repurposed logistics hub (DISCOESTATE) were directly enabled and monitored by the digital infrastructure of the Urban Freight Dataspace (DISCOLLECTION) and the infrastructure mapping (DISCOBAY). By evaluating them together, the assessment captures the true, cumulative effect of creating a cohesive logistics ecosystem, providing a more comprehensive and realistic picture of the transformation's overall impact rather than just the sum of its isolated parts.

6.4.1.1. Qualitative assessment

DISCOPROXI

This measure aimed to regulate the uncontrolled growth of smart locker installations in Thessaloniki by establishing a shared, regulated network, primarily in public spaces and low-traffic zones, and by enhancing the WareM&O platform with blockchain-enabled smart contracts for transparent space utilisation agreements. The implementation initiated with identifying the uncontrolled smart locker growth as a threat to public spaces, prompting the need for a shared, regulated locker network in low-traffic zones. The Logistics Real Estate Database (DISCOBAY) was established and its Smart Locker section continuously tracked locker locations across the city. This dynamic database creation facilitated the city's recognition of smart locker distribution. CERTH/HIT's facility location tool was deployed to analyse demand patterns, and consultations were held with the Municipality of Thessaloniki and ACS Courier to confirm strategic pilot locations. Based on these insights and feedback from a user questionnaire to gather performance data on perceptions of urban freight transport measures, a compelling argument was created for the City Council of Thessaloniki to initiate piloting activities for public space smart lockers. Pilot installations included two smart lockers in public spaces and three in semi-public areas, all designed to incorporate 24-hour access. Concurrently, the WareM&O platform was enhanced with blockchain technology to enable secure and transparent smart contracts among warehouse owners, courier companies, and other stakeholders, ensuring secure and transparent agreements. Throughout the process, continuous feedback was gathered, and user questionnaire data was systematically analysed to support the project's KPIs.

DISCOESTATE

This measure focused on demonstrating the temporary and multipurpose use of strategically positioned buildings at the TIF HELEXPO Exhibition Centre as a logistics hub during non-event periods, with the primary goal of reducing congestion in Thessaloniki's historical centre. The implementation initiated with recognizing the opportunity to repurpose TIF-HELEXPO’s pavilions, shops, and offices for logistics operations when events were not in session, aiming to reduce congestion in Thessaloniki’s historical centre and ease ACS's operations in its central historical centre location. Stakeholder collaboration was key, with discussions convened among the Thessaloniki Municipality, TIF, ACS, and CERTH/HIT to identify underutilised peri-urban transport infrastructures as potential consolidation centres.

The WareM&O platform was then upgraded with e-signature capabilities and an enriched data model to meet DISCOESTATE’s needs, enabling digital contracts, real-time occupancy tracking, and standardised data exchange. Negotiations between TIF-HELEXPO and ACS led to a collaborative agreement, which was finalised through the WareM&O platform’s e-signature feature. This agreement clarified operational responsibilities and cost-sharing for leasing exhibition spaces as logistics hubs. Following this, ACS moved its primary shop from the historical centre to TIF-HELEXPO, easing city-centre congestion.

To ensure 24/7 vehicle access and on-site logistics operations, TIF-HELEXPO implemented crucial infrastructure upgrades, including articulated barriers, cameras, and RFID-based entry systems, addressing challenges such as mismatched expo hours and restricted access. Simultaneously, TIF further developed its Building Management System for updating pavilion/warehouse availabilities to dynamically exchange availability data with the WareM&O platform. FM Logistic followed a similar approach with their WMS and a BigQuery-powered middleware to dynamically update warehouse capacities. This facilitated the demonstration phase and KPI tracking, with regular feedback loops and structured decision checkpoints helping to overcome technical and coordination challenges. Data on real-time availability and occupancy of the repurposed spaces was continuously collected, along with key operational KPIs.

DISCOBAY

This measure aimed to identify and map underused infrastructure to be repurposed as "freight hotels" across Thessaloniki, establishing an integrated space availability observatory. The implementation initiated with recognising the challenge that long travel distances from storage facilities (often over 60 km) contributed to increased traffic and higher CO_2 emissions, impacting Thessaloniki's historical centre. Stakeholder engagement was crucial, with discussions convened among the Thessaloniki Municipality, TIF HELEXPO, and ACS to identify underutilised peri-urban transport infrastructures as potential consolidation centres, based on the definition of DISCOBAY by

Erasmus UPT. A detailed mapping and survey of transport infrastructures near the historic centre was conducted to pinpoint strategic assets capable of operating as logistics infrastructure.
Selected sites—managed by GaiaOSE (railway estate), TIF Helexpo, and Thessaloniki Port—were integrated into a decentralised urban freight dataspace for real-time monitoring and connected with the WareM&O platform, allowing for direct available space booking. A simulation platform was then deployed to test different operational scenarios, comparing the performance of a single consolidation centre with a shared operation model. This included:

- **Scenario 0:** Ex-Ante operations (2023) This baseline scenario represents the existing situation. It is characterised by a central depot located within the city centre, a small network of only 3 parcel lockers, and a limited percentage (6%) of total parcels being delivered to these lockers.
- **Scenario 1:** Ex-Post operations (2025) This scenario reflects the envisioned future state after the implementation of DISCO measures. It features the central depot reallocated to TIF-HELEXPO, situated at the boundaries of the city centre, a substantially larger network of 35 parcel lockers, and a significant increase in deliveries directed to parcel lockers (25% of total deliveries).

Data collected included available transport infrastructure details, such as location and capacity, and comprehensive outcomes from these simulation scenarios, including total kilometres, fleet composition (vans and trucks), and detailed route indices.

DISCOLLECTION

This measure established a proof-of-concept for a local Urban Freight dataspace in Thessaloniki, with the Municipality and CERTH/HIT serving as trustees and data managers. The overarching goal was to gather, analyse, and share urban freight data to support informed decision-making and optimise urban freight flows. The implementation began with recognising the need for comprehensive urban freight data due to high cargo volumes and frequent freight trips within Thessaloniki’s central area. A local Urban Freight dataspace architecture (uldthess.imet.gr) was defined with three primary user pathways: "Manage Logistics Operations", "Plan Infrastructure", and "Access Data & Reports".

The dataspace was seamlessly connected to existing local systems, including the WareM&O platforms (from DISCOESTATE and DISCOPROXI), logistics company directories, the Municipality GIS, and the Logistics Real Estate Database from DISCOBAY. These local platforms' integration aggregated data on freight vehicle activity, warehouse availability, and operational hotspots, providing a comprehensive citywide overview of logistics flows. Data collection and visualization were enhanced by incorporating survey data from Open Day events and CERTH/HIT's vehicle classification measurements at the borders of the historical centre. These insights were visualised in the "Who is Who" registry and "See the city in numbers" dashboard, complete with georeferenced district data. The user interface was further upgraded with interactive maps and real-time dashboards, giving municipal planners the ability to pinpoint congestion hotspots, allocate loading bays, and forecast demand. A Voronoi diagram option was also introduced during this development step. Finally, CERTH/HIT prepared detailed documentation for stakeholders to dynamically retrieve data, facilitating integration with their existing systems.

6.4.1.2. Pilot evaluation

For the Thessaloniki Living Lab, the pilot evaluation was conducted holistically across all KPIs due to all measures taking place within the same pilot area and timeframe. The evaluation procedure involved a multi-faceted approach to KPI collection and calculation. Some KPIs were directly collected by the involved actors, such as data on parcel deliveries or operational costs. Other KPIs were calculated based on this real-world data provided by the actors. Additionally, a significant portion of the KPIs were derived from simulations conducted by CERTH/HIT. These simulations were meticulously set up and calibrated using real operational data from ACS, such as shipment details, and were used to test various "what-if" scenarios, enabling the projection of impacts under different conditions. This comprehensive approach allowed for a unified assessment of the integrated impact of all DISCO-X measures in Thessaloniki.

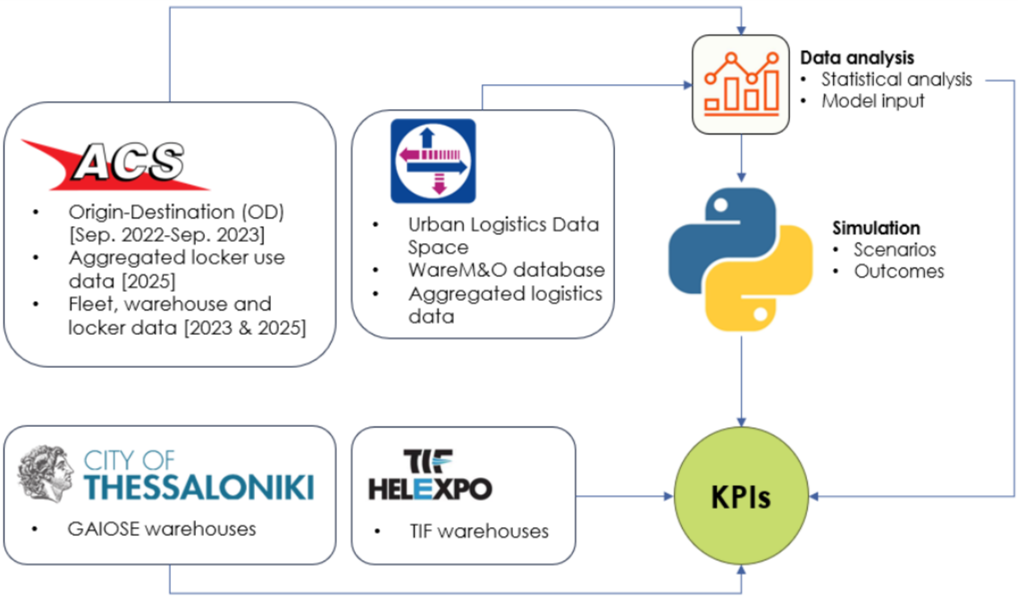

Figure 18: Overall approach for the impact assessment of Thessaloniki's LL

Data Collection and Assessment Methodology

For the impact assessment, detailed Origin-Destination (OD) data for courier deliveries, including both home and locker deliveries, were obtained directly from ACS company for the period of September 2022 to September 2023, along with aggregated courier data collected after pilot implementation. This primary source also provided crucial information about ACS's fleet composition, including fleet size and vehicle types, and detailed warehouse operational data encompassing the number of warehouses, staffing levels, rental costs, shift hours, and employee costs per hour. Complementing this operational data, information about the transport infrastructure within the city was collected by Thessaloniki's Urban Logistics Data Space, including details on size, location, and availability of infrastructure elements. Furthermore, data about the warehouse space supply in Thessaloniki was retrieved from the WareM&O database, which integrates information from diverse sources, including the TIF system, the Spitogatos real estate platform, and private warehouse owners who proactively registered their available spaces.

The assessment methodology adopted a multi-faceted approach, integrating various data sources and analytical tools to derive KPIs and assess operational changes. Fleet type information provided by ACS Logistics was critical for standardising variables across the dataset, enabling the precise calculation of equivalent CO_2 emissions ($eqCO_2$) per vehicle based on either kilometres driven or litres of fuel consumed. The extensive analytical data from ACS courier deliveries were meticulously analysed to derive a range of operational variables, including deliveries per day, average kilometres travelled per vehicle, and successful first-attempt delivery rates. Both the standardised fleet details and the analysed courier data were then synergistically utilised to calculate the comprehensive daily operational costs of the company, encompassing key expenditures such as fuel, labour costs (derived from employee cost per hour and shift hours), and warehouse rental expenses.

All this integrated and calculated data served as the foundation for developing a sophisticated Python simulation model. This model was configured with initial conditions encompassing detailed information about warehouses such as their location, size, and total number, as well as granular data on vehicles including total number, type, and stops per route. The configured model was instrumental in simulating various scenarios and projecting their impacts on relevant KPIs, particularly for metrics that could not be calculated directly from operational data alone.

In parallel, the local Thessaloniki Urban Logistics Dataspace was thoroughly analysed to calculate the volume of data transferred to the federated urban freight dataspace, demonstrating interoperability and data exchange capabilities. This same dataspace was instrumental in identifying available transport infrastructure for warehousing within Thessaloniki. The WareM&O database underwent detailed analysis to identify available space for shared warehouse operations within the city, providing a comprehensive overview of available logistics real estate through its integration of data from multiple sources.

Scenarios Setup, Calibration and Data Preparation

Two distinct scenarios were analysed to evaluate the impact of the implemented measures, delineating the operational landscape before and after the interventions in Thessaloniki.

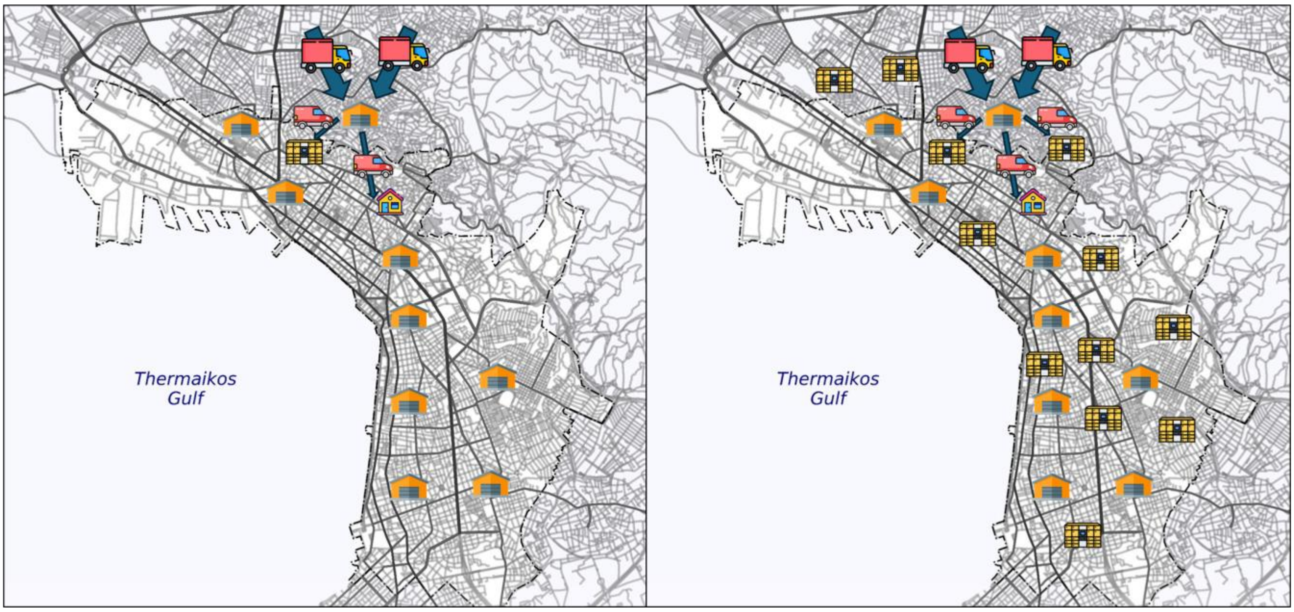

Figure 19: Visual representation of Thessaloniki current situation scenario (S1)

- **Baseline Scenario (S0)** represents the ex-ante operations in 2023, depicting the initial situation prior to the implementation of the DISCO-X measures. In this baseline scenario, the logistics operations were characterised by a fleet of 80 vehicles with the central depot located within the historical city center. The city operated with a small network consisting of only 3 parcel lockers, and data analysis of Origin-Destination information revealed that merely 6% of total parcels were delivered to these lockers.
- **Current Situation (S1)** portrays the ex-post operations in 2025, representing the projected operational state after the implementation of the DISCO-X measures. A key transformation in this scenario is the strategic reallocation of the central depot, with ACS moving its central depot from the historical city center to the boundaries of the city, now located within the TIF-HELEXPO premises utilising a rented warehouse through the WareM&O platform. The city benefits from a substantially expanded network of 35 parcel lockers, and reflecting the insights gained from post-implementation usage patterns, a significant proportion of 25% of all deliveries are now directed to these parcel lockers.

The results of the data analysis ended up to specific variables that can be used for the calibration of the model in order to best fit real-world data. These variables included a 5-minute delay per stop, 4,170 daily stops, petrol pricing at €1.768/liter, diesel at €1.578/liter, and LCV driver costs at €8/hour. CO_2 conversion factors were established at 2.347 kg/liter for petrol and 2.690 kg/liter for diesel. Depot operations involved 7 depots with 3 workers per depot, €1,500/month rent, and €5/hour working costs for 12-hour shifts. The fleet composition resulted in a weighted average of 0.238 kgCO_2/km.

Model outcomes for this baseline scenario demonstrated 772.63 total kilometers traveled, an average of 9.66 km per vehicle, 52.12 deliveries per vehicle, 24.28 moving minutes per vehicle, and an 82.14% successful first-attempt delivery rate. The daily costs calculated for Scenario 0 amounted to €204 for fuel, €4,299 for labor, and €457 for building rental.

For the ex-post operations in Scenario 1, where the number of lockers was substantially increased, the central depot was reallocated to the city boundaries, and the preference for parcel locker delivery significantly increased to 25%, the model outcomes project a total of 659.66 km traveled with an average of 9.99 km per vehicle. The average deliveries per vehicle is projected to be 63.18, and the average moving minutes per vehicle is estimated at 24.90 minutes. The successful first-attempt delivery rate is projected to improve to 85.75%, while the daily costs are projected to be €174 for fuel, €4,259 for labor, and €457 for building rental.

Beyond the direct model outcomes, other crucial data points informed the comprehensive KPI calculations, reflecting significant progress from the DISCO-X measures. The transport infrastructure database initially showed no existing infrastructure, but after DISCOBAY implementation, approximately 4,500 sqm were included. Similarly, the platform registered no available warehouse space within the city center at the project's onset, while about 17,000 sqm were subsequently included and made available following DISCOESTATE implementation. The Thessaloniki Urban Logistics Dataspace, initially connected to no external sources since it was developed during the project, is now linked with seven different data sources including the WareM&O platform, local real estate data, FM logistics, locker location data, live satisfaction surveys, on-demand logistics data from ACS, and OSM commercial activities. During the DISCO implementation, two new partnerships were established including a public-private collaboration between Thessaloniki City and ACS for locker installations in public spaces, and a private-private partnership for integrating TIF premises into the WareM&O platform. Leveraging DISCOLLECTION outcomes, the City of Thessaloniki approved a new loading/unloading time regulation, marking one logistics plan politically approved in the city.

Results & Discussion

The evaluation of the Thessaloniki Living Lab's DISCO-X measures, comparing Scenario 0 (ex-ante operations in 2023) with Scenario 1 (ex-post operations in 2025), reveals a multifaceted impact across various key performance indicators. The assessment demonstrates significant positive shifts towards more sustainable and efficient urban logistics operations.

Table 24: Thessaloniki pilot KPI Assessment

KPI	Cluster	KPI (before)	KPI (after)	KPI Value Change	Weight	Qualitative rating	KPI Value (integrated)
1 - Traffic Flow	C	26	22	-14.62%	2		2
2 - Distance Travelled	A	0.19	0.16	-14.63%	2		6
3 - Failed Deliveries	A	17.9%	14.3%	-20.21%	2		6
4 - Delivery time	A	24	25	2.55%	-1		-3

5 - Delivery Density	A	3.52	6.05	72.11%	3		9
6 - Cost per parcel	C	6.42	7.41	15.48%	-2		-2
7 - Operational Cost per day	A	€ 4,959	€ 4,890	-1.40%	1		3
8 - CO_2 Emissions per km	B	19.04	15.71	-17.50%	2		4
9 - CO_2 Emissions per parcel	B	0.07	0.04	-41.90%	3		6
17 - Transport infra offer	B	-	4,415	-	3		6
18 - Warehouse offer	C	-	16,819	-	3		3
19 - Lockers Volume	A	6%	25%	19.00%	2		6
20 - Microhub Capacity Utilisation	A	21%	34%	12.99%	2		6
21 - Data sources used	B	1	7	-	3		6
22 - Data Utilisation	A	1	3	-	3		9
23 - Number of partnerships for collaborative logistics	B	1	2	-	2		4
24 - Investment plans	C	0	1	-	1		1
25 - SULP	C	0	1	-	3		3

Several KPIs demonstrate significant positive shifts towards more sustainable and efficient urban logistics:

- Traffic Flow (KPI 1) and Distance Travelled (KPI 2) both saw notable reductions. Traffic flow decreased by -14.62% (from 26 to 22 units), and average distance travelled decreased by -14.63% (from 0.19 to 0.16 units). These improvements are directly attributable to the strategic relocation of the central depot from the historical city centre to the TIF-HELEXPO boundaries and the increased preference for parcel locker deliveries. By reducing vehicle presence and optimising routes within dense urban areas, the measures effectively alleviate congestion and overall travel burden.

- Failed Deliveries (KPI 3) showed a significant positive change, decreasing by -20.21% (from 17.9% to 14.3%). This improvement is a direct benefit of the expanded network of 35 parcel lockers and the increased preference for locker-based deliveries, as parcel lockers offer secure and accessible delivery points, reducing the likelihood of missed deliveries.

- Delivery Density (KPI 5) experienced a substantial increase of +72.11% (from 3.52 to 6.05 units). This indicates a more efficient use of vehicle capacity and routes, as more deliveries are completed per kilometre, largely driven by the optimised last-mile operations facilitated by the expanded locker network and depot relocation.

- Operational Cost per day (KPI 7) showed a slight but positive reduction of -1.40% (from €4,959 to €4,890). This marginal decrease indicates a general positive trend in overall operational efficiency, although as observed in the detailed cost breakdown, changes in fuel consumption (due to reduced kilometres) represent only a small proportion of the total cost, which is largely influenced by static parameters like building renting and labour.

- CO_2 Emissions per km (KPI 8) surprisingly recorded a -17.50% reduction (from 19.04 to 15.71 units), and CO_2 Emissions per parcel (KPI 9) achieved a significant -41.90% reduction (from 0.07 to 0.04 units). While the direct CO_2 emissions per kilometre related to the fleet's engine type and composition remained static (as fleet composition did not change between scenarios), this observed reduction in overall CO_2 Emissions per km (KPI 8) and per parcel (KPI 9) is attributed to the reduced total kilometres travelled and the improved delivery density. The model captures the positive effect of fewer kilometres driven overall, even if the per-kilometre emission factor of individual vehicles remains constant.
- The impact on Lockers Volume (KPI 19) is highly positive, increasing by 19 percentage points (from 6% to 25%). This directly reflects the successful expansion of the parcel locker network and the increased preference for their use by customers. Correspondingly, Microhub Capacity Utilisation (KPI 20) improved by 12.99% (from 21% to 34%), indicating a more efficient use of shared logistics spaces.
- The expansion of digital infrastructure and collaboration is clearly reflected in several KPIs. The Number of Data sources used (KPI 21) increased significantly from 1 to 7, and Data Utilisation (KPI 22) improved from 1 to 3. This demonstrates the successful integration of diverse data streams into the Thessaloniki Urban Logistics Dataspace. The Number of partnerships for collaborative logistics (KPI 23) also increased from 1 to 2, signifying stronger public-private collaboration, including the partnership for public locker installations and the integration of TIF premises into WareM&O.
- Finally, the project's strategic impact is highlighted by the increase in Investment plans (KPI 24) from 0 to 1 and SULP (KPI 25) from 0 to 1, as the City of Thessaloniki approved a new loading/unloading time regulation based on DISCOLLECTION outcomes.

However, some areas require further attention. Delivery time (KPI 4) showed a slight increase of +2.55% (from 24 to 25 minutes). This marginal increase might be attributed to the adjusted routes to the new depot location or the logistics of servicing an expanded, potentially more dispersed, locker network. Similarly, Cost per parcel (KPI 6) experienced an increase of +15.48% (from €6.42 to €7.41). While fuel costs saw some reduction due to decreased kilometres, the predominant components of last-mile delivery costs, such as labour and fixed building renting expenses, remained significant proportions of the total, leading to an overall per-parcel cost increase in this model run. Lastly, KPIs like Reliability of Sensors and Cameras (KPI 16), Transport infra offer (KPI 17), and Warehouse offer (KPI 18) were not directly quantifiable with a percentage change from the initial data, often starting from a baseline of zero, but show clear positive gains in available resources.

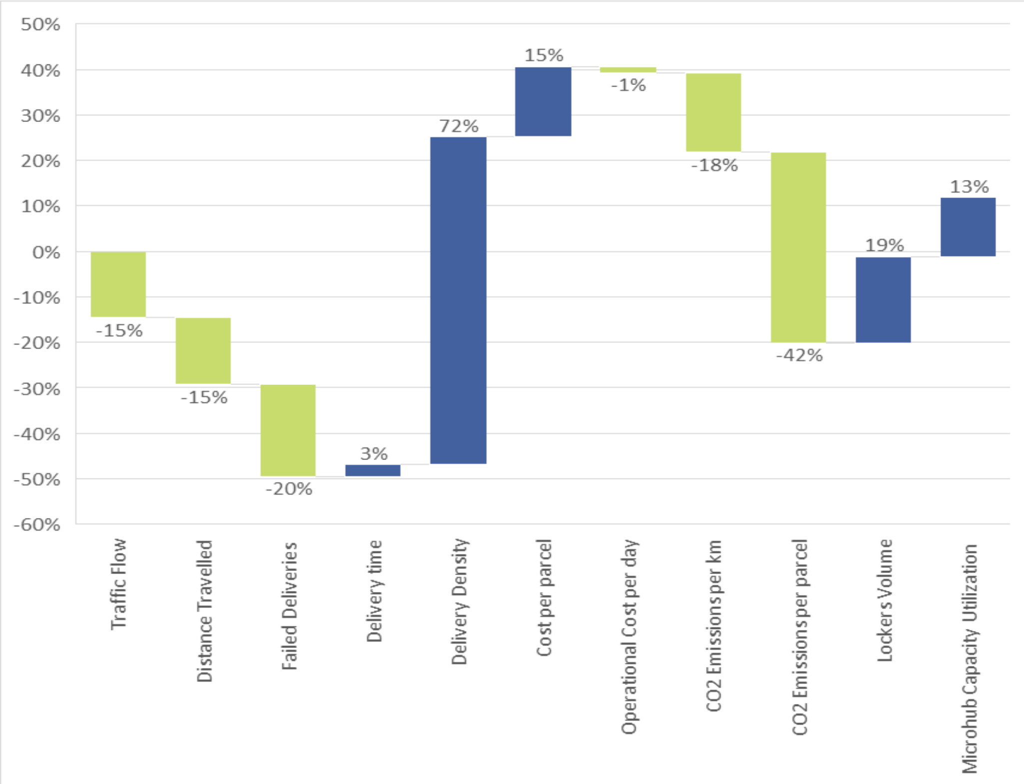

Figure 20: Impact assessment of the most interesting KPIs for the pilot of Thessaloniki

In conclusion, the assessment demonstrates that the DISCO-X measures in Thessaloniki, particularly through the depot reallocation, expanded locker network, and enhanced data infrastructure, are significant levers for reorganising urban logistics. While optimising for CO_2 reduction and delivery efficiency, continuous monitoring and refinement are essential to mitigate any trade-offs in delivery time and manage per-parcel costs effectively, ensuring a holistic advancement towards sustainable urban logistics.

6.4.1.3. Socioeconomic assessment for DISCOBAY

Here, **DISCOBAY Scenario (S2)** examines the performance of a single peri-urban transport infrastructure, specifically located at the Port, functioning as a multi-functional logistics hub. The core concept is to leverage this port infrastructure not only as a point of entry for long-haul volume but also as an active distribution centre. In this setup, the Port hub is designed to receive a portion of the total long-haul freight volume that arrives by train, signifying a notable modal shift. It then serves as a central warehouse for these goods, handles their sorting, and is responsible for the delivery and supply of local depots, effectively integrating into the urban logistics network. Critically, this Port infrastructure also performs as a depot for direct last-mile deliveries.

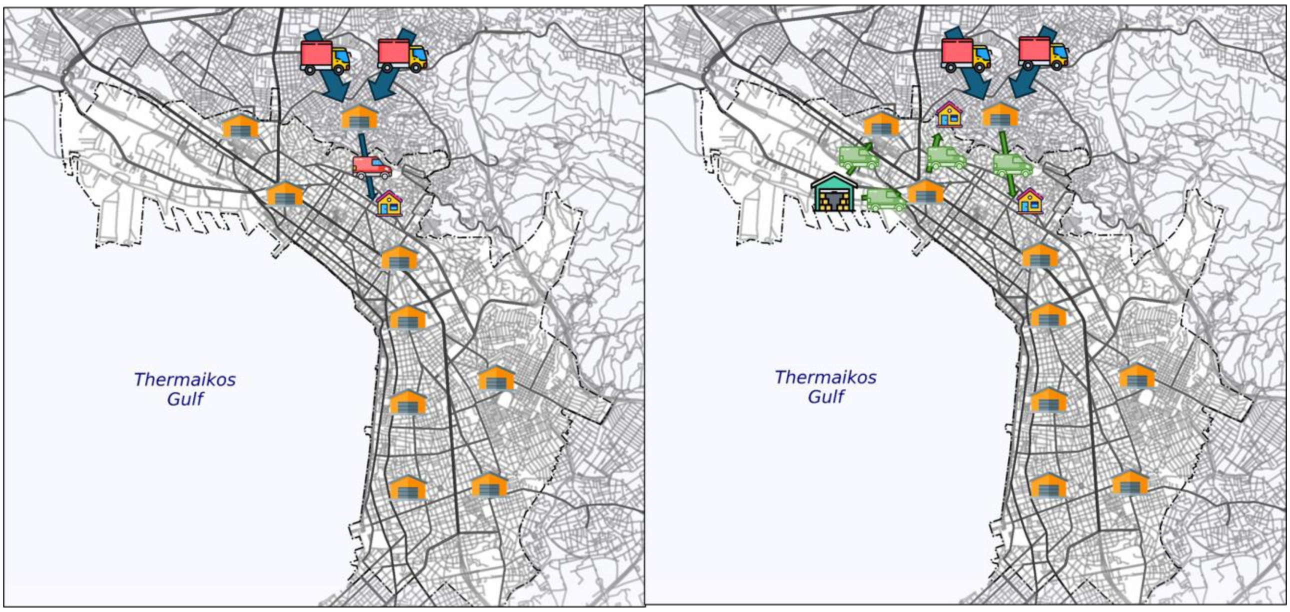

Figure 21: Visual representation of DISCOBAY scenario (S2) for the pilot of Thessaloniki

To facilitate this new operational model within the existing network, the ACS depot previously located closest to the railway station was strategically dropped from the model's configuration, signifying a consolidation or reallocation of resources. Deliveries originating specifically from this new Port depot will be conducted exclusively with electric vehicles (EVs), marking a targeted step towards fleet electrification within the urban context. The remaining demand across Thessaloniki, which is not served by this new Port-integrated hub, continues to be fulfilled based on the established "business as usual" model, utilising conventional vehicles from the remaining depots. All other operational variables, such as CO_2 consumption rates for conventional vehicles, remain consistent with the baseline parameters. These modified depot locations and the new EV fleet details for the Port hub were fed into the Python model, and the new model outcomes were subsequently calculated to assess the impact of this strategic intervention.

DISCOBAY scenario portrays the projected performance of Thessaloniki's urban logistics system with the integration of a single peri-urban transport infrastructure at the Port, serving as a multi-functional logistics hub and depot with dedicated electric vehicle (EV) deliveries. In this model, the ACS depot closest to the railway station was strategically dropped from the configuration, with all other conventional vehicle CO_2 consumption rates remaining constant.

The overall model outcomes of the DISCOBAY scenario project a total of 66 freight vehicles, comprising 55 conventional and 11 electric vehicles. The total kilometres travelled are estimated at 651.77 km, with EVs contributing 108.95 km of this total. The average km per vehicle is projected at 9.88 km, and the average deliveries per vehicle at 63.18. The average moving minutes per vehicle is estimated at 25.66 min, with EV moving minutes per vehicle at 28.04 min. Crucially, the successful first-attempt delivery rate is projected to be 85.75%.

Table 25: KPI Assessment DISCOBAY Thessaloniki

n.	KPI	Description	Unit	Baseline	DISCOBAY scenario	
1	Traffic Flow	Total freight kilometres driven per 10000 inh	km/10000 inhs	26	21.73	-15.64%
2	Distance Travelled	Average distance per delivery	km/del	0.19	0.15	-16.91%
3	Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	%	17.9%	14.3%	-20.21%
4	Delivery time	Average delivery time per route	mins	24	25.66	5.68%
5	Delivery Density	Number of deliveries per km	del/km	3.52	6.12	74.19%
6	Cost per parcel	Cost of delivery per km	€/km	6.42	7.48	16.53%
7	Operational Cost per day	Total delivery cost	€	€4,959	€4,875	-1.69%
8	CO_2 Emissions per km	Total kg of CO_2 emissions from all the vehicles per km	$kgCO_2$/km	19.04	13.331	-30.00%
9	CO_2 Emissions per parcel	Total kg of CO_2 emissions per parcel	$kgCO_2$/parcel	0.07	0.04	-42.59%

Traffic Flow (KPI 1) shows a reduction of -15.64% (to 21.73 units), and Distance Travelled (KPI 2) decreased by -16.91% (to 0.15 km/del), indicating even stronger positive impacts on urban mobility than in Scenario 1 due to the streamlined freight movement via the new Port hub. Failed Deliveries (KPI 3) decreased by -20.21% (to 14.3%), reflecting the continued benefits of the expanded parcel locker network. Delivery time (KPI 4) increased by +5.68% (to 25.66 minutes), suggesting that while overall efficiency improves, the new routing associated with the Port hub and EV operations may add slight time to individual routes. Delivery Density (KPI 5) saw a substantial increase of +74.19% (to 6.12 del/km), highlighting a robust gain in efficiency and vehicle utilisation. Cost per parcel (KPI 6) increased by +16.53% (to €7.48/km). Despite reductions in fuel consumption due to decreased total kilometres, this per-parcel cost increase is attributed to the predominant influence of labour and fixed building renting expenses on last-mile delivery costs, which constitute a larger proportion of total expenditure. Operational Cost per day (KPI 7) showed a further slight reduction of -1.69% (to €4,875), indicating continuous positive financial optimisation. CO_2 Emissions per km (KPI 8) achieved a remarkable reduction of -30.00% (to 13.331 $kgCO_2$/km), and CO_2 Emissions per parcel (KPI 9) saw a strong reduction of -42.59% (to 0.04 kgCO2/parcel). This substantial environmental improvement for CO_2 emissions per kilometre, even with a static conventional fleet composition, is directly attributable to the introduction of EVs for deliveries from the Port hub and the overall optimisation leading to fewer total kilometres travelled.

Other critical KPIs reflecting infrastructure and collaboration also show positive developments: Transport infra offer (KPI 17) increased to 4,415 sqm, and Warehouse offer (KPI 18) to 16,819 sqm, indicating significant gains in available logistics space. Lockers Volume (KPI 19) increased by 19 percentage points (to 25%), and Microhub Capacity Utilisation (KPI 20) improved by 12.99% (to 34%). Data sources used (KPI 21) increased from 1 to 7, Data Utilisation (KPI 22) from 1 to 3, and Number of partnerships for collaborative logistics (KPI 23) from 1 to 2. Finally, Investment plans (KPI

24) and SULP (KPI 25) both increased from 0 to 1, underscoring the strategic and political traction gained by the project.

6.4.2. Compliance to SULPs

The compliance of the four DISCO-X measures implemented in the Thessaloniki Living Lab has been assessed against the ELTIS SULP guidelines, using "socio-economic", "commercial", "operational", and "technical" perspectives as structuring elements. While Thessaloniki does not currently have a dedicated SULP, its 2021 SUMP includes logistics interventions, such as the commitment to developing a SULP. This year, leveraging DISCO outcomes and its participation in the NetZeroCities initiative, Thessaloniki successfully defined new regulations for loading/unloading operations, marking a significant step towards a formalised urban logistics plan. The following figure shows the results of the evaluation. Selected aspects are discussed in more detail below.

Mobility Governance: Services and measures	SULP guidelines		DISCO X			
			DISCOPROXI	DISCOESTATE	DISCOBAY	DISCOLLECTION
	Socio-economic	Reducing traffic impacts in the historical centre	2	1	3	1
		Increasing livability of urban environment	3	2	1	2
		Enhancing local economic development	2	3	1	1
	Commercial	Generate benefits on competetiveness and business	2	3	1	2
		Optimise logistics operation	2	3	3	2
		Reduce costs, improve knowledge of delivery cost	3	2	1	1
	Operational	Improved city access regulation	2	3	3	2
		Support adoption/use of sustainable vehicles	3	2	3	1
		Measures supporting transportation operators market	2	3	1	3
	Technical	Systems to optimise fleet delivery operation	3	3	2	3
		Systems to optimise logistics operation	2	3	3	3
		Improved integration of logistics in urban mobility	3	3	3	3
	State of compliance of technology, service and business model will be scored according to the following general criteria:		2,4	2,6	2,1	2,0
	3 = High compliance - no need for adaptation					
	2 = Medium compliance - short time adaptation					
	1 = Low compliance - long time adaptation					

Figure 22: PI compliance to SULP-Guidelines Thessaloniki

Socio-economic perspective

From this perspective, the DISCO-X measures collectively contribute to enhancing the urban environment. DISCOBAY shows high compliance in "Reducing traffic impacts in the historical centre" (3) by demonstrating how mapping underutilised transport infrastructure can significantly reduce travel distances and emissions in urban and peri-urban areas. DISCOPROXI (2) also contributes by introducing a shared, regulated locker network in low-traffic zones, aiming to reduce uncontrolled locker growth and associated vehicle trips in public spaces. DISCOESTATE (2) improves liveability by repurposing TIF-HELEXPO spaces, easing congestion in the historical centre, while DISCOLLECTION

(2) supports this through data-driven planning that optimises urban freight flows and reduces congestion.

Commercial perspective

The measures demonstrate varying degrees of commercial compliance. DISCOESTATE and DISCOPROXI both show strong compliance in "Generate benefits on competitiveness and business" (3 and 2, respectively). DISCOESTATE facilitates new economic models by turning underutilised exhibition spaces into active logistics hubs, which ACS has already found improves operations and reduces fines. DISCOPROXI, through its blockchain-powered WareM&O platform, enables secure and transparent smart contracts, fostering new business agreements for free space use. DISCOLLECTION (2) supports business optimisation by providing real-time data for planning and decision-making. Regarding "Optimise logistics operation", DISCOESTATE (3) and DISCOBAY (3) show high compliance, with DISCOESTATE providing a centralised logistics hub for smoother operations, and DISCOBAY demonstrating optimal use of strategically positioned buildings and green last-mile solutions. While DISCOPROXI (3) aims to "Reduce costs, improve knowledge of delivery cost" through its fair pricing algorithm for WaaS, the overall Cost per parcel (KPI 6) showed a slight increase in the model run.

Operational perspective

Operationally, the DISCO-X measures significantly advanced urban logistics goals. DISCOESTATE (3) and DISCOBAY (3) show high compliance in "Improved city access regulation" by repurposing infrastructure and mapping available real estate for consolidated logistics operations, reducing reliance on individual freight storage and unloading spaces. Notably, DISCOLLECTION (2) directly contributed to the City of Thessaloniki approving a new loading/unloading time regulation based on its outcomes, demonstrating its impact on logistics planning and policy. DISCOPROXI (3) supports "Support adoption/use of sustainable vehicles" by facilitating a shared, regulated locker network that can reduce vehicle trips. DISCOESTATE (3) and DISCOLLECTION (3) show high compliance in "Measures supporting transportation operators' market", with DISCOESTATE improving ACS operations through depot relocation, and DISCOLLECTION integrating diverse data streams for a citywide overview of logistics flows, benefiting operators.

Technical perspective

From a technical standpoint, the measures exhibit strong compliance with guidelines for optimising logistics systems. "Systems to optimise fleet delivery operation" is highly supported by DISCOPROXI (3) through the integration of blockchain with the WareM&O platform for secure and transparent smart contracts, and by DISCOLLECTION (3) with its development of a local urban freight dataspace for real-time insights and decision-making. DISCOESTATE (3) contributes by upgrading the WareM&O platform with e-signature capabilities and an enriched data model for real-time occupancy tracking. All four measures, including DISCOBAY (3) with its integrated space availability observatory, demonstrate "Improved integration of logistics in urban mobility" (3) by converging various data sources into unified frameworks to support evidence-based urban logistics planning and smart city solutions.

6.4.3. Contribution to SDGs

In this step the contribution of the DISCO-X measures to the Sustainable Development Goals (SDGs) is evaluated. To be able to make a sufficiently precise statement here, the use of the target level of the SDGs is chosen. The association of KPIs to SDGs as well as the association of KPIs to DISCO-X measures serve as input for the assessment. In correlation with the 7 SDGs that are addressed by the DISCO activities 11 SDG targets were identified and compared with the four measures implemented in the Thessaloniki Living Lab. The scale used is green = Direct contribution, light green = indirect contribution no colour = no contribution. In addition, comments were made to clarify the contribution of the respective measure.

Table 26: Contribution to SDGs Thessaloniki

SDG target	DISCO-X			
	DISCOPROXI Addr. KPIs: 1, 2, 4, 7, 8, 17, 18, 24, 25	DISCOSTATE Addr. KPIs: 1, 4, 8, 25	DISCOBAY Addr. KPIs: 1,16, 21, 22, 23, 25	DISCOLLECTION Addr. KPIs: 1, 2, 3, 4, 5, 6, 7, 8, 9, 19, 20, 23, 24, 25
3.9: Reduce the amount of deaths produced by dangerous chemicals and the pollution of the air, water and soil (…) Ass. KPIs: 1, 2, 3, 5, 8-13	reduced last mile CO_2 via optimised locker locations			Data-driven planning enables emission reduction measures
8.2: Achieve higher levels of economic productivity (…) Ass. KPIs: 6, 7, 24, 25	Smart contract locker model boosts space utilisation and throughput	shared use of expo facilities improves asset utilisation	integrated observatory reduces wasted travel and costs	insights from dataspace streamline ops
8.4: Improve (…) global resource efficiency in con-sumption and production (…) Ass. KPIs: 1, 2, 5, 10	fewer detours due to locker consolidation	multipurpose reuse of expo infrastructure	mapping & booking of idle space optimises land use	analytics guide more efficient routing
9.1: Develop quality, reliable, sustainable and resilient infrastructure (…) Ass. KPIs: 1, 5, 15, 17, 18, 20		retrofitting TIFHELEXPO pavilions for logistics hub		digital freight dataspace builds foundational IT
9.4: (…) upgrade infrastructure and retrofit industries to make them sustainable (…) Ass. KPIs: 17-20		physical & digital upgrades at expo for 24/7 green logistics		Data-sharing platforms support future retrofits

11.3: (…) enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management (…) Ass. KPIs: 11, 19, 20	user surveys & workshops on locker siting	codesign of expo hub with city & operators		Urban freight dataspace empowers participatory planning
11.6: (…) reduce the adverse per capita environmental impact of cities (…) Ass. KPIs: 8-13	optimised locker deliveries lessen curb conflicts		fewer, shorter trips cut urban emissions	Real-time data helps manage hotspots
11.A: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning Ass. KPIs: 24, 25		expo hub links periurban TIFHELEXPO with city centre	mapping periurban storage connects lastmile	Data sharing bridges stakeholder groups
12.6: Encourage companies (…) to adopt sustainable practices and to integrate sustainability information into their reporting cycle Ass. KPIs: 13, 23	blockchain contracts add transparency & accountability	esignature & cost sharing nudge greener ops		Freight dataspace integrates sustainability KPIs
13.2: Integrate climate change measures into national policies, strategies and planning Ass. KPIs: 25	Proof of concept feeds city's locker strategy	aligns hub with Thessaloniki's zero emission goals	mapping supports sustainable freight planning	dataspace outputs feed SULP updates
17.16: Enhance the Global Partnership for Sustainable Development (…) Ass. KPIs: 23	municipality, CERTH, ACS & platform providers	governance across TIF, ACS, city & research	collaboration with port authority, FM Logistic, TIF & municipality	city, CERTH & operators comanage urban freight dataspace

7. Discussion of the findings of the evaluation regarding their replication potential

The activities in the four Starring Living Labs play a central role in DISCO's endeavour to accelerate the process of upscaling into a new era of urban logistics and intelligent planning. This includes facilitating the transition to carbon-neutral and digital cities, developing new and innovative frameworks and tools, and transforming the paradigm of urban logistics and planning through a physical internet (PI)-led approach. Based on this overarching objective, the findings from the evaluation of the Starring Living Labs in terms of their impact and scalability are discussed below.

Reducing environmental impact and sustainable mobility transformation

The measures in Copenhagen and Helsinki, in particular, illustrated how switching the delivery fleet to electric vehicles, cargo bikes, and delivery robots in combination with the concept of microhubs can significantly reduce CO_2 emissions. However, it also became clear that, depending on its form, this approach also has disadvantages in terms of key indicators for transport and logistics efficiency. These disadvantages are the result of smaller delivery volumes due to the use of cargo bikes or delivery robots. In addition, sharing infrastructure, warehouses, consolidation microhubs (adopting a PI approach) also reduces emissions through efficiency gains, as witnessed by the case of Thessaloniki. In other words, mainstreaming a PI-led logistics system where resources are pooled may be a win-win option between cost efficiency (economy) and resource/emissions efficiency (environment). Eventually, another successful approach for reducing emissions is setting rules for LEZ or even ZEZ. However, for the roll-out of such zones is important to formulate regulations that reduce the environmental impact without creating new challenges such as increased traffic volumes in outlying districts.

Increasing traffic efficiency

Increasing traffic efficiency can be achieved through various approaches. A reduction in vehicle kilometres and fleet size should be aimed for, particularly with regard to the indicators. As part of DISCO, shared services and intelligent routing solutions were developed in the Living Labs that make a positive contribution to this. One example of this is the Urban Access Control System from Ghent, which has been used to optimise numerous traffic efficiency-related indicators. The implementation made it clear that a high level of digital maturity is required to realise such a solution. For example, a lot of information needs to be digitised and visualised before real-time services relating to (un)loading zones, school areas, and congestion hotspots can improve logistics companies' navigation and operational decisions. Another approach for reducing traffic flow is to define the location of microhubs, lockers, and loading/unloading zones based on traffic data, as done by Thessaloniki and Helsinki. Eventually, shared consolidation microhubs and lockers accessible to multiple actors also contribute highly to traffic reduction, as seen in Copenhagen and Thessaloniki. All these measures involve a planned and cooperative optimisation of flows and infrastructure use, hence, a set of data collection technologies and a logistic ecosystem characterized by trust and regulatory stability are necessary, as proposed by the PI paradigm.

Operational efficiency enhancement

Increasing first-time delivery rates and shortening transport routes with microhubs can be essential building blocks for increasing operational efficiency. In the course of the implementations, it has become clear that such microhub approaches are only economically successful if the methods used are interlinked. A complete conversion of the delivery fleet to cargo bikes or delivery robots, for example, would drastically increase delivery times in some cases and thus have a negative impact on the costs per delivery.

Optimise infrastructure and space utilisation

The implementation of DISCO measures demonstrated how infrastructure and space can be utilised more efficiently. This concerns both the retrofitting of existing infrastructure and warehouses and the utilisation of previously unused space. From a technological perspective, it has become clear that modern sensor technology (e.g., DISCOCURB), the utilisation of FCD, and the use of apps to plan logistics operations are game changers for the optimisation of existing areas as well as for planning new spaces. In addition, the use of modern mapping and simulation approaches can uncover previously unknown data treasures (e.g., Thessaloniki). However, a high level of digital maturity is also required throughout the entire logistics chain and among all stakeholders involved for widespread use, from initial data procurement to integration and the roll-out and provision of corresponding digital solutions.

Data-driven logistics management

To support data-driven logistics management, the potential of real-time data utilisation and tracking for agile and evidence-based planning became particularly apparent as part of the implementation measures. While the collection of real-time data was generally successful, the integration of real-time data into corresponding data spaces presented a challenge in some cases. One success factor identified was the early involvement of the necessary partners, who should be seen not just as 'suppliers' but as equal partners in the active design of urban logistics solutions. Moreover, providing clear business cases to the stakeholders for incentivising data sharing is a difficult but necessary step. Public authorities can have more leverage for fostering data sharing.

Exploit new business models:

New sustainable business models enrich the measures and approaches described above and ensure the long-term use of new solutions. In the context of the DISCO measures, it became clear that there are numerous starting points for their integration (e.g., Copenhagen, Ghent, Thessaloniki). However, operational implementation is not yet far advanced. Switching to green last-mile solutions, for example, can significantly reduce the environmental impact and contribute to improving the quality of life in cities. Unfortunately, the associated costs are often cited as a reason for not introducing them. The example of Thessaloniki however demonstrated the value of innovative business models and services for free space use, by adopting smart-contracts utilising the blockchain technology.

In summary, it can be said that the experience gained from the implementation of the DISCO-X measures in the Living Labs is critical to the success of the further design of urban logistics not only in the respective cities but also for other cities. A few aspects have emerged as key elements that need to be taken into account. This includes the development of digital maturity across the entire process chain, the earliest possible involvement of stakeholders and the development of collaborative logistics systems to build trust in new solutions, share data and work together on new tools and solutions.

Regarding the evaluation itself, it must be said that many stakeholders struggle with working with indicators (KPIs) due to insufficient data, limited analytical capacity, and a lack of technical expertise to calculate. Furthermore, it was recognised that some of the KPIs could not be used by the Living labs. This was either because the KPIs did not fit into the corresponding measure or simply because no data was or could be collected in this regard. A discussion about the selection of appropriate KPIs per Living Lab could also be held regarding the quality aspect of data. These circumstances should be remedied in order to have a better starting point in the future for the implementation and upscaling of logistics measures.

8. Potential impacts of an advanced PI-led logistics system – An example from Thessaloniki

The Physical Internet (PI) represents a paradigm shift in logistics operations, fundamentally reimagining how goods move through urban environments by transforming traditional, siloed logistics networks into interconnected, collaborative ecosystems. This concept, analogous to the digital internet's packet-switching methodology, proposes that freight and logistics operations should be organised around shared infrastructure, standardised protocols, and collaborative resource utilisation rather than individual company-centric approaches. In the context of urban logistics, the PI materialises through several key mechanisms:

- Shared transportation networks where multiple logistics operators utilise common vehicle fleets and routing systems.
- Collaborative warehousing where storage facilities serve multiple companies simultaneously.
- Integrated information systems that enable real-time coordination across different operators.
- Standardised handling procedures that allow for efficient cross-docking and consolidation operations.

This collaborative approach fundamentally challenges the conventional model where each logistics company operates its own dedicated fleet, maintains separate warehouse facilities, and optimises routes independently, often leading to suboptimal city-wide resource utilisation.

The theoretical foundation of PI rests on the principle of network effects and economies of scale. By pooling resources across multiple operators, the system can achieve higher vehicle utilisation rates, reduced empty running, optimised routing through consolidated demand patterns, and improved warehouse space efficiency. Furthermore, the collaborative model enables smaller logistics operators to access sophisticated optimisation technologies and infrastructure that would be prohibitively expensive for individual companies to develop and maintain independently. This democratisation of logistics capabilities is particularly relevant in urban environments where space constraints and regulatory pressures demand highly efficient resource utilisation.

The implementation of PI principles in urban logistics requires sophisticated coordination mechanisms, including advanced algorithms for dynamic resource allocation, real-time visibility systems for tracking assets across multiple operators, standardised data exchange protocols, and equitable cost-sharing mechanisms. These technological enablers must be complemented by organisational structures that facilitate trust-building, dispute resolution, and performance monitoring across collaborative partners.

Building upon the foundational concepts of collaborative logistics, the **Physical Internet Scenario (S3)** for Thessaloniki represents a comprehensive reimagining of the city's entire logistics ecosystem. This scenario transcends the individual company perspective adopted in previous analyses and instead considers the holistic optimisation of freight distribution across all logistics operators within the metropolitan area. The scenario assumes complete resource sharing and collaborative operations among all logistics service providers, effectively treating the city as a single, integrated logistics network.

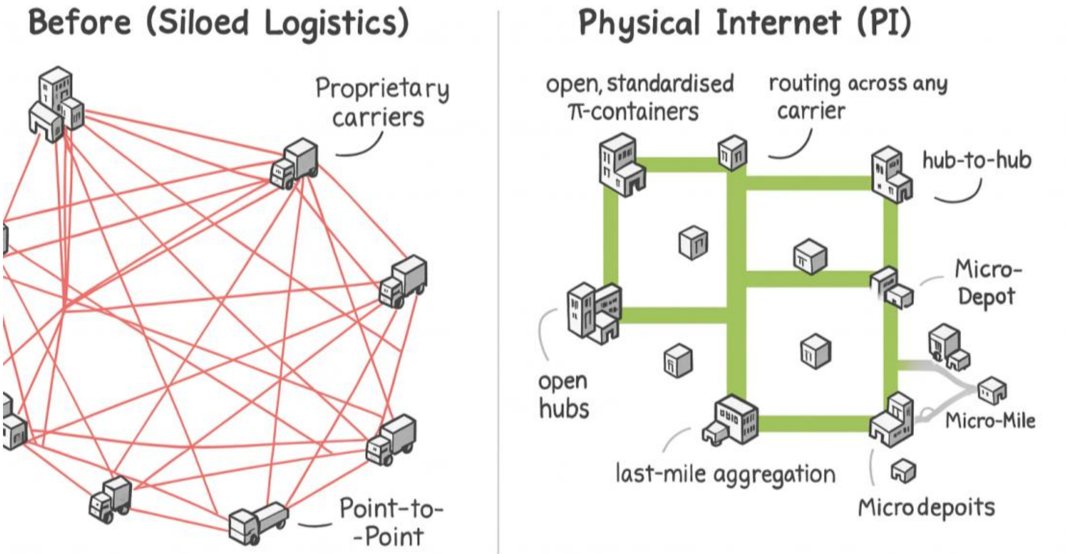

Figure 23: The concept of Physical Internet in last mile logistics

The scenario encompasses the totality of Thessaloniki's urban freight operations, incorporating approximately 12,000 daily parcel deliveries distributed across all major logistics operators active within the city. This comprehensive demand pattern reflects the aggregated requirements of residential, commercial, and institutional customers throughout the metropolitan area. The expanded scope necessitates a corresponding increase in infrastructure capacity, with the model incorporating over 20 strategically distributed depots and warehouses across the city, representing both existing facilities and additional capacity that would be required to support the integrated operations.

The PI scenario assumes optimal resource allocation mechanisms where the collective fleet of all operators becomes a shared resource pool, enabling dynamic assignment of vehicles based on real-time demand patterns and route optimisation algorithms. Similarly, the warehouse network operates as an integrated system where parcels can be processed, sorted, and dispatched from any facility regardless of their originating operator. This level of integration requires sophisticated information systems that provide real-time visibility across all network participants and enable coordinated decision-making for vehicle routing, facility utilisation, and capacity planning.

The collaborative framework also assumes standardised operational procedures across all participating operators, including common packaging standards, unified service level agreements, and harmonised delivery time windows. These standardisations eliminate the inefficiencies that arise from operational incompatibilities between different logistics providers and enable seamless handoffs of parcels between operators when such transfers optimise overall system performance.

The PI scenario simulation employs an advanced optimisation model that considers the entire city as a single logistics network with unified demand patterns and shared resource pools. The model incorporates sophisticated algorithms for facility location optimisation, vehicle routing problems with multiple depots, and dynamic capacity allocation across the expanded infrastructure network. The simulation framework accounts for economies of scale that emerge from the collaborative operations, including reduced per-unit handling costs, improved vehicle utilisation rates, and optimised routing efficiency through consolidated demand patterns.

The calibration process involved scaling operational parameters to reflect the expanded scope of operations while maintaining consistency with the empirical data collected from individual operators. Vehicle characteristics, cost structures, and performance metrics were adjusted to account for the increased operational complexity and coordination requirements inherent in collaborative logistics systems. The model also incorporated additional parameters related to inter-operator coordination costs, information system overhead, and the management complexity associated with shared resource utilisation.

The PI scenario simulation generated comprehensive operational metrics that demonstrate the potential impact of fully collaborative logistics operations in Thessaloniki. The model results indicate that the integrated system would require a total of 199 freight vehicles operating across the city to handle the consolidated demand of approximately 12,000 daily deliveries. This represents a significant improvement in resource utilisation efficiency compared to the fragmented approach of individual operators.

Table 27: Collaborative operations—routing optimisation results

Metric	**Value**	**Units**	**Description**
Total distance travelled (daily, fleet)	1,276.96	km/day	Aggregate distance after optimisation.
Average distance per vehicle (daily)	6.42	km/vehicle/day	Lower per-vehicle distance reflects improved route density and reduced deadheading from consolidated demand.
Average deliveries per vehicle (daily)	62.86	parcels/vehicle/day	Indicates high vehicle utilisation, outperforming individual-operator scenarios.

The temporal efficiency of the collaborative system is reflected in the average moving minutes per vehicle of 16.94 minutes, representing a significant reduction in non-productive time compared to fragmented operations. The successful first-attempt delivery rate of 86% maintains service quality standards while achieving operational efficiencies through the expanded infrastructure network and optimised routing.

The transformation of operational metrics into comparable key performance indicators reveals the substantial potential of PI implementation in Thessaloniki's urban logistics system. When rescaled to ACS's market share for comparative analysis with previous scenarios, the PI approach demonstrates remarkable improvements across all measured dimensions.

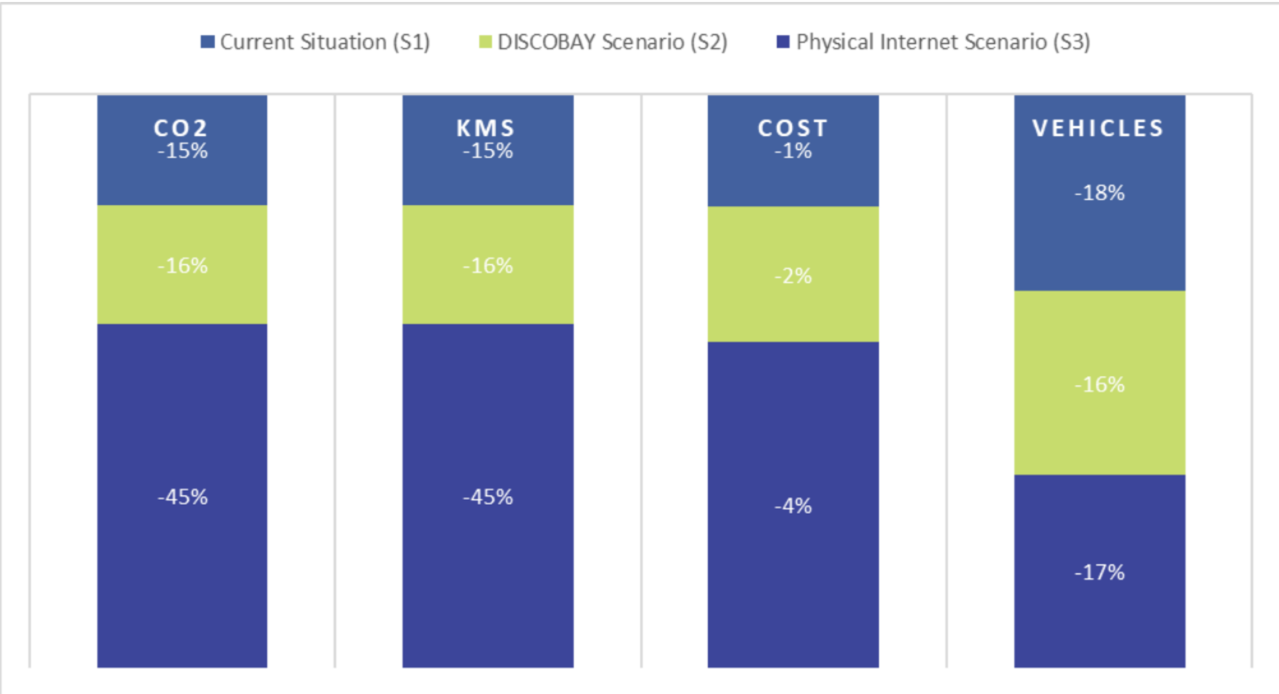

Figure 24: Comparative impact of the Current Situation (S1), DISCOBAY Scenario (S2), and Physical Internet Scenario (S3) on CO_2 emissions, kilometres travelled, cost, and fleet size in Thessaloniki's urban logistics system

The environmental impact assessment shows that collaborative operations would reduce CO2 emissions to 101.32 units, representing a 45% reduction compared to the baseline scenario (S0) and a 35% improvement over the current situation (S1). This substantial emission reduction results from the optimised routing, reduced total kilometres travelled, and improved vehicle utilisation rates that eliminate redundant movements and empty running.

The total distance travelled under the PI scenario amounts to 425.65 kilometres, constituting a 45% reduction from the baseline and demonstrating the efficiency gains achievable through collaborative route optimisation. This dramatic reduction in vehicle-kilometres travelled directly translates to reduced traffic congestion, lower infrastructure wear, and decreased environmental impact from freight operations.

The economic analysis reveals that daily operational costs under the PI scenario total €4,758.54, representing a 4% reduction compared to the baseline scenario despite the increased coordination complexity. While the cost savings are more modest than the environmental benefits, they demonstrate that collaborative logistics can achieve sustainability improvements without compromising economic viability.

The vehicle utilisation analysis indicates that the PI scenario would require only 66 vehicles to handle ACS's proportional share of the city's freight demand, representing a 17% reduction from the baseline scenario. This reduction in required vehicle fleet size reflects the improved efficiency of collaborative operations and the elimination of redundant capacity across multiple operators.

These results collectively demonstrate that the PI approach represents a transformative paradigm for urban logistics, offering substantial environmental benefits, operational efficiencies, and economic advantages through collaborative resource utilisation and integrated system optimisation. The scenario establishes a compelling case for policy interventions and industry collaboration initiatives that could facilitate the transition toward more sustainable and efficient urban freight systems.

Annex

Weighting Table v4

			Weights							Interval	Comment
			Very bad	Bad	Poor	None	Fair	Good	Very good		
Label	Description and data format	Unit	-3	-2	-1	0	1	2	3		
Traffic Flow	Total freight kilometers driven per 10000 inh	km/10000 inhs	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%	measure is "percentage increase or decrease in total freight km/inh"
Distance Travelled	Average distance per delivery	km/del	> +30%	+16-30%	+1-15%	0	-1-(-15)%	-16-(-30)%	< -30%	15%	measure is "percentage increase or decrease in average distance per delivery"; in this case interval should be larger than for the effort in freight kilometers reduction since there are additional levers (e.g. cargo bikes, lockers)
Failed Deliveries	Percentage of unsuccessful deliveries with the 1st attempt	%	> +30%	+16-30%	+1-15%	0	-1-(-15)%	-16-(-30)%	< -30%	15%	measure is "percentage increase or decrease of unsuccessful deliveries with the 1st attempt"
Delivery time	Average delivery time per route	mins	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%	measure is "percentage increase or decrease of average delivery time per route"
Delivery Density	Number of deliveries per km	del/km	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of number of deliveries per km "
Cost per parcel	Cost of delivery per km	€/km	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%	measure is "percentage increase or decrease of cost of delivery per km"
Operational Cost per day	Total delivery cost	€	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%	measure is "percentage increase or decrease of total delivery cost"
CO_2 Emissions per km	Total kg of CO_2 emissions per km	eCO_2/km	> +40%	+21-40%	+1-20%	0	-1-(-20)%	-21-(-40)%	< -40%	20%	measure is "percentage increase or decrease of total kg of CO_2 emissions per km"; in this case interval should be larger than for the effort in freight kilometers reduction since there are additional levers (e.g. electric freight vehicles, cargobikes)
CO_2 Emissions per parcel	Total kg of CO_2 emissions per parcel	eCO_2/parcel	> +40%	+21-40%	+1-20%	0	-1-(-20)%	-21-(-40)%	< -40%	20%	measure is "percentage increase or decrease of total kg of CO_2 emissions per parcel"; in this case interval should be larger than for the effort in freight kilometers reduction since there are additional levers (e.g. electric freight vehicles, cargobikes
EV Adoption Rate	Percentage of electric freight vehicles in the delivery fleet	%	< -30%	-16-(-30)%	-1-(-15)%	0	+1-15%	+16-30%	> +30%	15%	measure is "percentage increase or decrease of electric freight vehicles in the delivery fleet"
Cargo bike adoption rate	Number of cargo bikes in the local delivery fleet	-	< -30%	-16-(-30)%	-1-(-15)%	0	+1-15%	+16-30%	> +30%	15%	measure is "percentage increase or decrease of number of cargo bikes in the local delivery fleet"
Cargo bike deliveries	Percentage of the total deliveries performed by cargo bikes	%	< -30%	-16-(-30)%	-1-(-15)%	0	+1-15%	+16-30%	> +30%	15%	measure is "percentage increase or decrease of the total deliveries performed by cargo bikes"
Companies electrification	Percentage of companies that operate with cargo bikes	%	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of companies that operate with cargo bikes"
Parking fines	Parking fines per 10000 inh	€/10000 inhs	> +20%	+11-20%	+1-10%	0	-1-(-10)%	-11-(-20)%	< -20%	10%	measure is "percentage increase or decrease of Parking fines per 10000 inh"
Space Utilization Efficiency	Average occupancy of parking spaces	%	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of average occupancy of parking spaces"
Reliability of Sensors and Cameras	Average time that sensors were not working properly	mins	> +30%	+16-30%	+1-15%	0	-1-(-15)%	-16-(-30)%	< -30%	15%	measure is "percentage increase or decrease of average time that sensors were not working properlys"
Transport infra offer	Average offered space of a transport infrastructure to be used as (shared) space for logistics operations	sq.m	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of average offered space of a transport infrastructure to be used as (shared) space for logistics operations"
Warehouse offer	Average offered space of a warehouses be used as (shared) space for logistics operations	sq.m	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of average offered space of a warehouses be used as (shared) space for logistics operations"
Lockers volume	Percentage of freight volume delivered through lockers	%	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of freight volume delivered through lockers"
Microhub Capacity Utilization	Average utilization rate of a parcel locker	%	< -20%	-11-(-20)%	-1-(-10)%	0	+1-10%	+11-20%	> +20%	10%	measure is "percentage increase or decrease of average utilization rate of a parcel locker"
Data sources used	Number of data sources or platforms that are connect	-				0	1	2	>2	1	
Data Utilization	Number of new/enhanced services utilizing old/new d	-				0	1	2	>2	1	
Number of partnerships for collabo	Number private-private and -or public-private partner	-				0	1	2	>2	1	
Investment plans	Number of investment logistics plans of local private	-				0	1	2	>2	1	
SULP	Number of locally politically approved SULP or freight	-				None	Drafted	Issued	Approved	N/A	

Contribution to SDGs (full list of all 11 SDG targets relevant for DISCO)

SDG target	DISCO-X			
	DISCOCURB Addr. KPIs: to be filled in per LL	DISCOPROXI Addr. KPIs: to be filled in per LL	DISCOBAY Addr. KPIs: to be filled in per LL	DISCOLLECTION Addr. KPIs: to be filled in per LL
3.9: Reduce the amount of deaths produced by dangerous chemicals and the pollution of the air, water and soil (…) Ass. KPIs: 1, 2, 3, 5, 8-13				
8.2: Achieve higher levels of economic productivity (…) Ass. KPIs: 6, 7, 24, 25				
8.4: Improve (…) global resource efficiency in con-sumption and production (…) Ass. KPIs: 1, 2, 5, 10				
9.1: Develop quality, reliable, sustainable and resilient infrastructure (…) Ass. KPIs: 1, 5, 15, 17, 18, 20				
9.4: (…) upgrade infrastructure and retrofit industries to make them sustainable (…) Ass. KPIs: 17-20				
11.3: (…) enhance inclusive and sustainable urbanisation and capacity for participatory, integrated and sustainable human settlement planning and management (…) Ass. KPIs: 11, 19, 20				
11.6: (…) reduce the adverse per capita environmental impact of cities (…) Ass. KPIs: 8-13				
11.A: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning Ass. KPIs: 24, 25				
12.6: Encourage companies (…) to adopt sustainable practices				

and to integrate sustainability information into their reporting cycle Ass. KPIs: 13, 23				
13.2: Integrate climate change measures into national policies, strategies and planning Ass. KPIs: 25				
17.16: Enhance the Global Partnership for Sustainable Development (…) Ass. KPIs: 23				