Deliverable 3.15

Impact Assessment, Solutions Validation and Learning Conclusions

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Acronyms

Acronyms	Explanation
AW	Adjusted Weights
B2B	Business to Business
B2C	Business to Consumer
BAU	Business-as-Usual
C2C	Consumer to Consumer
CoP	Community of Practice
CW	Convergent Weights
DT	Digital Twin
EV	Electric Vehicle
FIRR	Financial Internal Rate of Return
GHG	Greenhouse gas
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
LEZ	Low Emission Zone
LL	Living Lab
LML	Last-Mile Logistics
MCDM	Multicriteria Decision-Making
PPP	Public-Private Partnership
PS	Present Situation
SL	Severity Level
T	Trends
UCC	Urban Consolidation Center

Executive Summary

Urban logistics is becoming increasingly important due to the population growth in urban areas, changes in consumer behaviour driven by new technologies, and the boom of e-commerce demand. To address the sustainability challenges of urban freight operations the LEAD project has explored different sustainable Last-Mile Logistics solutions. This deliverable presents the results of the sustainability impact assessment of LEAD solutions to achieve low-emissions adaptative last-mile logistics along with the validation of the project’s results based on the stakeholders’ feedback.

This deliverable describes and implements the STAR Logistics Methodology, which consist of a multicriteria method that evaluates different Last-Mile Logistics (LML) solutions by providing a sustainability rating that allows the comparison of different solutions. The STAR Logistics Methodology provides a robust environmental, social, and economic evaluation implemented in each solution of the six Living Labs of the LEAD project.

Moreover, the deliverable describes the LML solutions’ validation with the aim of knowing whether the solutions tested have accomplished the original objectives set at the beginning of the LEAD project. The validation methodology includes both the LEAD value case impact validation and LEAD Living Labs (LLs) validation.

1 Introduction

1.1 The LEAD project

LEAD has created Digital Twins (DTs) of urban logistics networks in six cities to support experimentation and decision-making with on-demand logistics operations in a public-private urban setting. Innovative solutions for city logistics are represented by value case scenarios that address the requirements of the on-demand economy while aligning competing interests and creating value for all stakeholders. Each value scenario encompasses a combination of various measures, known as LEAD strategies. These strategies include:

a. Inventive business models
b. Flexible urban freight storage and last-mile distribution systems
c. Environmentally friendly, automated, electric, or hybrid delivery vehicles
d. Intelligent logistics solutions.

Cost, environmental, and operational efficiencies for value cases have been measured in 6 Living Labs (LL). Evidence-proven value cases and associated logistics solutions have been delivered as exploitable DTs, incorporating the models that support adaptation to different contexts and provide incentives for public-private partnerships (PPPs). The LEAD consortium comprises 22 partners, all of whom are involved in the LLs. This structure incentivised the co-creation of solutions by city authorities, logistics industry leaders, start-ups, and research experts in freight modelling, complex simulation and logistics optimisation.

1.2 Scope and objectives of this deliverable

This deliverable comprises the results of Task 3.8, with the goal of assessing the potential of LEAD solutions to achieve low-emission adaptive last-mile logistics. The aim of D3.15 is three-fold:

- To analyse the impact of the different solutions implemented in the LLs based on the sustainability triple bottom line. This objective is covered by the measurements of KPIs and the development of an evaluation tool, "STAR Logistics Methodology", for assessing the sustainability of LML solutions. This part also includes the long-term impact assessment approach that has been adopted.
- To provide a validation methodology to evaluate whether the solutions tested have accomplished the original objectives. To that end, the validation methodology includes LEAD value case impact validation and LEAD LLs validation.
- To consolidate lessons learned and practices derived from the value cases analysis.

1.3 Structure of the document

The deliverable is structured as follows:

- Chapter 2 describes the STAR Logistics Methodology used to assess the impact of last-mile logistics solutions of LEAD strategies.

- Chapter 3 contains the impact assessment results of the LEAD value cases by Living Lab.
- Chapter 4 describes the LEAD solutions' validation methodology and a summary of the overall results of the validation of the case studies.
- Chapter 5 provides the lessons learned and practices derived from the LEAD value cases and conclusions.
- Chapter 6 includes the references and bibliography.
- Annex 1: Experts Survey for STAR Logistics Methodology.
- Annex 2: LEAD final LLs Local Workshops instructions and validation questionnaires.
- Annex 3: STAR logistics reports per LL.

2 Impact Assessment of Last-Mile Logistics Solutions

2.1 Background

Sustainability in last-mile logistics refers to meeting the current needs of customers and businesses while protecting the environment and ensuring social and economic well-being for future generations. This includes minimising the environmental impact of transportation and delivery, promoting economic growth, and ensuring that all members of society have access to goods and services now and over the years. To achieve sustainability in LML, the **LEAD project** proposes the combination of several measures (LEAD strategies): a) innovative business models, b) agile urban freight storage and last-mile distribution schemes, c) low-emissions, automated, electric, or hybrid delivery vehicles, and d) smart logistics solutions. It is important to note that sustainability in LML is a multidimensional concept that goes beyond minimising the environmental impact, by also promoting social and economic well-being. In LML, several sustainability criteria can be considered, such as (i) Environmental impact: emissions, energy consumption, air pollution, and use of natural resources; (ii) Social impact: labour standards, community engagement, and fair-trade practices; and (iii) Economic impact such as cost efficiency, financial stability, and return on investment.

European cities have already been evolving in this direction in recent years, with an increasing number of research and development projects focusing on LML Living Labs (i.e., CITYLAB[1], NOVELOG[2], STRAIGHTSOL[3] projects, and currently ULAADS[4]), where different sustainable LML solutions have been implemented: innovative vehicles, proximity stations or points, collaborative urban logistics, optimisation of transport management and routing, and innovations in public policies and infrastructures. The **LEAD project** progresses on these aspects by demonstrating strategies for shared-connected, low-emission logistics operations in six European cities with different logistics profile characteristics and stakeholders, and diverse urban planning challenges.

The evaluation of LML solutions must seek to balance the impacts from a sustainability point of view and align with the stakeholders' needs and interests. The successful implementation of these solutions depends on the city's characteristics, stakeholders' goals, and the ability to achieve economic, social, and environmental sustainability.

To address this need, some researchers propose using multicriteria analysis, which is a tool for decision-making that involves quantitative and qualitative aspects (Mardani et al., 2015). This method allows for the consideration of conflicting criteria (Watróbski et al., 2017). Multicriteria Decision-Making (MCDM) methods are becoming increasingly important for evaluating urban freight logistics and supporting local authorities in their decision-making (Alvarez and Maheut, 2022; Jamshidi et al., 2019).

[1] https://civitas.eu/projects/citylab
[2] http://novelog.eu/
[3] http://www.straightsol.eu/
[4] https://ulaads.eu/

The LEAD project capitalises on the **STAR Logistics Methodology**, which is an adaptation of the ***STAR Methodology***[5] developed by UPM based on the MCDM method for the sustainability assessment of LEAD strategies.

2.2 The STAR Logistics Methodology

The **STAR Logistics Methodology** is a methodological tool developed by UPM for assessing the sustainability of LML solutions by **producing an integrated sustainability rating** to facilitate the decision-making process when selecting among different strategies.

The STAR Logistics Methodology conducts an integrated impact assessment of LML solutions from the sustainability perspective (economic, environmental and social). Sustainability criteria based on KPIs are aggregated through a multicriteria decision analysis whose weights are estimated depending on both the geographical and social context of the area where LML solutions are implemented, and consensus-based comparative judgment and preferences from experts' stakeholders. The model aims to provide a sustainability rating of LML solutions compared to the baseline scenario.

The STAR Logistics Methodology is structured in three steps (see Figure 1):

Step 1. Scenario Definition and Setting Sustainability Criteria.

This step defines a set of scenario-based value cases including the baseline scenario —the Business as Usual (BAU) scenario— and the LEAD value cases scenarios. In addition, a set of KPIs are identified and quantified to characterise the sustainability of different LML solutions. For each specific policy or project, sustainability criteria are set to characterise the well-known sustainability triple bottom dimensions: economic efficiency, environmental preservation, and social considerations. The criteria can be measured through KPIs on either a quantitative or a qualitative scale depending on their characteristics (Bueno & Vassallo, 2015; Vassallo & Bueno, 2021). The KPIs will compare the impact of conducting the BAU scenario compared to the proposed LEAD strategies in each value case.

Step 2. Obtaining Criteria Adjusted Weights.

This step addresses the relative impact of each criterion on sustainability by obtaining the adjusted weights. After selecting sustainability criteria for the sustainability assessment of LEAD strategies, this step sets the weights of the criteria to reflect the expert's preferences and the geographical and social context where the last-mile solution is implemented. Following the methodology outlined by Bueno & Vassallo (2015), the Adjusted Weights (AW) are calculated based on both consensus-based comparative judgments based on expert opinions (Convergent Weights – CW) and sensitivity of sustainability criteria in the urban context (Severity Level - SL).

$$AW_i = CW_i \cdot SL_i$$

where AW_i – Adjusted Weight for criterion *i*; CW_i – Convergent Weight for criterion *i*; SL_i – Severity Level of criterion *i*.

[5] *https://www.upm.es/recursosidi/en/offers-resources/technological-solutions/sustainability-assessment-of-mobility-projects-star/*

Step 3. Quantifying the sustainability performance of the scenarios

To select the option with the best sustainability score, the final step involves measuring the sustainable performance of each scenario. This process begins by estimating each scenario's Key Performance Indicators (KPIs). Next, the percentage change of the KPIs in each scenario is calculated relatively to the Business as Usual (BAU) scenario. This calculation is made according to the following formula:

$$Percentage\ Change = \left(\frac{(New\ Scenario - BAU)}{BAU}\right) * 100 \qquad \forall_{KPI}$$

Then, the sustainability performance of each scenario is estimated by multiplying the change rate by the adjusted weight (AW calculated in Step 2). Finally, all values for each scenario are aggregated and ranked from the highest to the lowest.

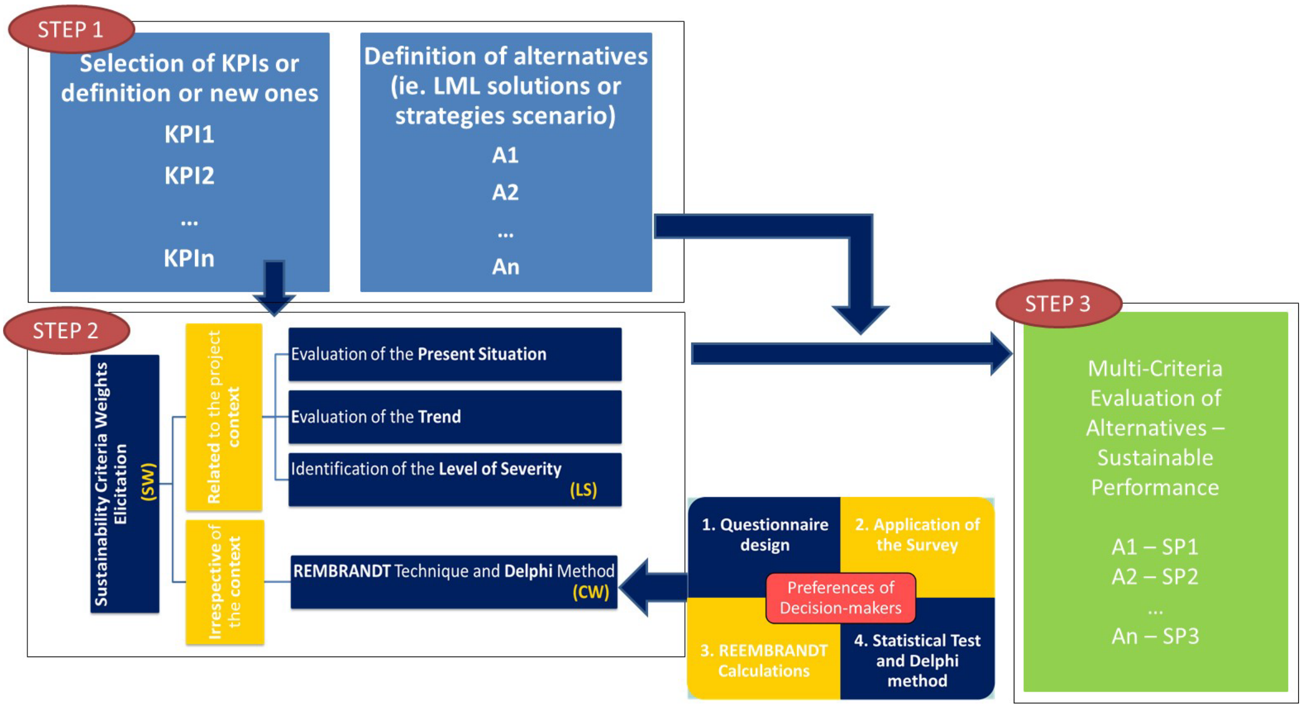

Figure 1: STAR Logistics methodology framework

The STAR Logistic Methodology is transferable as it is applicable to any value case and any context where an innovative logistic solution is implemented, though it may need a specific calibration of the weights for each context. STAR Logistics can be utilised on a large scale by multiple end-users (policymakers, planners, logistics operators, consultants and researchers) who can showcase and publicise the environmental, social and economic benefits of innovative last-mile logistics solutions.

The following chapters include a description of the steps taken to apply the STAR Logistic methodology to the use cases of the six Living Labs of the LEAD project. Chapter 2.3 explains the selection of sustainability criteria based on the KPIs. Chapter 2.4. explains the calculation of the

Converge Weights (CW) for each criterion (KPI) based on the experts' judgements for the LEAD project. Then, Chapter 2.5 shows the calculation of the Severity Levels (SL) of each LEAD LL context. Chapter 2.6 includes the estimation of the Adjusted Weights (AW) for each LEAD LL. Finally, the main conclusions of the application of STAR Logistics to the LEAD project are described in Chapter 2.7.

2.3 LEAD sustainability criteria and measurement

The first step of the STAR Logistic methodology sets the sustainability criteria (KPIs) adapted to each specific case study. The sustainability criteria for assessing LEAD strategies within the project were defined by the consensus of all project partners based on a first list of KPIs. As a result, 15 KPIs (see Deliverable 1.4) were selected and defined based on the triple bottom line of sustainability (see Table 1):

- *Social criteria*. Job creation, quality of the jobs, and neighbourhood quality of life criteria were chosen.
- *Environmental criteria*. Energy consumption, GHG emissions, NOx emissions, PM emissions, and noise pollution were chosen.
- *Economic criteria*. Average delivery cost of the business model, congestion, urban storage & parking space, financial Internal Rate of Return (FIRR) of the business models, shop retail benefits, delivery time, and delivery reliability within the time windows.

The KPIs will compare the impact of implementing the proposed LEAD scenarios with the baseline (BAU) scenario. Additionally, for each KPI its direction is included (see the last column of Table 1), which means that if it is positive (+1) the more is better and if it negative (-1) the less is better. The definition and measurement of such KPIs are included in Chapter 3 of Deliverable 3.1 of the LEAD project. Basically, the measurement of the KPIs can be carried out directly by using data provided by the operator or companies involved in the LL, through the use of the DT for hypothetical scenarios (via simulations), through surveys for qualitative KPIs, or through the use of transport models or other specific methodologies.

Table 1: KPIs selected

Component	Name	Unit	Direction [a]
Social	Job Creation	Employee	+1
Social	Quality of the jobs	Value between 1 to 5	+1
Social	Neighbour quality of life	Value between 1 to 5	+1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	gNO2e/delivery	-1
Environmental	PM emissions	gPM/delivery	-1
Environmental	Noise pollution	dBA*h/day	-1

Component	Name	Unit	Direction [a]
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	%	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	Financial Internal Rate of Return	%	+1
Economic	Shop retail benefits	Value between 1 to 5	+1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	+1
[a](+1) More is better, (-1) Less is better			

2.4 Expert decision-makers survey for LEAD: Convergent Weights

Step 2 of STAR Logistics Methodology (see Section 2.2) calculates the Adjusted Weight (AW) corresponding to each criterion. The AWs incorporate both geographical and social context and expert decision-makers judgments.

In fact, involving experts with diverse backgrounds in LML is crucial for bridging theoretical approaches, current design practices, and decision-making processes. To achieve that, the STAR Logistics Methodology follows the five-step process proposed by Bueno and Vassallo (2015) that combines the DELPHI and REMBRANDT methods (see Step 2 of Figure 1) and consist of the following steps:

1. *Designing a questionnaire*. Develop a questionnaire that includes pairwise comparisons among sustainability criteria. The questionnaire was defined in the SurveyMonkey platform (see Annex 1).
2. *Expert selection*. Choose a minimum of thirty participants who can provide trustworthy responses for the weighting exercise.
3. *Survey administration*. Distribute the questionnaire to the selected experts and collect their preferences using the REMBRANDT technique described by Olson et al. (1995) to derive criteria weights.
4. *Consensus evaluation*. Conduct a statistical test to assess the level of consensus among the experts. Utilise R software to perform a simulation-based cross-validation technique for estimating consensus.
5. *Converge weights*. Once the consensus values have been obtained, the next step is to estimate the convergence weights. These weights represent each criterion's relative importance or priority based on the experts' collective judgment. The convergence weights provide valuable insights to know each criterion's significance within the study context. This process provides a solid foundation for the subsequent analysis and evaluation of last-mile logistics sustainability criteria. Overall, estimating convergence weights is a crucial step in the research process, as it provides valuable insights into the relative importance of different

criteria, aiding in the development of sustainable last-mile logistics strategies and decision-making.

The online survey was distributed via email to the Community of Practice of each LEAD LL, which includes various public and private stakeholders involved or interested in the urban freight transport value chain, such as public administration and local authorities, universities and logistics research centres, mobility clusters, logistics service providers, and freight transport associations, among others. The survey was disseminated to all LLs through media channels, with the support of all project partners (LEAD Project, 2020).

Experts were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector. More than 90% of participants were from European countries, with significant participation from Spain (28%), Hungary (15%), and Belgium (9%). Around 30% of the representatives were from public authorities, another 30% from the academic and research community, and the remaining from the logistics industry, including logistics operators, shippers, and consultants. Concerning the years of experience in LML, 35% of participants had more than 10 years, 28% between 5-10, 24% between 2 – 5, and only 13% less than 2 years (see Figure 2).

Figure 2: Experts' experience distribution

Annex 1 shows the whole pairwise comparison questionnaire. The answers collected are open and available from Vassallo et al. (2023). They compare the importance of different sustainability criteria based on a range from -8 (Very strong preference from Criteria 1 over Criteria 2) to +8 (Very strong preference from Criteria 2 over Criteria 1). This range is known as the REMBRANDT scale (Karbassi Yazdi and Abdi, 2017; Olson et al., 1995). To help experts understand trade-offs between criteria, the questionnaire provided an example to show how to analyse pairwise comparison.

Applying the methodology described above, the weights for each sustainability criterion were calculated and normalised. As shown in Figure 3, the most important criteria for the stakeholders are (i) increasing job creation within the social criteria, reducing energy consumption within the environmental criteria; and (iii) reducing delivery costs of LML services for the economic criteria. Another insight of the analysis is that the social component is crucial for the experts.

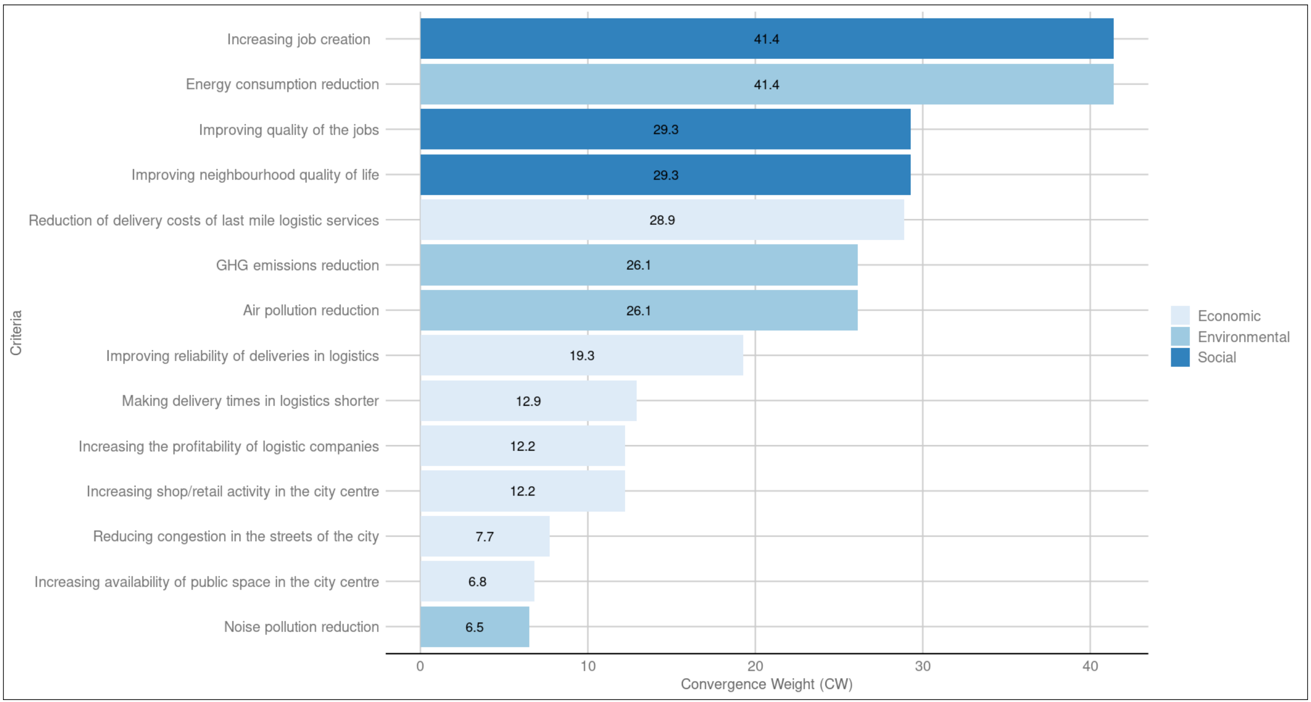

Figure 3: Experts' Weights for each criterion

2.5 LEAD Living Labs context weights: Severity Level

To assess a LL context, the *Severity Level* (SL) index is defined as a composite index including both the *Present Situation* (PS) and *Trend* (T) for the selected sustainable criteria at the urban context where the specific Living Lab is implemented. The Present Situation for each criterion and LL is evaluated on a scale of 0 to 5 points based on how it is compared to the average in the context. The Trend is classified as "improving", "stable", or "worsening" and allocated 0 to 2 points accordingly. The SL is the sum of the Present Situation and Trend, with a range from 0 to 7.

$$SL_i = PS_i + T_i$$

where SL_i – Severity Level of criterion *i*; PS_i – Present Situation for criterion *i*; T_i – Trend for criterion *I* for each LL area.

For each criterion, the situation of the urban context measured through a specific attribute (for instance, air quality performance) is compared with the average for all LLs through the *Present Situation*. Suppose that a city has air quality levels worse than the average of the cities in context, and their tendency (*Trend*) in the near future is to keep on worsening. In that case, a higher *SL* will be applied to such criterion compared to other cities where air quality is not as critical for sustainability as it is for this city.

The situation in each urban context for sustainability criteria can be measured either quantitatively or qualitatively depending on their nature. Quantitative attributes were consulted in official reports or databases at the city or country level. Regarding qualitative criteria, LEAD project stakeholders from each city (public authorities, logistic operators or both, depending on the criteria) were asked to rate each criterion. For example, regarding the qualitative criteria "urban and parking space," the stakeholders were asked: “how important are the problems of urban and parking space in your city compared to cities with similar characteristics? with five potential answers: *(1) Not at all important, (2) Slightly important, (3) Moderately important, (4) Very important, and (5) Extremely important*. For the qualitative criteria "average delivery cost" criteria, the stakeholders were asked: “how are average delivery costs for last-mile logistics in your city compared to other cities with similar characteristics? *Much lower/ Lower/ About the same/ Higher/ Much Higher*. Table 2 shows the present situation (PS) and trends (T) for criteria attributes of all LL cities and the average in context of the six cities.

Table 2: Present situation (PS) and trends (T) for criteria attributes of all cities Living Labs and average in the context

	Criteria	Attributes	Unit	Present Situation *Trends*						
				Madrid	The Hague	Lyon	Budapest	Oslo	Porto	Average in Context
Social	**Job Creation**	Unemployment rate (%) - ***Region level (2020)*** (Eurostat, 2022a)	%	12.50% *Improving*	4.40% *Improving*	7.20% *Improving*	3.30% *Stable*	5.10% *Stable*	6.90% *Stable*	6.80%
	Quality of the Jobs	OECD Better Life Index: Jobs - **Country Level** ***(2019)*** (OECD, 2020)	[0-10]	5.3 *Stable*	9.1 *Stable*	7.5 *Worsening*	7.0 *Worsening*	8.8 *Stable*	6.5 *Stable*	7.4
	Neighbours' Quality of Life	Citizens' Satisfaction with living in the city [1-100] **City Level** ***(2019)*** (European Commission, 2020)	[1-100]	84.20 *Worsening*	94.70 *Improving*	95.80 *Improving*	86.20 *Worsening*	97.10 *Worsening*	97.30 *Stable*	92.55
Environmental	**Energy consumption**	Share of renewable energy in gross final energy consumption in transport (%) - ***Country-level*** / *Context EU* ***(2020)***(Eurostat, 2022b)	%	9.50% *Improving*	12.60% *Improving*	9.20% *Improving*	11.60% *Stable*	28.70% *Improving*	9.70% *Improving*	13.55%
	GHG emissions	Global criteria		- *Worsening*	- *Worsening*	- *Worsening*	- *Worsening*	- *Worsening*	- *Worsening*	-
	NOx emissions	Annual means concentration of NO2 (µg/m3) - *Mean across urban stations* - ***City level (2019)*** (European Environment Agency, 2020)	µg/m3	21.3 *Improving*	26.13 *Improving*	21.13 *Improving*	24.8 *Stable*	24.02 *Improving*	24.75 *Stable*	23.7
	PM emissions	Annual means concentration of PM2.5 (µg/m3) - *Mean across urban stations* - ***City level***	0-10 µg/m3 = Good / 10-15 moderate / 15-25 poor / 25-35 very poor	Good *Stable*	Good *Improving*	Moderate *Improving*	Moderate *Improving*	Good *Improving*	Good *Stable*	

	Criteria	Attributes	Unit	Present Situation *Trends*						
				Madrid	The Hague	Lyon	Budapest	Oslo	Porto	Average in Context
		(2019) (European Environment Agency, 2021)								
	Noise pollution	People exposed to day-evening-night average sound levels of ≥55dB (%) - ***City level (2019)*** (European Environment Agency, 2020)	Number of people	36% *Improving*	56% *Worsening*	63% *Improving*	64% *Worsening*	74% *Stable*	16% *Worsening*	52%
Economic	**Average delivery cost of the business model**	QUALITATIVE[1]	[Much lower / Lower / About the same / Higher / Much higher]	About the same *Stable*	About the same *Improving*	About the same *Worsening*	Higher *Worsening*	About the same *Worsening*	About the same *Worsening*	
	Congestion	Time lost per year in congestion - (Hours) - ***City Level /*** *Context average LEAD cities* ***(2021)*** (TomTom, 2022)	Hour/driver-year	41 *Stable*	59 *Stable*	66 *Stable*	69 *Stable*	46 *Stable*	52 *Improving*	55.5
	Urban storage & parking space	QUALITATIVE[2]	[Not at all important / Slightly important / Moderately important / Very important / Extremely important]	Very important *Stable*	Very important *Improving*	Moderately important *Improving*	Very important *Stable*	Very important *Worsening*	Very important *Worsening*	
	Financial Internal Rate of Return (FIRR)	QUALITATIVE[3]	[Much lower / Lower / About the same / Higher / Much higher]	Lower *Worsening*	Lower *Improving*	Higher *Improving*	About the same *Stable*	Lower *Improving*	Lower *Stable*	
	Shop retail benefits	Retail Trade Turnover Index (2015=100) ***Country-level /*** *Context EU* ***(2021)*** (Eurostat, 2022c)	Index 2015=100	121.3 *Worsening*	121.1 *Improving*	126 *Improving*	166 *Stable*	131.8 *Improving*	127.7 *Improving*	132.3

Criteria	Attributes	Unit	Present Situation *Trends*						
			Madrid	The Hague	Lyon	Budapest	Oslo	Porto	Average in Context
Delivery time	QUALITATIVE[4]	[Much lower / Lower / About the same / Higher / Much higher]	About the same *Improving*	About the same *Improving*	About the same *Improving*	About the same *Stable*	About the same *Stable*	About the same *Stable*	
Delivery reliability within the time windows	Frequency with which shipments reach consignee within schedule or expected time. [1-5] - ***Country level (2018)*** (The World Bank, 2020)	[1-5]	4.06 *Stable*	4.25 *Worsening*	4.15 *Stable*	3.79 *Worsening*	3.94 *Stable*	4.13 *Improving*	4.05

[1] **How are average delivery costs for last mile logistics in your city compared to other cities with similar characteristics?**
[2] **How important are the problems of urban and parking space in the city of your Living Lab compared to cities with similar characteristics?**
[3] **Compared to other sectors of the local economy, the logistics sector's return on investment in the Living Lab region is…**
[4] **How long are average delivery times for last-mile logistics in your city compared to other cities with similar characteristics?**

The ***Severity Level (SL)*** for each city was estimated by summing up the *Present Situation* value and the *Trend* value. As shown in Table 3, the *SL* is presented for each criterion and city. PS is calibrated on a 0-5 scale for numerical attributes criteria. This calibration involved comparing the numerical value of the attribute with the contextual average. The procedure assumes a baseline value of 3 within the context and then estimates the attribute's value as a proportionate adjustment on a scale of up to 5. For instance, consider Madrid's unemployment rate at 12.5%, compared to the context average of 6.8%. The calculation would be 3 * (12.5/6.8) ≈ 5.5. However, since the scale is limited to a maximum of 5, the assigned value would be 5. In cases where more is better, the scale, such as the OECD Better Life Index - Jobs, must be inverted. Otherwise, when the attributes are qualitative, the present situation (PS) was defined directly by the stakeholders of the city (see Section 3.2.2). At first glance, it is clear how each city presents different concerns. That demonstrates the importance of considering the urban context in the analysis.

The social component of sustainability is important for Madrid since, compared to other cities, the unemployment rate is the highest and the Quality of the jobs the poorest among the cities considered. Moreover, the expected trends for those factors are not promising. In the rest of the cities, the social component is not as sensitive as it is in Madrid, and trends are more stable.

As for the environmental component, there are different results among the cities. For Madrid, Lyon, and Porto, energy consumption is more sensitive compared to other cities. For The Hague, reduction of nitrous oxides is important. It is important to note that noise pollution reduction is highly sensitive in The Hague, Budapest, and Oslo. Although CO_2 is included within the criteria, it does not directly affect the local level, as climate change is a global environmental impact. For that reason, no context weights were assigned to that criterion.

Different concerns are identified among the cities about the economic component. For example, for Budapest, the average delivery cost of the business model is the most important among the economic criteria. Lyon, which maintains a medium severity level in the other criteria, reports congestion as a significant issue. Madrid, Oslo, and Porto have a lack of storage space and urban parking, and the situation is not expected to improve in the future. Finally, Madrid considers retail profits as a sensitive criterion.

Table 3: Severity Level Index for LEAD Living Labs areas

	Criteria	Madrid			The Hague			Lyon			Budapest			Oslo			Porto		
		PS	T	SL	PS	T	SL	PS	T	SL	PS	T	SL	PS	T	SL	PS	T	SL
Social	Job Creation	5	0	***5***	1	0	***1***	3	0	***3***	1	1	***2***	1	1	***2***	2	1	***3***
	Quality of the Jobs	5	1	***6***	1	1	***2***	2	2	***4***	2	2	***4***	1	1	***2***	3	1	***4***
	Neighbours' Quality of Life	3	2	***5***	1	0	***1***	1	0	***1***	3	2	***5***	1	2	***3***	1	1	***2***
Environmental	Energy consumption	5	0	***5***	3	0	***3***	5	0	***5***	3	1	***4***	1	0	***1***	5	0	***5***
	GHG emissions[1]	3	0	***3***	3	0	***3***	3	0	***3***	3	0	***3***	3	0	***3***	3	0	***3***
	NOx emissions	2	0	***2***	5	0	***5***	2	0	***2***	3	1	***4***	3	0	***3***	3	1	***4***
	PM emissions	1	1	***2***	1	0	***1***	3	0	***3***	3	0	***3***	1	0	***1***	1	1	***2***
	Noise pollution	1	0	***1***	4	2	***6***	4	0	***4***	4	2	***6***	5	1	***6***	1	2	***3***
Economic	Average delivery cost of the business model	3	1	***4***	3	0	***3***	3	2	***5***	4	2	***6***	3	2	***5***	3	2	***5***
	Congestion	1	1	***2***	4	1	***5***	5	1	***6***	5	0	***5***	2	1	***3***	2	0	***2***
	Urban storage & parking space	4	1	***5***	4	0	***4***	3	0	***3***	4	0	***4***	4	2	***6***	4	2	***6***
	Financial Internal Rate of Return (FIRR)	2	2	***4***	2	0	***2***	4	0	***4***	3	0	***3***	2	0	***2***	2	1	***3***
	Shop retail benefits	4	2	***6***	4	0	***4***	4	0	***4***	1	0	***1***	3	0	***3***	4	0	***4***
	Delivery time	3	0	***3***	3	0	***3***	3	0	***3***	3	0	***3***	3	1	***4***	3	1	***4***
	Delivery reliability within the time windows	3	1	***4***	3	2	***5***	3	1	***4***	3	2	***5***	3	1	***4***	3	0	***3***

PS: Present Situation, T: Trend and SL: Severity Level
[1] GHG emissions are a global criterion that is equally important for all cities.

2.6 Criteria Weights for each Living Lab: Adjusted Weights

We notice significant differences across cities from previous sections because of the context. Those differences are used to adjust the weights previously calculated by the experts. Following the description of Step 2 in Section 2.2, Table 4 summarises the most relevant results of the adjusted weights for each city and criterion. The comparison between all cities and each sustainability component shows the main results obtained after applying the STAR Logistics methodology. For this analysis, Adjusted Weights can vary from 0 to 290 (considering an *SL* of 7 and the highest obtained Experts' Weights in Section 2.4).

Table 4: Adjusted Weight for each criterion and Living Lab

Criteria	Madrid	The Hague	Lyon	Budapest	Oslo	Porto
Job Creation	207.10	41.42	124.26	82.84	82.84	124.26
Quality of the Jobs	175.74	58.58	117.16	117.16	58.58	117.16
Neighbour Quality of Life	146.45	29.29	29.29	146.45	87.87	58.58
Energy consumption	206.85	124.11	206.85	165.48	41.37	206.85
GHG emissions	78.18	78.18	78.18	78.18	78.18	78.18
NOx emissions	52.12	130.30	52.12	104.24	78.18	104.24
PM emissions	52.12	26.06	78.18	78.18	26.06	52.12
Noise pollution	6.51	39.06	26.04	39.06	39.06	19.53
Average delivery cost of the business model	115.8	86.85	144.75	173.70	144.75	144.75
Congestion	15.34	38.35	46.02	38.35	23.01	15.34
Urban storage & parking space	34.15	27.32	20.49	27.32	40.98	40.98
FIRR	48.68	24.34	48.68	36.51	24.34	36.51
Shop retail benefits	73.02	48.68	48.68	12.17	36.51	48.68
Delivery time	38.67	38.67	38.67	38.67	51.56	51.56
Delivery reliability within the time windows	77.28	96.60	77.28	96.60	77.28	57.96

As shown in Table 4, Madrid is quite sensitive to social criteria, especially in terms of job creation. The environmental component is also significant, with energy consumption ranking particularly high. Reducing noise in Madrid is not as important as it is in other cities, given that noise does not appear to be a big problem. Overall, the city of Madrid should stress implementing last-mile solutions positively impacting the creation of high-quality jobs, reducing energy consumption and reducing delivery costs.

The Hague context places greater emphasis on the environmental component rather than the social one. Table 4 illustrates that the highest adjusted weights for the city are for NOx emissions and energy consumption, followed by delivery reliability within specified time frames, and average delivery costs, two of the main economic criteria. In contrast to Madrid, noise pollution has great importance, leaving the Financial Internal Rate of Return (FIRR) and the PM emissions at the bottom of the list. Some social and economic criteria have similar weights, such as Quality of jobs and benefits for retail stores, as well as urban storage and parking space and the Quality of life in neighbourhoods. In short, sustainable LML solutions for The Hague, should preferably have positive impacts on NOx emissions, energy consumption reduction, average delivery cost reduction and improved delivery reliability.

Lyon and Porto follow a similar behaviour. The energy consumption criterion corresponded to the most significant adjusted weight, followed by the average delivery cost of the business model (see Table 4). Job creation and Quality of jobs also received a notable weight, indicating the crucial role played by various social factors in achieving sustainable LML. Interestingly, the adjusted weight obtained by the city of Lyon for neighbourhood quality of life was one of the lowest, despite the high importance assigned by the experts. In addition, the other economic criteria did not receive a significant weight, except for the average delivery cost of the business model. However, the adjusted weights for Lyon are higher than Porto.

In Budapest, as shown in Table 4, the sustainability criteria with the greatest importance are the average delivery cost of the business model, energy consumption, and neighbourhood quality of life. Thus, each dimension of sustainability (economic, environmental and social) has to be tackled. Notably, the adjusted weights for environmental criteria related to air quality emissions have also shown significant importance, following a similar pattern to the experts.

Oslo substantially differs from other cities. While for other cities the energy consumption criterion is crucial, this is not the case for Oslo. Table 4 reveals that for Oslo, the most significantly adjusted weight was the average delivery cost, indicating that reducing the cost is critical to achieving more sustainable LML. While GHG and NOx emissions have high adjusted weights, PM emissions have the lowest.

Although each city has differences in the importance of the criteria towards achieving sustainable LML, the results suggest that, in general, all six Living Labs aim to implement strategies that achieve a positive impact on all three pillars of sustainability, but with a special focus on improving the environmental and social aspects, which are the dimensions that have been least considered when developing the business models for LML solutions.

2.7 Conclusions

In conclusion, the STAR Logistics Methodology adapted to the LEAD project assessed the impacts of LEAD strategies through different value cases in six European cities. The methodology shows that STAR Logistics allows taking tailor-made decisions according to each city's sustainability needs, considering the context's sensitivity and expert perspectives.

In fact, significant differences have been found when the experts' preferences are combined with each city's needs factoring in the urban context. For instance, last-mile strategies impacting employment are much more critical in cities like Madrid, with high unemployment rates, compared to cities like The Hague, where unemployment rates are negligible.

Environmental and social sustainability components have different importance across cities. Madrid is more sensitive to both, while The Hague mainly emphasises the environmental component. Lyon and Porto prioritise energy consumption and job creation, while Budapest prioritises the average delivery cost of the business model and energy consumption. Oslo focuses on enhancing the business model, with a lower priority for PM emissions.

Consequently, the STAR Logistics methodology adapted to the LEAD LLs supports making sustainability-oriented decisions when selecting different LEAD value cases towards low-emission adaptive LML supporting the on-demand economy.

3 LEAD Sustainability Performance for Last-Mile Logistics Solutions: STAR Logistics Results

Chapter 3 contains the sustainability impact assessment of different LML solutions proposed by each LEAD LL. The aim is to conduct the sustainability assessment of different LML solutions alternatives based on the pilot LLs using the STAR Logistics Methodology (Chapter 2). Each of the following subchapters correspond to each LEAD LL and is structured as follows:

- *Subchapter 3.X.1*. *Scenario definition* where the “what if” scenarios to be assessed for each LL are set.
- *Subchapter 3.X.2. KPIs* needed in the STAR Logistic Methodology (see Table 1) are estimated for each scenario using a threefold approach: (i) via simulation using the Digital Twin Tool which generates specific KPIs based on DT models, (ii) from the logistic operator data which provided KPI values through internal estimation, and (ii) survey-based for qualitative KPIs in the public workshops organized through the LEAD project in which participants were engaged in a survey-based approach, offering valuable feedback and insights after being presented with each scenario.
- *Subchapter 3.x.3. Sustainable performance* where the adjusted weights for each LL (from Table 4) are presented, and the sustainability rating for each of the scenarios are calculated following the STAR Logistics Methodology.
- *Subchapter 3*.x.4. *Long-term impact assessment* where a long-term impact assessment is included for one scenario selected.

3.1 Madrid LL Last-Mile Logistic Solutions Alternatives

The Madrid LL proposed to evaluate the sustainability impacts of implementing a UCC in the Low Emission Zone (LEZ) located in the city centre of Madrid and using low-carbon vehicle fleets for parcel deliveries. The steps followed to obtain the results of the sustainability performance for the alternatives studied in the LL Madrid are described below (Annex 3 also contains the results obtained from the STAR Logistics software in detail).

3.1.1 Scenarios definition

LL1 - Madrid LL partners decided to evaluate two delivery system scenarios (BAU with two use cases and UCC with three use cases) (see Table 5):

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

Table 5: Madrid LL scenarios definition

Scenarios	Nomenclature	Description
Scenario 0	BAU: Diesel Van	BAU scenario with direct delivery using diesel internal combustion engine cargo vans from a logistics platform located 25km from the city centre.
Scenario 1	BAU: E-Van	BAU scenario with direct delivery using 100% electric powertrains small cargo vans from a logistic platform located 25km from the city centre.
Scenario 2	UCC: Hybrid Van + E-scooter	UCC scenario, delivery first to a UCC in underground parking located in the city centre with a hybrid small cargo van and last-mile delivery with 100% electric powertrains three-wheeled delivery trikes.
Scenario 3	UCC: E-van + E-scooter	UCC scenario, delivery first to a UCC in underground parking located in the city centre with 100% electric powertrains small cargo vans and last-mile delivery with 100% electric powertrains three-wheeled trikes.
Scenario 4	UCC: Big E-van + E-scooter	UCC scenario, delivery first to a UCC in underground parking located in the city centre with 100% electric powertrains large cargo vans and last-mile delivery with 100% electric powertrains three-wheeled trikes.

3.1.2 KPIs for Madrid LL Scenarios

The impacts of the scenarios are measured by monitoring a set of common LEAD KPIs. The KPIs compare the impact of conducting the scenarios with the baseline scenario (scenario 0). Table 6 summarizes the values obtained for each KPI and scenarios assessed.

Table 6: KPIs estimation for Madrid LL scenarios

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Social	Job creation (employees)	5	5	10	10	10
Social	Quality of the jobs [1 – 5]	3.0	3.0	3.6	3.6	3.6
Social	Neighbourhood quality of life [1-5]	3.0	4.4	4.4	4.4	4.4
Environmental	Energy consumption (MJ/delivery)	1.33	0.07	0.28	0.07	0.07
Environmental	GHG emissions (gCO_2e/delivery)	356.960	0.030	63.610	0.020	0.010
Environmental	NOx emissions (gNO_2/delivery)	0.440	0.000	0.000	0.000	0.000
Environmental	PM emissions (gPM/delivery)	0.030	0.000	0.010	0.000	0.000

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Environmental	Noise pollution (% population)	59.73	49.13	34.96	34.96	34.96
Economic	Average delivery cost of the business model (€/delivery)	2.3	2.4	2.5	2.6	2.4
Economic	Congestion (m^2*h/day)	300.65	300.65	180.56	180.56	180.56
Economic	Urban storage & parking space (m^2)	45.07	45.07	245.07	245.07	245.07
Economic	FIRR (%)	4.0	3.0	2.0	1.0	2.0
Economic	Shop retail benefits [1-5]	3.0	3.0	3.8	3.8	3.8
Economic	Delivery time (min/delivery)	5.0	5.0	4.0	4.0	4.0
Economic	Delivery reliability within the time windows (%)	0.8	0.8	0.9	0.9	0.9

In order to compare all the KPIs in a homogenous way throughout all LLs, and normalize their values, the variation of each scenario compared to the base scenario (Scenario 0) is calculated (see Table 7). It should be noted that the value 0 means that there is no change with respect to Scenario 0 (BAU scenario). As it can be seen, there is much change in urban storage and parking space, job creation, and environmental KPIs.

Table 7: KPIs change from baseline scenario Madrid Living Lab

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Social	Job creation	0.0	1.0	1.0	1.0
Social	Quality of the jobs	0.0	0.2	0.2	0.2
Social	Neighbourhood quality of life	0.5	0.5	0.5	0.5
Environmental	Energy consumption	-0.9	-0.8	-0.9	-0.9
Environmental	GHG emissions	-1.0	-0.8	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0	-1.0
Environmental	PM emissions	-1.0	-0.7	-1.0	-1.0
Environmental	Noise pollution	-0.2	-0.4	-0.4	-0.4
Economic	Average delivery cost of the business model	0.0	0.1	0.1	0.0
Economic	Congestion	0.0	-0.4	-0.4	-0.4
Economic	Urban storage & parking space	0.0	4.4	4.4	4.4
Economic	FIRR	-0.2	-0.5	-0.8	-0.5
Economic	Shop retail benefits	0.0	0.3	0.3	0.3
Economic	Delivery time	0.0	-0.2	-0.2	-0.2

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Economic	Delivery reliability within the time windows	0.0	0.1	0.1	0.1

3.1.3 Sustainable Performance for Madrid LL scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for Madrid LL (from Table 4) and the change rate (Table 7) is made. The sign was changed according to its effect on sustainability as explained in Table 1 (+1 More is better, -1 Less is better). Table 8 presents the aggregate values obtained for each scenario. As it can be seen, scenarios that have a favourable impact on job creation, energy consumption, GHG emissions or delivery reliability, will be the ones with the best sustainability score.

Table 8: Sustainable Performance for Madrid LL scenarios

Dimension	KPI	Adjusted Weight	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Social	Job creation	*207.1*	0.000	207.100	207.100	207.100
	Quality of the jobs	*175.74*	0.000	35.148	35.148	35.148
	Neighbourhood quality of life	*146.45*	73.225	73.225	73.225	73.225
Environmental	Energy consumption	*206.85*	186.165	165.482	186.165	186.165
	GHG emissions	*78.18*	78.180	62.544	78.180	78.180
	NOx emissions	*52.12*	52.120	52.120	52.120	52.120
	PM emissions	*52.12*	52.120	36.484	52.120	52.120
	Noise pollution	*6.51*	1.302	2.604	2.604	2.604
Economic	Average delivery cost of the business model	*115.8*	0.000	-11.580	-11.580	0.000
	Congestion	*15.34*	0.000	6.136	6.136	6.136
	Urban storage & parking space	*34.15*	0.000	-150.260	-150.260	-150.260
	FIRR	*48.68*	-9.736	-24.340	-38.944	-24.340
	Shop retail benefits	*73.02*	0.000	21.906	21.906	21.906
	Delivery time	*38.67*	0.000	7.734	7.734	7.734
	Delivery reliability within the time windows	*77.28*	0.000	7.728	7.728	7.728
Sustainable Performance			**433.376**	**492.029**	**529.382**	**555.566**
Sustainable Rating			4th	3rd	2nd	1st

The results indicate that **Scenarios 4 and 3** reach the highest sustainability rate compared to Scenario 0, thereby demonstrating that a UCC utilising 100% electric vehicles for B2C deliveries in Madrid's city centre is the most sustainable approach.

3.1.4 Long-term impact assessment for Madrid

In Madrid, one of the priorities of the Urban Goods Distribution Strategy within the Madrid 360º Sustainable Urban Mobility Plan (Ayuntamiento de Madrid, 2023) is the promotion of UCCs or micro-hubs through public-private collaboration.

The long-term impacts of implementing UCCs in Madrid consist of estimating impacts (GHG emissions, energy consumption or time) on the city if the UCC is implemented at a large scale replicating the Madrid pilot solution (Scenario 2).

Table 9 presents the KPIs value of the BAU scenario vs. Scenario 2 UCC for the Madrid LL that will be used in the long-term impact assessment.

Table 9: Some KPIs for the BAU scenario vs. Scenario 2 UCC in Madrid Living Lab

Dimension	KPI	Units	Scenario BAU	Scenario 2 UCC Plaza Mayor pilot
Environmental	Energy consumption	kWh/delivery	1.330	0.280
Environmental	GHG emissions	gCO2/delivery	356.960	63.610
Economic	Delivery time	min/delivery	5.000	4.000

With the current characteristics of the Plaza Mayor UCC, the ideal situation is to operate at maximum capacity, being able to move 2,000 deliveries/day, which means a total of 700,000 deliveries/year. Table 10 shows the annual energy consumption, GHG emissions, and time savings at full capacity. For instance, if an average household in Spain consumes 3,272kWh/year[6] with the 100% operational utilisation of Plaza Mayor UCC, we could save the equivalent energy of more than 220 Spanish households.

Table 10: Annual savings for Scenario 2 UCC in Plaza Mayor at maximum capacity

Maximum capacity of UCC Plaza Mayor: 700,000 deliveries/year			
KPI (Units)	**Scenario BAU**	**Scenario 2 UCC**	**Annual Savings**
Energy consumption (kWh/year)	931,000	196,000	**735,000**
GHG emissions (tCO_2/year)	249.9	44.5	**205.4**
Delivery time (h/year)	58,333.3	46,666.7	**11,666.7**

In a **5-year horizon**, Madrid city is expected to have 4 UCCs similar to Plaza Mayor around the city, which means a total of 2,800,000 deliveries/year. Table 11 shows the annual savings of energy consumption, GHG emissions and time for this 5-year horizon situation in comparison to the BAU scenario.

Table 11: Annual savings situation for a 5-year horizon in Madrid city

5 years horizon x 4 UCCs Plaza Mayor (max. capacity)			
KPI (Units)	**Scenario BAU**	**Scenario 2 UCC**	**Annual Savings**
Energy consumption (kWh/year)	3,724,000	784,000	**2,940,000**
GHG emissions (tCO_2/year)	999.5	178.1	**821.4**

6 https://www.naturgy.es/hogar/blog/cuanta_electricidad_consume_una_casa#:~:text=Seg%C3%BAn%20Red%20El%C3%A9ctrica%20Espa%C3%B1ola%20(REE,anual%20es%20de%203.272%20kWh.

Delivery time (h/year)	233,333.3	186,666.7	**46,666,7**

In a **10-year horizon**, Madrid city is expected to have 7 UCCs similar to the one implemented in Plaza Mayor, which means a total of 4,900,000 deliveries/year. Table 12 shows the annual savings of energy consumption, GHG emissions and time for this 5-year horizon situation in comparison to the BAU scenario.

Table 12: Annual savings situation for a 10-year horizon in Madrid city

10 years horizon x 7 UCCs Plaza Mayor (max. capacity)			
KPI (Units)	**Scenario BAU**	**Scenario 2 UCC**	**Annual Savings**
Energy consumption (kWh/year)	6,517,000	1,372,000	**5,145,000**
GHG emissions (tCO_2/year)	1,749.1	311.7	**1,437.4**
Delivery time (h/year)	408,333.3	326,666.7	**81,666.7**

In conclusion, and based on the results of the LEAD project on the city of Madrid, the long-term implementation of the UCCs will positively impact the city.

Furthermore, Madrid LL LEAD participants highlight that the following aspects may facilitate or hinder the implementation of this solution in the city and should be considered for a successful implementation in the medium-long term in the city:

- The availability of urban space and the cost uncertainty of that space makes the business model feasible for the logistic operator.
- A favourable regulatory or strategic framework of the city.
- Involvement and interest of logistic operators.
- Involvement of large shippers/retailers for these sustainable models that benefit them in terms of reputation while meeting operational objectives (cost and time, primarily).
- Neighbourhood involvement and agreement.
- Availability of vehicle technologies adapted to low-carbon logistics.
- For a wider adoption of UCCs in the city, a facilitator will be the adequate infrastructure (space, gauge, access ramps, etc.) for loading/unloading.

3.2 The Hague LL Last-Mile Solutions Alternatives

The Hague Living Lab proposed to evaluate the sustainability impacts of implementing *crowdshipping* and parcel lockers or the combination of both in the city of The Hague. The *crowdshipping* service is assumed to be available for both Business to Consumer (B2C) and Consumer to Consumer (C2C) parcel deliveries by a local pool of bringers. The parcel lockers will be provided in public spaces. The steps followed to obtain the results of the sustainability performance for the alternatives studied in The Hague LL are described below (Annex 3 also contains the results obtained from the STAR Logistics software in detail).

3.2.1 Scenarios definition

LL2 - The Hague LL partners decided to evaluate three delivery system scenarios (BAU, Crowdshipping and Parcel Lockers), consisting of four use cases summarised in Table 13 (for more information regarding scenarios, see Deliverable 3.6):

Table 13: The Hague LL scenarios definition

Scenarios	Nomenclature	Description
Scenario 0	BAU	Current situation: no crowdshipping services or parcel lockers.
Scenario 1	Crowdshipping	Nimber CS app used widely in the market for The Hague.
Scenario 2	Parcel Lockers	Parcel lockers are fulfilled by bikes and located in the Kakelhof.
Scenario 3	Parcel Lockers + Crowdshipping	Scenario 1 and 2 simultaneously

3.2.2 KPIs for The Hague LL Scenarios

The impacts of the scenarios are measured by monitoring a set of common LEAD KPIs. The KPIs will compare the impact of conducting the scenarios with the baseline scenario (scenario 0), defined as results based on the BAU scenario. The KPIs estimated are included in Table 14. There are four KPIs that could not be estimated by The Hague Living Labs partners, in grey (for more details see Deliverable 3.6). For the missing KPIs, the STAR model will consider no change compared to Scenario 0, being their ratios considered as 0. Note that, it is assumed that for these criteria there is no change compared to the baseline scenario, **so the results of the impact assessment are not entirely conclusive and different scores could be obtained if all KPIs were included**.

Table 14: KPIs estimation for The Hague LL scenarios

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Social	Job creation (employees)	10	48	10	48
Social	Quality of the jobs [1 – 5]	3	3	3	3

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Social	Neighbourhood quality of life [1-5]	3	4.1	4.1	4.1
Environmental	Energy consumption (MJ/delivery)	0.089	0.08165	0.08848	0.08165
Environmental	GHG emissions (gCO_2/delivery)	6.63308	6.0854	6.59477	6.0854
Environmental	NOx emissions (gNO_2/delivery)	0.00244	0.00224	0.00243	0.00224
Environmental	PM emissions (gPM/delivery)	0.00109	0.00100	0.00108	0.00100
Environmental	Noise pollution (% population)	100	100	100	100
Economic	Average delivery cost of the business model (€/delivery)	9.2	5.95	9.2	5.95
Economic	Congestion (m^2*h/day)	343.5	310.5	308.3	308.3
Economic	Urban storage & parking space (m^2)	1	1	1	2
Economic	FIRR (%)	1	1	6	6
Economic	Shop retail benefits [1-5]	3	3.8	3.8	3.8
Economic	Delivery time (min/delivery)	1	1	1	1
Economic	Delivery reliability within the time windows (%)	1	1	1	1

In order to compare all the KPIs and consider them in the same order of magnitude, the change of each scenario concerning the base scenario (Scenario 0) is estimated (see Table 15). It should be noted that the value 0 means that there is no change with respect to the Scenario 0 (BAU scenario). Some criteria, such as Job Creation and FIRR, have relevant changes in some scenarios.

Table 15: KPIs change from baseline scenario The Hague

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3
Social	Job creation	3.8	0.0	3.8
Social	Quality of the jobs	0.0	0.0	0.0
Social	Neighbourhood quality of life	0.4	0.4	0.4
Environmental	Energy consumption	-0.1	0.0	-0.1
Environmental	GHG emissions	-0.1	0.0	-0.1
Environmental	NOx emissions	-0.1	0.0	-0.1
Environmental	PM emissions	-0.1	0.0	-0.1
Environmental	Noise pollution	0.0	0.0	0.0
Economic	Average delivery cost of the business model	-0.4	0.0	-0.4
Economic	Congestion	-0.1	-0.1	-0.1
Economic	Urban storage & parking space	0.0	0.0	1.0

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3
Economic	FIRR	0.0	5.0	5.0
Economic	Shop retail benefits	0.3	0.3	0.3
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0

3.2.3 Sustainable Performance for The Hague LL scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for The Hague and the change rate (see Table 15) is conducted. The sign was changed according to its effect on sustainability (+1 more is better, -1 less is better). Table 16 presents the aggregate values obtained for each scenario. As it can be seen, scenarios in The Hague that have a favourable impact on environmental KPIs and on the average delivery cost of the business models, will be the ones with the best sustainability score.

Table 16: Sustainable Performance for The Hague LL Last-Mile Logistics Alternatives

Dimension	KPI	Adjusted Weight	Scenario 1	Scenario 2	Scenario 3
Social	Job creation	*41.42*	157.396	0.000	157.396
Social	Quality of the jobs	*58.58*	0.000	0.000	0.000
Social	Neighbourhood quality of life	*29.29*	11.716	11.716	11.716
Environmental	Energy consumption	*124.11*	12.411	0.000	12.411
Environmental	GHG emissions	*78.18*	7.818	0.000	7.818
Environmental	NOx emissions	*130.3*	13.030	0.000	13.030
Environmental	PM emissions	*26.06*	2.606	0.000	2.606
Environmental	Noise pollution	*39.06*	0.000	0.000	0.000
Economic	Average delivery cost of the business model	*86.85*	34.740	0.000	34.740
Economic	Congestion	*38.35*	3.835	3.835	3.835
Economic	Urban storage & parking space	*27.32*	0.000	0.000	-27.320
Economic	FIRR	*24.34*	0.000	121.700	121.700
Economic	Shop retail benefits	*48.68*	14.604	14.604	14.604
Economic	Delivery time	*38.67*	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	*96.6*	0.000	0.000	0.000
	Sustainable Performance		**258.156**	**151.855**	**352.536**
	Sustainable Rating		2nd	3rd	1st

The results indicate that **Scenario 3** reaches the highest sustainability rate, followed by Scenario 1, thereby demonstrating that crowdshipping and parcel lockers for B2C and C2C deliveries in The Hague city is the most sustainable approach.

3.2.4 Long-term impact assessment for The Hague

In The Hague, among the proposed alternatives, the implementation of parcel lockers and crowdshipping (Scenario 3) is at the top of the city's plans.

The long-term impact of implementing parcel lockers and crowdshipping in The Hague consists of estimating environmental impacts (GHG emissions and energy consumption) on the city if the parcel lockers and crowdshipping (Scenario 3) is implemented on a large scale in the long term.

Table 17 presents the KPIs value of the BAU scenario vs Scenario 3 for The Hague Living Lab that will be used in the long-term impact assessment.

Table 17: Some KPIs for the BAU scenario vs Scenario 3 in The Hague Living Lab

Dimension	KPI	Units	Scenario BAU	Scenario 3 Parcel Lockers+ Crowdshipping
Environmental	Energy consumption	kWh/delivery	0.02472	0.02268
Environmental	GHG emissions	gCO2/delivery	6.63308	6.08540

Table 18 shows the annual savings of energy consumption and GHG emissions for the 5-year and 10-year horizon situation compared to the BAU scenario. In a **5-year horizon**, The Hague city is expected to have a total market demand volume of 1,280,000 deliveries/year and a maximum penetration rate over the market volume for Scenario 3 (parcel lockers+crowdshipping) of 8%. For a **10-year horizon,** it is expected a total market demand volume of 6,300,000 deliveries/year and a maximum penetration rate over the market volume of Scenario 3 of 40%.

Table 18: Annual savings situation for 5- and 10- year horizon in The Hague city

5 years horizon (8% penetration rate of parcel lockers + *crowdshipping*)			
KPI (Units)	**Scenario BAU**	**Scenario 3: Parcel Lockers + Crowdshipping**	**Annual Savings**
Energy consumption (kWh/year)	31,641.6	31,432.7	**208.9**
GHG emissions (tCO_2/year)	8.5	8.4	**0.06**
10 years horizon (40% penetration rate of parcel lockers + crowdshipping**)**			
Energy consumption (kWh/year)	155,736	150,595.2	**5,140.8**
GHG emissions (tCO_2/year)	41.79	40.41	**1.38**

In conclusion, and based on the results of the LEAD project on The Hague city, the long-term simultaneous implementation of *parcel lockers* and *crowdshipping* will have a modest impact on energy consumption and GHG emissions in the city. The implementation of the proposed more sustainable solution (Scenario 3) is facilitated by the interest shown by the partners in the LEAD project to continue it in the future. In addition, the APP needed to provide the service is ready, and during the pilot, a base number of bringers for the crowdshipping has been recruited.

On the other hand, The Hague LL participants identified some aspect that may hinder the implementation of this solution that should be considered, such as the acceptance of this solution into city logistics planning policy together with permits and bureaucracy and that relatively good delivery services currently exist and would have to make their way into the market along with high minimum wages of bringers.

3.3 The Lyon LL Last-Mile Solutions Alternatives

The Lyon LL proposed to evaluate the sustainability of different LML solutions based on UCC, with low-emissions vehicles (i.e. cargo-bikes, or delivery robots) in Lyon. The steps followed to obtain the results of the sustainability performance for the alternatives studied in the LL Lyon are described below (Annex 3 also contains the results obtained from the STAR Logistics software in detail).

3.3.1 Scenarios definition

LL3 - Lyon LL partners decided to evaluate two delivery system scenarios. The first one consisting of the comparison of the BAU scenario with the introduction of UCCs today and in the future containing four use cases (see Table 519). And the second one consisting of the comparison of the future 2030 scenarios BAU, UCC, E-VEHICLES containing seven use cases (see Table 520):

- BAU today: Business As Usual with today’s demand of parcels.
- UCC today: the introduction of three urban consolidation centres (UCC) in underground garages managed by LPA located in Confluence, Part-Dieu (attached to Lyon’s main rail station), and Cordelirer (in proximity to the historical centre and city core of Lyon). All parcel deliveries within these areas are made by cargo-bikes.
- BAU 2030: Consist of the business as usual scenario but with the predicted demand of 2030 year.
- UCC 2030: is the UCC scenario but with 2030-year demand of parcels.
- ELEZ 2030: the implementation of a Low Emission Zone in the city centre of Lyon. The “Electric LEZ” scenario it is assumed that only electric vehicles are allowed to enter this zone and deviler parcels. The scenario is based on the predicted demand of 2030 year.
- PRICE +20% 2030: it is All ELECTRIC 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +20% with the predicted demand of 2030 year.
- PRICE +40% 2030: it is All ELECTRIC 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +20% with the predicted demand of 2030 year.
- PRICE +60% 2030: it is BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +20% with the predicted demand of 2030 year.

Table 19: Lyon LL scenarios definition A: UCC today and UCC in 2030 year

Scenarios	Nomenclature	Description
Scenario 0A	BAU Today	Business as usual with today’s demand of parcels
Scenario 1A	UCC Today	3 UCCs + cargo-bikes today’s demand of parcels
Scenario 2A	BAU 2030	BAU with 2030 demand of parcels
Scenario 3A	UCC 2030	UCC scenario with 2030 demand of parcels

Table 20: Lyon LL scenarios definition B: 2030 scenarios

Scenarios	Nomenclature	Description
Scenario 0B	BAU 2030	BAU with 2030 demand of parcels
Scenario 1B	UCC 2030	UCC scenario with 2030 demand of parcels
Scenario 2B	ELEZ 2030	Only e-vehicles are allowed to enter LEZ zone in Lyon with 2030 demand of parcels
Scenario 3B	PRICE +20% 2030	BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +20% with the predicted demand of 2030 year
Scenario 4B	PRICE +40% 2030	BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +40% with the predicted demand of 2030 year
Scenario 5B	PRICE +60% 2030	BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +60% with the predicted demand of 2030 year

3.3.2 KPIs for Lyon LL Scenarios

The impacts of the scenarios are measured by monitoring a set of common LEAD KPIs. The KPIs will compare the impact with the baseline scenario (scenario 0). Notice that for Lyon there have been defined two BAU scenarios for current demand and future 2030 year demand. The KPIs are estimated as included in Table 21 and Table 22. There are some KPIs that could not be estimated by Lyon Living Labs partners, in grey (see Deliverable 3.8) for which it is proposed to set the same value for all scenarios (see in grey). For the missing KPIs, the STAR model will consider no change compared to Scenario 0, being their ratios considered as 0. Note that, it is assumed that for these criteria there is no change compared to the baseline scenario, **so the results of the impact assessment are not entirely conclusive and different scores could be obtained if all KPIs were included**.

Table 21: KPIs estimation for Lyon LL Scenarios UCC

Dimension	KPI	Scenario 0A	Scenario 1A	Scenario 2AA	Scenario A
Social	Job creation (employees)	10	11	10	11
Social	Quality of the jobs [1 – 5]	3.5	4,6	3,5	4,6
Social	Neighbourhood quality of life [1-5]	3.5	4	3,5	4

Dimension	KPI	Scenario 0A	Scenario 1A	Scenario 2AA	Scenario A
Environmental	Energy consumption (MJ/delivery)	1.51855	1.42604	1.26558	1.25689
Environmental	GHG emissions (gCO_2e/delivery)	107.713	99.6353	91.8221	91.5983
Environmental	NOx emissions (gNO_2/delivery)	0.57087	0.52518	0.48937	0.4888
Environmental	PM emissions (gPM/delivery)	0.00065	0.00065	0.0005	0.00048
Environmental	Noise pollution (% population)	45	45	45	45
Economic	Average delivery cost of the business model (€/delivery)	2.08846	2.09973	1.7655	1.76841
Economic	Congestion (m^2*h/day)	6.17421	6.10289	4.62199	5.02685
Economic	Urban storage & parking space (m^2)	1	45	1	45
Economic	FIRR (%)	1	1	1	1
Economic	Shop retail benefits [1-5]	3.5	4.125	3.5	4.125
Economic	Delivery time (min/delivery)	1	1	1	1
Economic	Delivery reliability within the time windows (%)	1	1	1	1

Table 22: KPIs estimation for Lyon LL Scenarios 2030

Dimension	KPI	Scenario 0B	Scenario 1B	Scenario 2B	Scenario 3B	Scenario 4B	Scenario 5B
Social	Job creation (employees)	10	11	10	10	10	10
Social	Quality of the jobs [1 – 5]	3.5	4.6	3.5	3.5	3.5	3.5
Social	Neighbourhood quality of life [1-5]	3.5	4	3.5	3.5	3.5	3.5
Environmental	Energy consumption (MJ/delivery)	1.26558	1.25689	1.01565	1.21939	1.056	0.48982
Environmental	GHG emissions (gCO_2e/delivery)	91.8221	91.5983	65.0722	87.0171	69.8892	12.2454
Environmental	NOx emissions (gNO_2/delivery)	0.48937	0.4888	0.32561	0.45485	0.34974	0
Environmental	PM emissions (gPM/delivery)	0.0005	0.00048	0.0005	0.0005	0.0005	0.00047
Environmental	Noise pollution (% population)	45	45	45	45	45	45
Economic	Average delivery cost of the business model (€/delivery)	1.7655	1.76841	1.82233	1.8139	1.83654	1.87016

Dimension	KPI	Scenario 0B	Scenario 1B	Scenario 2B	Scenario 3B	Scenario 4B	Scenario 5B
Economic	Congestion (m^2*h/day)	4.62199	5.02685	5.01045	4.59996	4.93807	4.82565
Economic	Urban storage & parking space (m^2)	1	45	1	1	1	1
Economic	FIRR (%)	1	1	1	1	1	1
Economic	Shop retail benefits [1-5]	3.5	4.125	3.5	3.5	3.5	35
Economic	Delivery time (min/delivery)	1	1	1	1	1	1
Economic	Delivery reliability within the time windows (%)	1	1	1	1	1	1

In order to compare all the KPIs and consider them in the same order of magnitude, the change of each scenario concerning the base scenario today and 2030 year (Scenario 0) are estimated (see Table 15 and 24). It should be noted that the value 0 means that there is no change with respect to the Scenario 0 (BAU scenario). Some criteria, quality of the jobs, urban storage and parking space or environmental criteria, have relevant changes in some scenarios.

Table 23: KPIs change from baseline scenario UCC Lyon

Dimension	KPI	Change Scenario 1A	Change Scenario 2A	Change Scenario 3A
Social	Job creation	0.1	0.0	0.1
Social	Quality of the jobs	0.3	0.0	0.3
Social	Neighbourhood quality of life	0.1	0.0	0.1
Environmental	Energy consumption	-0.1	-0.2	-0.2
Environmental	GHG emissions	-0.1	-0.1	-0.1
Environmental	NOx emissions	-0.1	-0.1	-0.1
Environmental	PM emissions	0.0	-0.2	-0.3
Environmental	Noise pollution	0.0	0.0	0.0
Economic	Average delivery cost of the business model	0.0	-0.2	-0.2
Economic	Congestion	0.0	-0.3	-0.2
Economic	Urban storage & parking space	0.4	0.0	0.4
Economic	FIRR	0.0	0.0	0.0
Economic	Shop retail benefits	0.2	0.0	0.2
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0

Table 24: KPIs change from baseline scenario 2030 Lyon

Dimension	KPI	Change Scenario 1B	Change Scenario 2B	Change Scenario 3B	Change Scenario 4B	Change Scenario 5B
Social	Job creation	0.1	0.0	0.0	0.0	0.0
Social	Quality of the jobs	0.3	0.0	0.0	0.0	0.0
Social	Neighbourhood quality of life	0.1	0.0	0.0	0.0	0.0
Environmental	Energy consumption	0.0	-0.2	0.0	-0.2	-0.6
Environmental	GHG emissions	0.0	-0.3	-0.1	-0.2	-0.9
Environmental	NOx emissions	0.0	-0.3	-0.1	-0.3	-1.0
Environmental	PM emissions	0.0	0.0	0.0	0.0	-0.1
Environmental	Noise pollution	0.0	0.0	0.0	0.0	0.0
Economic	Average delivery cost of the business model	0.0	0.0	0.0	0.0	0.1
Economic	Congestion	0.1	0.1	0.0	0.1	0.0
Economic	Urban storage & parking space	0.4	0.0	0.0	0.0	0.0
Economic	FIRR	0.0	0.0	0.0	0.0	0.0
Economic	Shop retail benefits	0.2	0.0	0.0	0.0	0.0
Economic	Delivery time	0.0	0.0	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0	0.0	0.0

3.3.3 Sustainable Performance for Lyon LL scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for Lyon (Table 4) and the change rate (Table 15 and 24) is conducted. The sign was changed according to its effect on sustainability (+1 more is better, -1 less is better). The following Table 25 and Table 26 present the aggregate values obtained for each scenario. As it can be seen, scenarios in Lyon that have a favourable impact on energy consumption, average delivery cost of the business models and job creation will be the ones with the best sustainability score.

Table 25: Sustainable Performance for Lyon LL scenarios UCC

Dimension	KPI	Adjusted Weight	Scenario 1A	Scenario 2A	Scenario 3A
Social	Job creation	*124.26*	12.426	0.000	12.426
Social	Quality of the jobs	*117.16*	35.148	0.000	35.148
Social	Neighbourhood quality of life	*29.29*	2.929	0.000	2.929
Environmental	Energy consumption	*206.85*	20.685	41.370	41.370

Dimension	KPI	Adjusted Weight	Scenario 1A	Scenario 2A	Scenario 3A
Environmental	GHG emissions	*78.18*	7.818	7.818	7.818
Environmental	NOx emissions	*52.12*	5.212	5.212	5.212
Environmental	PM emissions	*78.18*	0.000	15.636	23.454
Environmental	Noise pollution	*26.04*	0.000	0.000	0.000
Economic	Average delivery cost of the business model	*144.75*	0.000	28.950	28.950
Economic	Congestion	*46.02*	0.000	13.806	9.204
Economic	Urban storage & parking space	*20.49*	-8.196	0.000	-8.196
Economic	FIRR	*48.68*	0.000	0.000	0.000
Economic	Shop retail benefits	*48.68*	9.736	0.000	9.736
Economic	Delivery time	*38.67*	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	*77.28*	0.000	0.000	0.000
	Sustainable Performance		**85.758**	**112.792**	**168.051**
	Sustainable Rating		3rd	2nd	1st

The results from Table 25 indicate that **Scenario 3** reaches the highest sustainability rate which corresponds to the implementation of UCC with the estimated demand for 2030 year. Thereby demonstrating that *UCCs* for B2C deliveries in Lyon is the most sustainable approach.

Lyon LL partners highlight that the main aspects that would facilitate the implementation of UCCs in underground parking areas in Lyon is the urgent needs from the logistic operators to find suitable space in the city centres together with the fact that no additional major investments are needed since Lyon have existing underground car parks. Additionally, local public and private stakeholders have started working on this issue. On the contrary, there are some hindering aspects that should be considered such as the definition of a suitable business model for managing the UCC (whether it is a private, semiprivate, public company) and the fact that underground facilities were not originally designed for logistics activities (not proper steep ramps, insufficient energy networks, low ceilings, small lifts).

Table 26: Sustainable Performance for Lyon LL scenarios 2030

Dimension	KPI	Adjusted Weight	Scenario 1B	Scenario 2B	Scenario 3B	Scenario 4B	Scenario 5B
Social	Job creation	*124.26*	12.426	0.000	0.000	0.000	0.000
Social	Quality of the jobs	*117.16*	35.148	0.000	0.000	0.000	0.000
Social	Neighbourhood quality of life	*29.29*	2.929	0.000	0.000	0.000	0.000
Environmental	Energy consumption	*206.85*	0.000	41.370	0.000	41.370	124.110
Environmental	GHG emissions	*78.18*	0.000	23.454	7.818	15.636	70.362
Environmental	NOx emissions	*52.12*	0.000	15.636	5.212	15.363	52.120

Dimension	KPI	Adjusted Weight	Scenario 1B	Scenario 2B	Scenario 3B	Scenario 4B	Scenario 5B
Environmental	PM emissions	*78.18*	0.000	0.000	0.000	0.000	7.818
Environmental	Noise pollution	*26.04*	0.000	0.000	0.000	0.000	0.000
Economic	Average delivery cost of the business model	*144.75*	0.000	0.000	0.000	0.000	-14.475
Economic	Congestion	*46.02*	-4.602	-4.602	0.000	-4.602	0.000
Economic	Urban storage & parking space	*20.49*	-8.196	0.000	0.000	0.000	0.000
Economic	FIRR	*48.68*	0.000	0.000	0.000	0.000	0.000
Economic	Shop retail benefits	*48.68*	9.736	0.000	0.000	0.000	0.000
Economic	Delivery time	*38.67*	0.000	0.000	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	*77.28*	0.000	0.000	0.000	0.000	0.000
Sustainable Performance			**47.441**	**75.858**	**13.030**	**68.040**	**239.935**
Sustainable Rating			4th	2nd	5th	3rd	**1st**

The results from Table 26 indicate that **Scenario 5** reaches the highest sustainability rate which corresponds to the introduction of a penalty factor on the price of combustion vehicles for +60% with the predicted demand of 2030 year. In the second position is the Scenario 2 which correspond to deliver parcel only with e-vehicles in the LEZ Lyon zone which is a high priority scenario for the coming years in the city. It should be noted that **these results are not entirely conclusive and different results could be obtained if delivery time, FIRR or reliability are included.**

3.3.4 Long-term impact assessment for Lyon

In Lyon, among the proposed alternatives, the base future scenarios (Baseline 2030) and the derived scenarios (Electric LEZ, All Electric, Pricing) have been prepared.

First, the assessment focuses on the comparison of today's baseline scenario and the baseline scenario of 2030 (only includes increasing parcels demand). Table 27 shows a 108% increase in total number of deliveries, which increases GHG emissions, emissions, energy consumption and fuel consumption by more than 70%. These changes are due to the 45% increase in distance travelled and the corresponding fleet mix in the simulation result. Due to scale effects, delivery costs are reduced by approximately 15%.

Table 27: Comparison of baseline today versus baseline future 2030 (KPIs per day, whole study area for Lyon LL)

	Today	Future 2030	Change [%]
Deliveries	**16252**	**33923**	**+108%**
Distance [km]	12451	18129	+45%
Energy [kWh]	6855	11925	+74%
CO2eq [kg]	1750	3115	+78%
Fuel [L]	635	1143	+80%
Electricity [kWh]	510	500	-2%
Cost per delivery [EUR]	2.09	1.77	-15%

This analysis shows that strategies to reduce the environmental impact of parcel delivery are needed not only to reduce emissions today, but also to moderate the expected growth until 2030. Figure 4 shows a comparison of future scenarios of annual GHG emissions and delivery cost per package.

The baseline scenario for 2030 appears at the bottom of the Figure. It offers the lowest cost per delivery, but also produces the highest emissions of the scenarios analysed, more than 1000 tCO2e/year. In the middle, the limited coverage of the electric LEZ amounts to approximately 700 tCO2e/year at a higher price of 1.82 euros per package. Here, many vehicles serving the Lyon area are not yet electrified. If all vehicles became electric (upper left corner), we would get about 100 tCO2e/year for the cost of one package of 1.87 euros (which is also the calculated price today), which is then only the result of electricity production and depends on certain energy sources. For comparison, we also present the price scenarios. It can be seen that the initial CO2eq reduction when increasing combustion vehicles costs by 20% is limited compared to the baseline. Even if the costs increases to 40%, the emissions would still be more than 900 tCO2e/year. Only after the 60% costs increase margin, emissions begin to fall to almost the same level as when the Electric LEZ was launched.

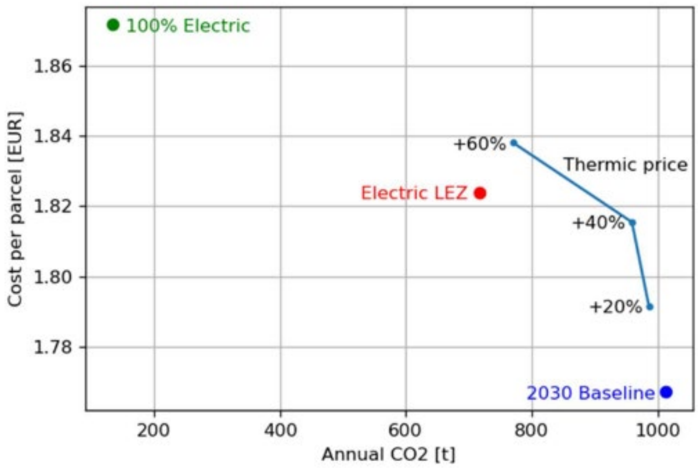

Figure 4: Comparison of future scenarios for Lyon Living Lab.

In conclusion, the results of the previous sustainability rating pointed out that the best scenarios are the taxation of combustion vehicles at +60% of the price or the implementation of a LEZ within Lyon. From the future impact estimates it is possible to observe these impacts on GHG emissions and cost per delivery.

3.4 Budapest LL Last-Mile Solutions Alternatives

The Budapest LL proposed evaluating the sustainability impacts of implementing a minihub using different low-carbon freight vehicle fleets and store facilities to find the best scenario for sustainable last-mile operation in the city. These scenarios outline different logistics and supply chain configurations for business-to-business (B2B) operations. They encompass various combinations of transportation methods, warehouse facilities, and operational hours, aimed at exploring different approaches to optimize regional distribution and delivery processes. The steps followed to obtain the results of the sustainability performance for the alternatives studied in the LL Madrid are described below (Annex 3 also contains the results obtained from the STAR Logistics software in detail).

3.4.1 Scenarios definition

Budapest LL partners proposed to evaluate five delivery system scenarios for business-to-business (B2B) deliveries (see Table 28). These scenarios contain a combination of facilities, various types of vehicles and different lengths of operational time windows for B2B deliveries.

Table 28: Budapest LL scenarios definition

Scenarios	Nomenclature	Description
Scenario 0	BAU	Business as Usual B2B
Scenario 1	Minihub (LNG vehicle) + permanent warehouse 24h/day	LNG vehicle from BILK to the mini-hub. Minihub: permanent regional service warehouse operating 24 hours a day. B2B. Between mini hub and shops: an electric van
Scenario 2	Minihub (e-vehicle 16t) + continuous warehouse (7 am to 12 pm)	Electric 16t vehicle from BILK. Minihub: continuous regional warehouse open from 7 a.m. to 12 p.m. B2B. Between mini hub and shops: an electric van
Scenario 3	Minihub (LNG vehicle) + 24h transhipment point	LNG vehicle from BILK to the mini-hub. Mini-hub: 24-hour transhipment point. B2B. Between mini hub and shops: an electric van
Scenario 4	Minihub (e-vehicle 16t) + transhipment point (7 am to 12 pm)	16t electric vehicle from BILK to the mini-hub. Minihub: transhipment point open from 7 a.m. to 12 p.m. B2B. Between mini hub and shops: an electric van

3.4.2 KPIs for Budapest LL Scenarios

The impacts of the scenarios are measured by monitoring a set of LEAD KPIs. The KPIs are used to compare the impact of conducting the scenarios with the baseline scenario (scenario 0). Table 29 presents the values obtained for each KPIs and scenarios assessed. As it can be seen, there are some KPIs that could not be estimated by the LLs partners, for which it is proposed to set no variation for all scenarios (see in grey). As the variations are unknown, the ratios are considered as 0.

Table 29: KPIs estimation for Budapest LL scenarios

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Social	Job creation (employees)	13	18	15	18	15
Social	Quality of the jobs [1 – 5]	4	4.5	5	4.5	5
Social	Neighbourhood quality of life [1-5]	3	3.5	4	4.5	4
Environmental	Energy consumption (litres/partner)	69.3	8.5	0.0	8.5	0
Environmental	GHG emissions (tCO_{2e}/partner)	1.0800	0.0224	0.0000	0.0224	0.0000
Environmental	NOx emissions (gNO_{2e}/partner)	582.12	5.94	0.00	5.94	0.00
Environmental	PM emissions (gPM/partner)	8.316	0.84	0.00001	0.224	0.00001
Environmental	Noise pollution (dBA over 8 hours)	400.00	400.00	400.00	400.00	400.00
Economic	Average delivery cost of the business model (€)	630.00	722.61	720.9	715.68	718.83
Economic	Congestion (m^2*h/day)	863.2	322.84	354.68	322.84	354.68
Economic	Urban storage & parking space (m^2)	742.5	209.1	240.92	113.08	144.92
Economic	FIRR (%)	1	1	1	1	1
Economic	Shop retail benefits [1-5]	3.5	3.5	3.5	3.5	3.5
Economic	Delivery time (min/partner)	2,400	1,728	1,728	1,728	1,728
Economic	Delivery reliability within the time windows (%)	90.0	90.0	90.0	90.0	90.0

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each scenario concerning the base scenario (Scenario 0) is estimated (see Table 30). It should be noted that the value 0 means that there is no change with respect to the Scenario 0 (BAU scenario). Environmental criteria have relevant changes compared with the baseline scenario.

Table 30: KPIs change from baseline scenario Budapest

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Social	Job creation	0.4	0.2	0.4	0.2
Social	Quality of the jobs	0.1	0.2	0.1	0.2
Social	Neighbourhood quality of life	0.2	0.3	0.5	0.5
Environmental	Energy consumption	-0.9	-1.0	-0.9	-1.0
Environmental	GHG emissions	-1.0	-1.0	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0	-1.0
Environmental	PM emissions	-0.9	-1.0	-1.0	-1.0
Environmental	Noise pollution	0.0	0.0	0.0	0.0
Economic	Average delivery cost of the business model	0.1	0.1	0.1	0.1
Economic	Congestion	-0.6	-0.6	-0.6	-0.6
Economic	Urban storage & parking space	-0.7	-0.7	-0.8	-0.8
Economic	FIRR	0.0	0.0	0.0	0.0
Economic	Shop retail benefits	0.0	0.0	0.0	0.0
Economic	Delivery time	-0.3	-0.3	-0.3	-0.3
Economic	Delivery reliability within the time windows	0.0	0.0	0.0	0.0

3.4.3 Sustainable Performance for Budapest LL scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for Budapest LL (Table 4) and the change rates (see Table 30) are conducted. The sign was adjusted according to the effect on the KPI on sustainability (+1 more is better, -1 less is better). Table 31 presents the aggregate values obtained for each scenario. As it can be seen, scenarios that have a favourable impact on average delivery cost of the business model, energy consumption, NOx emissions, quality of the jobs, are the ones with the best sustainability score.

Table 31: Sustainable Performance for Budapest LL scenarios

Dimension	KPI	Adjusted Weights	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Social	Job creation	*82.84*	33.136	16.568	33.136	33.136
Social	Quality of the jobs	*117.16*	11.716	23.432	11.716	11.716
Social	Neighbourhood quality of life	*146.45*	29.290	43.935	73.225	29.290
Environmental	Energy consumption	*165.48*	148.932	165.480	149.932	148.932
Environmental	GHG emissions	*78.18*	78.180	78.180	78.180	78.180
Environmental	NOx emissions	*104.24*	104.240	104.240	104.240	104.240
Environmental	PM emissions	*78.18*	70.362	78.180	98.180	70.362

Dimension	KPI	Adjusted Weights	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Environmental	Noise pollution	*39.06*	0.000	0.000	0.000	0.000
Economic	Average delivery cost of the business model	*173.7*	-17.370	-17.370	-17.370	-17.370
Economic	Congestion	*38.35*	23.010	23.010	23.010	23.010
Economic	Urban storage & parking space	*27.32*	19.124	19.124	21.856	19.124
Economic	FIRR	*36.51*	0.000	0.000	0.000	0.000
Economic	Shop retail benefits	*12.17*	0.000	0.000	0.000	0.000
Economic	Delivery time	*38.67*	11.601	11.601	11.601	11.601
Economic	Delivery reliability within the time windows	*96.6*	0.000	0.000	0.000	0.000
Sustainable Performance			**512.221**	**546.380**	**566.706**	**578.402**
Sustainable Rating			4rd	3rd	**2nd**	**1st**

The results indicate that **Scenario 4** reaches the highest sustainability, closely followed by Scenario 3, thereby demonstrating that a minihub plus transhipment centre or continuous warehouse using e-vehicles is the most sustainable approach for Budapest Living Lab. The framework applied in this study may assist policymakers in promoting sustainable last-mile logistics following the specific urban context.

3.4.4 Long-term impact assessment for Budapest

For Budapest's city future plans, it is planned to implement the last mile solution of Scenario 1 for B2B deliveries: using an LNG vehicle from BILK to the mini-hub, in the mini-hub a regional service warehouse operating 24 hours/day and then between minihubs and shops using electric vans.

The medium and long-term impact of implementing Scenario 1 in Budapest LL consists of estimating impacts that may depend on the city if Scenario 1 is implemented on a large scale in the medium and long term. Figure 5 shows an example of the annual GHG emissions if Scenario 1 is implemented in a 5-year horizon and 10-year horizon in the Budapest LL. For instance, in a 5-year horizon, an average implementation of scenario 1 for 1,200 partners is estimated, which will lead to 1,269 tCO2e/year savings.

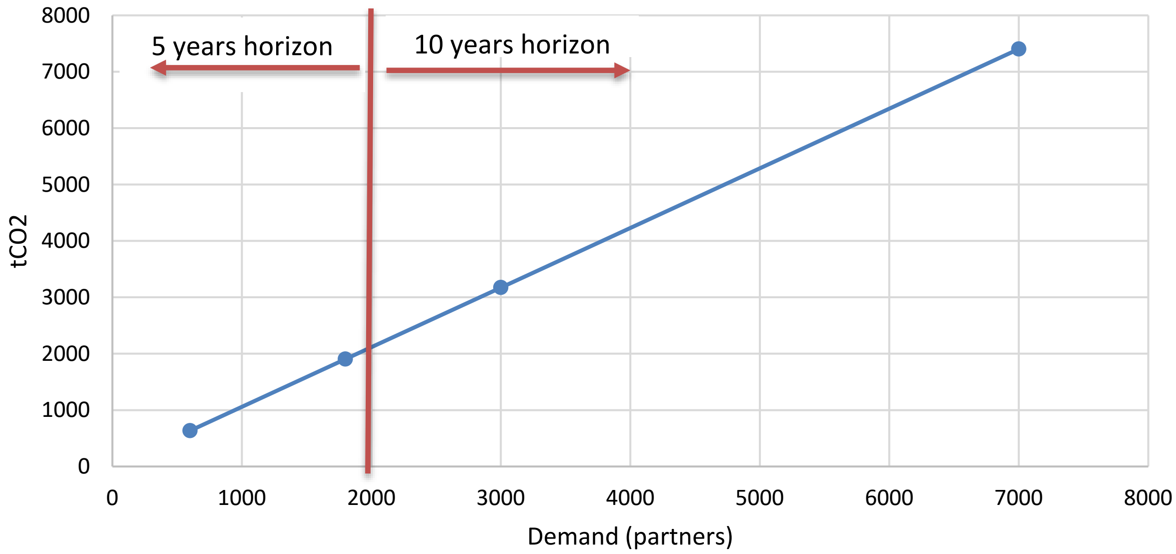

Figure 5: Annual GHG emissions savings if Scenario 1 is implemented in medium and long term in Budapest Living Lab.

In conclusion, and based on the results of the LEAD project in Budapest city, the long-term implementation of a mini-hub will positively impact the city. The implementation of the proposed scenario 1 solution is facilitated by the stakeholder's engagement as a result of the LEAD project. In addition, other facilitators are identified, such as the possibility of off-peak deliveries, the higher penetration of LNG vehicles and electric vans, and the possibility of a higher service level or new job creation. On the other hand, Budapest LL partners identified some aspects that may hinder the implementation of this solution that should be taken into account, such as the insufficient public space near the city centre for the implementation, the insufficient support by local government, the higher initial investment and more extended payback period of electric vans, poor charging infrastructure for low emissions vehicles, and the lack of an urban plan in connection with the establishment of a mini-hub.

3.5 Oslo LL Last-Mile Solutions Alternatives

The Oslo LL proposed to assess the sustainability impacts of implementing micro-hubs, electric freight vehicles, crowdshipping (including returns) for B2C deliveries. The consolidation is based on urban consolidation centres and micro hubs. In Oslo city, there are ongoing projects and experiments with deliveries using nano-store B2C with E-vehicles, light electric vehicles, retail stores with EV charging and EV fast charging. One is also attempting to use delivery modes where networks of local, non-professional couriers are leveraged. The steps followed to obtain the results of the sustainability performance for the alternatives studied in the Oslo LL are described below (Annex 3 contains the detailed results obtained from the STAR Logistics software).

3.5.1 Scenarios definition

LL5 - Oslo LL partners decided to evaluate business as usual scenario with four delivery system scenarios for B2C deliveries combining different LML solutions: micro-hub, using electric vehicles for delivery, crowdshpping and including C2B -as Table 32 shows (for more information regarding scenarios, see Deliverable 3.12).

Table 32: Oslo LL scenarios definition

Scenarios	Nomenclature	Description
Scenario 0	BAU	Business as Usual B2C (mix of diesel van and e-van fleet)
Scenario 1	E-vans	BAU scenario but with 100% e-van fleet
Scenario 2	E-vans + microhub	Scenario 1 but with the introduction of a micro-hub closer to Oslo city centre. From the microhub to the final consumer there are dedicated bringers.
Scenario 3	E-vans + microhub + crodwshipper	Scenario 2 but with the option from the microhub to be done by crowdshippers together with dedicated bringers.

3.5.2 KPIs for Oslo LL Scenarios

The impacts of the scenarios are measured by monitoring a set of common LEAD KPIs. The KPIs compare the impact of conducting the scenarios with the baseline scenario (scenario 0), defined as results based on the BAU scenario. Table 29 presents the values obtained for each KPIs and scenarios assessed. As it can be seen, there are various KPIs that could not be estimated by the Living Labs partners, for which it is proposed to set the same value for all scenarios (see in grey). In this way, it is avoided that in the STAR Logistics Methodology their change ratios are considered as they take the value of 0, as the changes are not known.

Table 33: KPIs estimation for Oslo LL scenarios

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Social	Job creation	1	1	1	1
Social	Quality of the jobs	1	1	1	1
Social	Neighbourhood quality of life [1-5]	3.4	3.4	3.4	3.4
Environmental	Energy consumption (MJ/delivery)	126.6	56.0	43.3	21.1
Environmental	GHG emissions (gCO_{2e}/delivery)	11.88473	0.07227	0.05588	0.02727
Environmental	NOx emissions (gNO_{2e}/delivery)	18.4	0.0	0.0	0.0
Environmental	PM emissions (gPM/delivery)	0.03	0.00	0.00	0.00
Environmental	Noise pollution (dBA*h/day)	1	1	1	1
Economic	Average delivery cost of the business model (€/delivery)	275.0	261.0	210.0	246.0
Economic	Congestion (%)	22.5	22.5	23.2	25.8

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Economic	Urban storage & parking space (m^2)	201458.5	114542.6	122031.3	55617.315
Economic	FIRR (%)	1	1	1	1
Economic	Shop retail benefits [1-5]	1	1	1	1
Economic	Delivery time (min/delivery)	51	40	41	27
Economic	Delivery reliability within the time windows (%)	84.5	82.5	75.5	93.1

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each scenario concerning the base scenario (Scenario 0) is estimated (see Table 30). For the missing KPIs, the STAR model will consider no change compared to Scenario 0, being their ratios considered as 0. Note that, it is assumed that for these criteria there is no change compared to the baseline scenario, so the results of the impact assessment are not entirely conclusive and different scores could be obtained if all KPIs were included. Environmental criteria have relevant changes compared with the baseline scenario.

Table 34: KPIs change from baseline scenario Oslo

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3
Social	Job creation	0.0	0.0	0.0
Social	Quality of the jobs	0.0	0.0	0.0
Social	Neighbourhood quality of life	0.0	0.0	0.0
Environmental	Energy consumption	-0.6	-0.7	-0.8
Environmental	GHG emissions	-1.0	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0
Environmental	PM emissions	-1.0	-1.0	-1.0
Environmental	Noise pollution	0.0	0.0	0.0
Economic	Average delivery cost of the business model	-0.1	-0.2	-0.1
Economic	Congestion	0.0	0.0	0.1
Economic	Urban storage & parking space	-0.4	-0.4	-0.7
Economic	FIRR	0.0	0.0	0.0
Economic	Shop retail benefits	0.0	0.0	0.0
Economic	Delivery time	-0.2	-0.2	-0.5
Economic	Delivery reliability within the time windows	0.0	-0.1	0.1

3.5.3 Sustainable Performance for Oslo LL Scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for the Oslo LL (Table 4) and the change rate (see Table 30) is performed. The sign was changed according to its effect on sustainability ((+1) More is better, (-1) Less is better). The following Table 31 presents the aggregate values obtained for each scenario. As it can be seen, scenarios that have a favourable impact on average cost of the business model, social and environmental criteria, will be the ones with the best sustainability score.

Table 35: Sustainable Performance for Oslo LL Last-Mile Logistics Alternatives

Dimension	KPI	Adjusted Weight	Scenario 1	Scenario 2	Scenario 3
Social	Job creation	*82.84*	0.000	0.000	0.000
Social	Quality of the jobs	*58.58*	0.000	0.000	0.000
Social	Neighbourhood quality of life	*87.87*	0.000	0.000	0.000
Environmental	Energy consumption	*41.37*	24.822	28.959	33.096
Environmental	GHG emissions	*78.18*	78.180	78.180	78.180
Environmental	NOx emissions	*78.18*	78.180	78.180	78.180
Environmental	PM emissions	*26.06*	26.060	26.060	26.060
Environmental	Noise pollution	*39.06*	0.000	0.000	0.000
Economic	Average delivery cost of the business model	*144.75*	14.475	28.950	14.475
Economic	Congestion	*23.01*	0.000	0.000	-2.301
Economic	Urban storage & parking space	*40.98*	16.392	16.392	28.686
Economic	FIRR	*24.34*	0.000	0.000	0.000
Economic	Shop retail benefits	*36.51*	0.000	0.000	0.000
Economic	Delivery time	*51.56*	10.312	10.312	25.780
Economic	Delivery reliability within the time windows	*77.28*	0.000	-7.725	7.728
	Sustainable Performance		**248.421**	**259.305**	**289.884**
	Sustainable Rating		3rd	2nd	**1st**

The results indicate that **Scenario 3** reaches the highest sustainability, thereby demonstrating that using a full fleet of e-vans together with a microhub close to the city center and introducing crowdshipping from the microhub is the most sustainable approach for Oslo Living Lab. However, some criteria should have been estimated and could probably have produced different results, such as social ones.

3.5.4 Long-term impact assessment for Oslo

For Oslo City’s future plans a priority would be to implement microhubs and crowdshipping for last-mile B2C deliveries using electric vehicle fleets, as shown in the Scenario 3. The medium and long-term impact of implementing scenario 3 in Oslo Living Lab consists of estimating impacts that may depend on the city if scenario 3 is implemented on a large scale in the medium and long term. Figure 6 shows an example of the annual GHG savings if Scenario 3 is implemented in a 5 year horizon and 10 years horizon in Oslo Living Lab. For instance, in a 10 year horizon, an average of 34,000 deliveries/year will lead to savings around 400kgCO2/year.

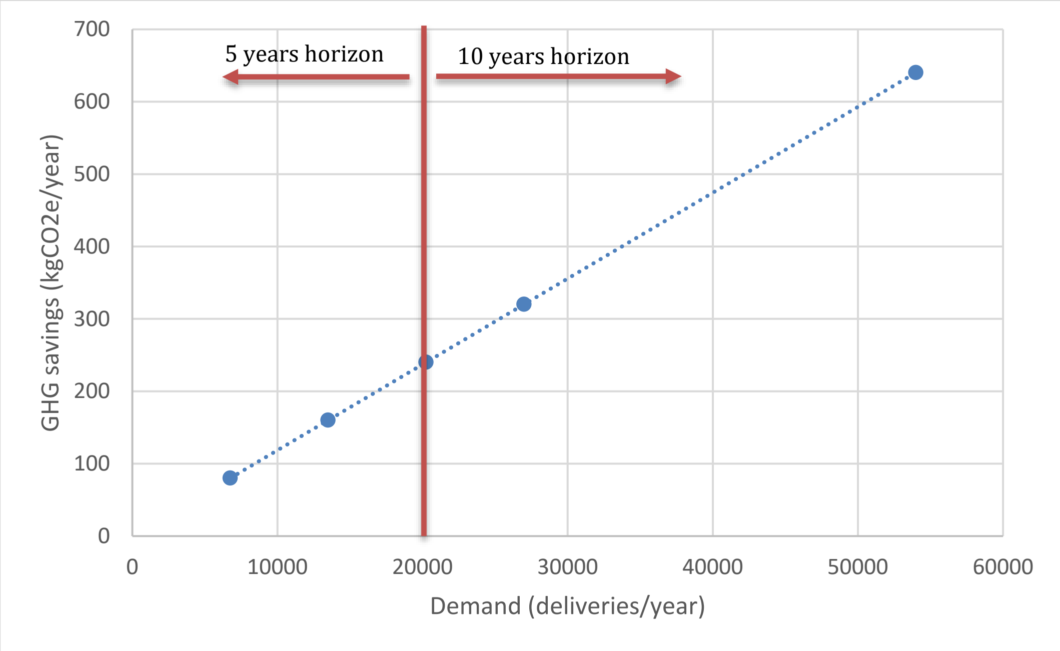

Figure 6: Annual GHG savings if scenario 3 is implemented in the medium and long term in Oslo Living Lab.

In conclusion, and based on the results of the LEAD project in Oslo City, the long-term implementation of a microhub close to the city centre with electric vehicle fleets for LML and crowdshipping services for the second echelon have positive impacts. Implementing the proposed scenario 3 solution is a somewhat priority for Oslo's city future plans. Oslo LL partners highlight that this solution will be facilitated by the incentives from the public policies for electric vehicles and the cooperation and sharing of assets among delivery companies with regard to microhub utilization. On the other hand, some identified aspects that may hinder the implementation of this solution that should be considered are some public policies for delivering hours and the lack of urban space to install the hubs.

3.6 Porto LL Last-Mile Solutions Alternatives

Porto LL proposed to evaluate the sustainability impacts of introducing electric vehicle fleet for B2B deliveries. The objective is to conduct experiments in green mobility and logistics through the simulation and optimization enabled by Digital Twins. These efforts are based on the principles of the Physical Internet, specifically focusing on the adoption strategy for the PI Network. The steps followed to obtain the results of the sustainability performance for the alternatives studied in the LL Porto are described below (Annex 3 contains the detailed results obtained from the STAR Logistics software).

3.6.1 Scenarios definition

LL6 - Porto LL partners decided to evaluate four delivery system scenarios for business-to-business deliveries, consisting of three use cases summarised in Table 36 (for more information regarding scenarios, see Deliverable 3.14). These scenarios contain the combination of different charging station locations and penetration levels of electric vehicles fleets.

Table 36: Porto LL scenarios definition

Scenarios	Nomenclature	Description
Scenario 0	BAU	Business as Usual B2B
Scenario 1	75% e-vehicles	Deliver with 75% of e-vehicles fleet
Scenario 2	50% e-vehicles	Deliver with 50% of e-vehicles fleet
Scenario 3	25% e-vehicles	Deliver with 25% of e-vehicles fleet

3.6.2 KPIs for Porto LL Scenarios

The impacts of the scenarios are measured by monitoring a set of common LEAD KPIs. The KPIs will compare the impact of conducting the scenarios with the baseline scenario (scenario 0), defined as results based on the BAU scenario. Table 37 presents the values obtained for each KPIs and scenarios assessed. As it can be seen, some KPIs could not be estimated by the Porto LLs partners, for which it is proposed to set the same value for all scenarios (see in grey). In this way, it is avoided that in the STAR Logistics Methodology, their ratios are considered as they take the value of 0, as the changes are unknown.

Table 37: KPIs estimation for Porto LL scenarios

Dimension	KPI	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Social	Job creation (employees)	31	32	33	32
Social	Quality of the jobs [1 – 5]	3.5	4.1	4.1	4.1
Social	Neighbourhood quality of life [1-5]	4.7	4.9	4.8	4.7
Environmental	Energy consumption (MJ/delivery)	3.2438	1.8920	2.4515	2.7507
Environmental	GHG emissions (gCO_{2e}/delivery)	150.44	93.39	116.34	135.93
Environmental	NOx emissions (gNO_{2e}/delivery)	0.0027	0.0001	0.0016	0.0021
Environmental	PM emissions (gPM/delivery)	0.0166	0.0056	0.0083	0.0138
Environmental	Noise pollution (dB)	70.00	66.24	67.49	68.75
Economic	Average delivery cost of the business model (€/delivery)	2.05	1.25	1.62	1.84
Economic	Congestion (m^2*h/day)	610.03	189.70	333.11	471.01
Economic	Urban storage & parking space (m^2)	1	1	1	1
Economic	FIRR (investment €)	775,000	390,577	547,383	639,791
Economic	Shop retail benefits [1-5]	3.5	3.5	3.5	3.5
Economic	Delivery time (min/delivery)	6.34	6.52	6.61	6.52
Economic	Delivery reliability within the time windows (%)	94	94	94	94

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario (Scenario 0) is estimated (see Table 38). Environmental criteria, congestion or investment present relevant changes with respect to the baseline scenario.

Table 38: KPIs change from baseline scenario Porto

Dimension	KPI	Change Scenario 1	Change Scenario 2	Change Scenario 3
Social	Job creation	0.0	0.1	0.0
Social	Quality of the jobs	0.2	0.2	0.2
Social	Neighbourhood quality of life	0.0	0.0	0.0
Environmental	Energy consumption	-0.4	-0.2	-0.2
Environmental	GHG emissions	-0.4	-0.2	-0.1
Environmental	NOx emissions	-0.6	-0.4	-0.2
Environmental	PM emissions	-0.7	-0.5	-0.2
Environmental	Noise pollution	-0.1	0.0	0.0
Economic	Average delivery cost of the business model	-0.4	-0.2	-0.1
Economic	Congestion	-0.7	-0.5	-0.2
Economic	Urban storage & parking space	0.0	0.0	0.0
Economic	FIRR	-0.5	-0.3	-0.2
Economic	Shop retail benefits	0.0	0.0	0.0
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0

3.6.3 Sustainable Performance for Porto LL scenarios

In order to measure the Sustainable Performance of each scenario, the multiplication between the Adjusted Weight for Porto LL (Table 4) and the change rate (see Table 38) is performed. The sign was changed according to its effect on sustainability ((+1) More is better, (-1) Less is better). The following Table 39 presents the aggregate values obtained for each scenario. As it can be seen, scenarios that have a favourable impact on the average cost of the business model, social criteria and environmental criteria, will be the ones with the best sustainability score.

Table 39: Sustainable Performance for Porto LL scenarios

Dimension	KPI	Adjusted Weight	Scenario 1	Scenario 2	Scenario 3
Social	Job creation	*124.26*	0.000	12.426	0.000
Social	Quality of the jobs	*117.16*	23.432	23.432	23.432
Social	Neighbourhood quality of life	*58.58*	0.000	0.000	0.000
Environmental	Energy consumption	*206.85*	82.740	41.370	41.370

Dimension	KPI	Adjusted Weight	Scenario 1	Scenario 2	Scenario 3
Environmental	GHG emissions	*78.18*	31.272	15.636	7.818
Environmental	NOx emissions	*104.24*	62.544	41.696	20.848
Environmental	PM emissions	*52.12*	36.484	26.060	10.424
Environmental	Noise pollution	*19.53*	1.953	0.000	0.000
Economic	Average delivery cost of the business model	*144.75*	57.900	28.950	14.475
Economic	Congestion	*15.34*	10.738	7.670	3.068
Economic	Urban storage & parking space	*40.98*	0.000	0.000	0.000
Economic	FIRR	*36.51*	-18.255	-10.953	-7.302
Economic	Shop retail benefits	*48.68*	0.000	0.000	0.000
Economic	Delivery time	*51.56*	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	*57.96*	0.000	0.000	0.000
Sustainable Performance			**288.808**	186.287	114.133
Sustainable Rating			1st	2nd	3rd

The results indicate that **Scenario 1** reaches the highest sustainability, thereby demonstrating that the higher the penetration of electric vehicles, the better the sustainability of deliveries in Porto. As before, the framework applied in this study may assist policymakers in promoting sustainable LML in accordance with the specific urban context.

3.6.4 Long-term impact assessment for Porto

For Porto City future plans is a high priority to extend the use of the electric vehicle fleet for last mile deliveries, as shown in Scenario 1. The medium and long-term impact of implementing scenario 1 in Porto LL consists of estimating impacts that may depend on the city if scenario 1 is implemented on a large scale in the medium and long term. Figure 7 presents an example of the annual kWh savings if scenario 1 is implemented in a 5 year horizon and a 10 year horizon in Porto LL. For instance, in a 10 year horizon, an average of 350,000 deliveries/year will lead to 131,425 kWh /year savings if using scenario 1.

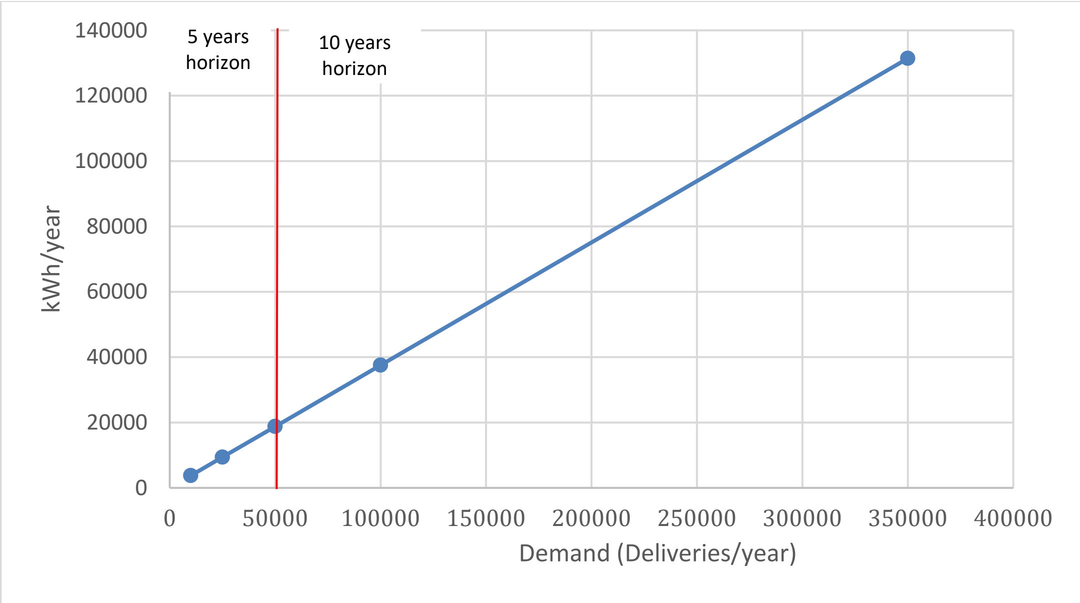

Figure 7: Annual energy savings if scenario 1 is implemented in the medium and long term in Porto Living Lab.

In conclusion, and based on the results of the LEAD project in Porto City, the long-term implementation of a low-carbon vehicle fleet for LML has positive impacts. Implementing the proposed scenario 1 solution is a high priority for Porto City’s future plans. It is facilitated by the environmental subjects of the city and the stakeholder's engagement as a result of the LEAD project. On the other hand, some identified aspects that may hinder the implementation of this solution -all related to e-vehicles- should be considered, such as the limited access to charging infrastructure and autonomy (battery charging rationale) and the battery lifespan.

3.7 Conclusions

Within the LEAD project a new sustainability assessment framework is developed, the STAR Logistic Methodology, for the evaluation of solutions in the field of last-mile logistic strategies from the sustainability perspective.

KPIs were estimated for each LEAD scenario (“what if” scenarios described in Deliverables: D3.4; D3.6; D3.8; D3.10, D3.12 and D3.14 compared to the baseline scenario of each LL) using either Digital Twins Tools outcomes, data from pilot operators or survey-based to stakeholders. Based on the KPIs, the STAR Logistic Methodology was applied to each of the LLs’ scenarios to get sustainability performance ratings that kelp selecting different LEAD value cases towards low-emission adaptive LML supporting an on-demand economy.

Table 40 shows the sustainability ratings for the scenarios of each LL measured according to the *Sustainability Performance Rating* of the STAR Logistics methodology. The results show that all the measures that lead to the shift towards low-carbon and low-pollutant vehicle delivery models (electric vehicles, delivery bicycles or tricycles), new business models (crowdshipping, parcel lockers) or new delivery models (UCC or microhubs) are successful from a sustainable point of view. The performance rating, however, depends on how effective the solution is to improve sustainability, and also on the baseline situation that is used to calculate the incremental ratings. For instance, although the sustainability ratings of the Budapest LL are much higher than those of the Oslo LL, that does not necessarily mean that Budapest’s solution is better than Oslo’s. First, because the baseline in each city is different, and second because the sensitivity to the context of each sustainability criteria varies across cities. In addition, we should not forget that not all the LLs were able to calculate all the KPI. For example, in the case of Madrid all KPIs have been calculated, while in Budapest and Oslo only 11 and 9 KPI out of 15 have been provided.

Finally, it is worth noting that even though all the scenarios improve the sustainability performance compared to the baseline situation, the sustainability impact assessment conducted through STAR allows decision-makers to select the best scenario from a sustainability point of view, as it is shown in Table 40.

Table 40: Best sustainable Last-mile Logistic scenario for each LEAD LL.

Living Lab	Sustainable LML scenario	Sustainable Performance Rating
Madrid	B2C: BAU with E-van	**433.736**
	B2C: Hybrid van + UCC + E-scooter	**492.029**
	B2C: E-van + UCC + E-scooter	**529.382**
	B2C: Big E-van + UCC + E-scooter	**555.566**
The Hague	B2C: Crowdshipping	**258.156**
	B2C: Parcel Lockers	**151.855**
	B2C: Parcel Lockers (bikes) + Crowdshipping	**352.536**
Lyon A	B2C: 3 UCCs + cargo-bikes today’s demand of parcels	**85.758**
	B2C: BAU with 2030 demand of parcels	**112.792**
	B2C: UCC scenario with 2030 demand of parcels B2C	**168.051**
Lyon B	B2C: UCC scenario with 2030 demand of parcels	**47.441**
	B2C: Only e-vehicles are allowed to enter LEZ zone in Lyon with 2030 demand of parcels	**75.858**
	B2C PRICE +20% 2030: BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +20% with the predicted demand of 2030 year	**13.030**
	B2C PRICE +40% 2030: BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +40% with the predicted demand of 2030 year	**68.040**
	B2C PRICE +60% 2030: BAU 2030 scenario but with a penalty factor on the price of combustion vehicles (taxes) of +60% with the predicted demand of 2030 year	**239.935**

Living Lab	Sustainable LML scenario	Sustainable Performance Rating
Budapest	B2B: Minihub (LNG vehicle) + permanent warehouse 24h/day	**512.221**
	B2B: Minihub (e-vehicle 16t) + continuous warehouse (7 am to 12 pm)	**546.380**
	B2B: Minihub (LNG vehicle) + 24h transhipment point	**566.706**
	B2B: Minihub (e-van) + transhipment point (7 am to 12 pm)	**578.402**
Oslo	B2C: E-vans	**248.421**
	B2C: E-vans + microhub	**259.305**
	B2C: E-vans + microhub + Crodwshipper	**289.884**
Porto	B2B: 25% e-vehicles	**114.133**
	B2B: 50% e-vehicles	**186.284**
	B2B: 75% e-vehicles	**288.808**

4 LEAD Solutions Validation Methodology

4.1 Methodology

The **LEAD Solutions Validation** is an action included in '*Task 3.8. Impact Assessment, Solutions Validation and Learning Conclusions*'. The aim is to know whether the solutions developed and tested have accomplished the objectives originally set. The validation methodology includes the items described below:

1. **LEAD value cases impact validation**. Each LL reports of the accomplishment of the LEAD KPIs originally set in the grant agreement (see Deliverables D3.4; D3.6; D3.8; D3.10; D3.12; D3.14). Additionally, the results were presented in the Final LLs Local Workshops.

2. **LEAD Living Labs validation**

    a. **LEAD pilots, scale-up and business value validation** based on a questionnaire to the participants at the end of the Final LLs Local Workshops**.**

    b. LEAD Digital Twins validation
        i. LLs partners should verify the accuracy of the results of the DTs' models (see Deliverable 3.x).
        ii. Validate DTs' utility with the CoP and other players based on a questionnaire at the end of the Final LLs Local Workshops.

Annex 2 includes the Instructions for LEAD Final LLs Local Workshops and the questionnaires of the two different surveys disseminated within the workshops.

4.2 The LEAD Living Labs validation

4.2.1 Pilots, scalability and business value validation

In the Final LL local workshop, a brief presentation of each LL Pilot was made to give the participants an overview of progress made in LEAD. Multiple questions were asked to assess the LLs Pilot (see Annex 2 questionnaire). Below we show a summary of the answers for all LEAD LLs pilots.

Stakeholders participants

A total of 88 valid surveys from stakeholders’ participants in the workshops were obtained, with a balanced distribution across stakeholders. Around 20% of the representatives were from public authorities, another 18% from research and academia; 17% from consultancy firms; and 10% from logistic operators. There was also participation of independent professionals, shippers, lawyers, citizens and neighbours, 8%, 5%, 3%, respectively. Table 41 displays the distribution of answers by LL and stakeholders’ group.

Table 41: Stakeholders participants per Living Lab in the validation surveys.

Stakeholder	Madrid	The Hague	Lyon	Budapest	Oslo	Porto
Public administration	13.8%	66.7%	13.0%	23.8%	16.7%	25.0%
Shipper	3.5%	0.0%	8.7%	9.5%	0.0%	0.0%
Logistic Operator	13.8%	16.7%	8.7%	4.8%	0.0%	25.0%
Consultancy firm	20.7%	0.0%	26.1%	9.5%	0.0%	25.0%
Research / University	20.7%	0.0%	0.0%	23.8%	83.3%	25.0%
Lawyer	0.0%	0.0%	0,0%	19.0%	0.0%	0.0%
Independent professional	0.0%	0.0%	30.4%	0.0%	0.0%	0.0%
Citizens / Neighbour	0.0%	0.0%	13.0%	0.0%	0.0%	0.0%
Other (NGO, etc.)	27.6%	16.7%	0.0%	9.5%	0.0%	0.0%
No. Respondents	29	6	23	21	5	4

Perceived implementation and impacts assessment of the LEAD pilots.

To evaluate the success of the pilots within the LLs, four questions were posed to the participants (see Table 42).

Firstly, participants were asked to rate the implementation of the pilot on a 5-point scale ranging from Poor to Excellent. The feedback received was overwhelmingly positive, with almost no negative opinions being expressed. On average from all LEAD LLs, 37% rated the implementation as Good and 38% as very good. A small percentage of participants chose not to respond. These results suggest that stakeholders positively valued the implementation of the pilots in their cities.

Then, they were asked to rate the feasibility of the business model implemented by the pilot on a 5-point scale ranging from “Not feasible” at all to “Extremely feasible”. The responses received were also very positive, with more than 40% of them considering the business models very feasible and 30% moderately feasible. No negative opinions were expressed.

After the business model description, the sustainability impacts of the pilots were presented by showing LEAD KPIs and comparing them with the targets set at the beginning of the LEAD project. Respondents were asked to rate the performance of the impacts on a 5 point scale ranging from Poor to Extremely good performance. In general, there were positive results with around 60% of the answers being good and very good.

Finally, medium- long-term impacts of LML LEAD strategies were presented, and participants were asked their agreement or disagreement with such impacts on a 5 point scale ranging from Strongly Disagree to Strongly Agree. Almost 50% of the respondents agree with the medium- and long-term impacts and 20% Strongly Agree.

In conclusion, these results from the pilot validation surveys suggests that the perceived implementation and impacts of the pilots within the LEAD LLs are very positive and they have a high potential for success.

Table 42: Perceived implementation and impacts assessment of the LEAD pilots

1. Please rate how successful has been the **implementation** of [PILOT X] in the [CITY] Living Lab.

	Poor	Fair	Good	Very Good	Excellent	NR/ DK
Madrid LL	0,0%	0,0%	13,6%	36,4%	27,3%	22,7%
The Hague LL	0,0%	0,0%	33,3%	66,7%	0,0%	0,0%
Lyon LL	4,3%	34,8%	43,5%	17,4%	0,0%	0,0%
Budapest LL	0,0%	8,0%	32,0%	48,0%	4,0%	8,0%
Oslo LL	0,0%	0,0%	50,0%	33,3%	16,7%	0,0%
Porto LL	0,0%	0,0%	50,0%	25,0%	25,0%	0,0%
LEAD LLs average	**0,7%**	**7,1%**	**37,1%**	**37,8%**	**12,2%**	**5,1%**

2. According to your opinion, the **business model** presented to implement the [PILOT`X] in the [CITY] Living Lab is…

	Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/ DK
Madrid LL	0,0%	0,0%	19,1%	52,4%	28,6%	0,0%
The Hague LL	0,0%	0,0%	50,0%	50,0%	0,0%	0,0%
Lyon LL	0,0%	26,1%	47,8%	26,1%	0,0%	0,0%
Budapest LL	0,0%	16,0%	16,0%	36,0%	32,0%	0,0%
Oslo LL	0,0%	0,0%	50,0%	33,3%	16,7%	0,0%
Porto LL	0,0%	0,0%	25,0%	50,0%	25,0%	0,0%
LEAD LLs average	**0,0%**	**7,0%**	**34,6%**	**41,3%**	**17,0%**	**0,0%**

3. Please rate the degree of **performance** of the [PILOT X] KPIs **impact results compared to the KPIs objectives set** at the beginning of the LEAD project.

	Poor performance	Fair performance	Good performance	Very good performance	Extremely performance	NR/ DK
Madrid LL	0,0%	0,0%	15,4%	69,2%	15,4%	0,0%
The Hague LL	0,0%	16,7%	33,3%	33,3%	16,7%	0,0%
Lyon LL	0,0%	13,0%	4,4%	0,0%	0,0%	78,3%
Budapest LL	0,0%	8,0%	12,0%	44,0%	32,0%	4,0%
Oslo LL	0,0%	0,0%	50,0%	50,0%	0,0%	0,0%
Porto LL	0,0%	0,0%	75,0%	0,0%	0,0%	25,0%
LEAD LLs average	**0,0%**	**6,3%**	**31,7%**	**32,8%**	**10,7%**	**17,9%**

4. Please indicate whether you agree or disagree with the medium- long-term impacts of LML LEAD strategies presented?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	NR/ DK
Madrid LL	0,0%	3,5%	3,5%	13,8%	17,2%	62,1%
The Hague LL	0,0%	0,0%	50,0%	33,3%	16,7%	0,0%
Lyon LL	0,0%	4,3%	17,4%	56,5%	21,7%	0,0%
Budapest LL	0,0%	4,0%	4,0%	36,0%	48,0%	8,0%
Oslo LL	0,0%	16,7%	16,7%	50,0%	16,7%	0,0%
Porto LL	0,0%	0,0%	0,0%	100,0%	0,0%	0,0%
LEAD LLs average	**0,0%**	**4,7%**	**15,3%**	**48,3%**	**20,1%**	**11,7%**

Perceived scalability of the LEAD pilots.

To assess the possibility of replicating the LEAD pilots in other areas of the city or at a larger scale and their expected impacts, 3 questions were asked. See below in Table 43.

Firstly, participants of the final local workshops were asked to rate the feasibility to apply the LEAD pilots on a larger scale in the city (e.g. all logistics operators, other districts, etc.) on a 5-point scale ranging from “Not at all feasible” to “Extremely feasible”. More than 60% of the respondents considered very and extremely feasible to replicate the pilots at a larger scale. No negative answers were received. So, these results are valuable for decision-makers considering implementing similar initiatives in other parts of the cities and beyond other cities.

Then, they were asked about the impact on the quality of life of city’s inhabitants and the impact on the business performance of logistic operators in case that the pilots were scaled-up. As before, more than 60% of respondents considered that the scalability of the pilots will have positive impacts on the quality of life, and 50% considered that they will have positive impacts on logistics operators.

In conclusion, it is important for policymakers and logistics operators to carefully consider the potential impacts of scaling up LEAD strategies, considering both the benefits and any potential challenges or drawbacks.

Table 43: Perceived scalability of the LEAD pilots

5. Do you consider that applying the [PILOT X] launched in the [CITY] Living Lab **on a larger scale** in the city (e.g. all logistics operators, other districts, etc.) is?

	Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/DK
Madrid LL	0,00%	0,00%	9,52%	66,67%	9,52%	14,29%
The Hague LL	0,00%	0,00%	33,33%	33,33%	33,33%	0,00%
Lyon LL	0,00%	8,70%	43,48%	39,13%	8,70%	0,00%
Budapest LL	0%	0%	12%	20%	56%	12%
Oslo LL						
Porto LL	0%	0%	0%	25%	75%	0%
LEAD LLs average	**0,00%**	**1,45%**	**16,39%**	**30,69%**	**30,42%**	**4,38%**

6. If the [PILOT X] presented in the [CITY] Living Lab were **applied on a larger scale** (e.g. other logistics operators, other districts, etc.), do you think it would have **positive impact on the quality of life of city’s inhabitants**?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	NR/DK
Madrid LL	0%	0%	0,00%	17,24%	20,69%	62,07%
The Hague LL	0,00%	16,67%	16,67%	25%	41,67%	0,00%
Lyon LL	0,00%	8,70%	8,70%	56,52%	26,09%	0,00%
Budapest LL	0%	0%	0%	44%	48%	8%
Oslo LL						
Porto LL	0%	0%	25%	25%	50%	0%
LEAD LLs average	**0,00%**	**4,23%**	**8,39%**	**27,96%**	**31,07%**	**11,68%**

7. If the [PILOT X] presented in the [CITY] Living Lab were **applied on a larger scale** (e.g. all logistics operators, other districts, etc.), do you think it would have a **positive impact on the business performance of logistics operators**?

	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree	NR/DK
Madrid LL	0%	3%	17,25%	10,34%	10,34%	58,62%
The Hague LL	0,00%	8,33%	16,67%	33,33%	41,67%	0,00%
Lyon LL	0,00%	0,00%	21,74%	60,87%	17,39%	0,00%
Budapest LL	0%	8%	32%	40%	8%	12%
Oslo LL						
Porto LL	0%	0%	0%	50%	50%	0%
LEAD LLs average	**0,00%**	**3,30%**	**14,61%**	**32,42%**	**21,23%**	**11,77%**

4.2.2 Digital Twins validation

In the final LL local workshop, a brief presentation of the DT models used in each LL was made for comparing the sustainability impacts of the pilots versus the baseline situations (without pilots). Additionally, different “what if” scenarios were simulated using the DT. Results from the simulation were presented to the stakeholders’ participants in the workshops. Multiple questions were asked to validate the DT as a decision support system (see Annex 2 questionnaire). Below we show a summary of the answers for the validation of the DTs (see Table 44).

Firstly, from a non-technical perspective, participants were asked to assess if the objective of using the DTs is sound and understandable. Overall, 50% of participants agreed and strongly agreed that the objective was sound and understandable. However, 18% of participants had a neutral opinion and 7% disagreed with that.

Then, attendees were asked to assess whether the results of the DTs are clear and understandable by non-technical people. Overall, responses varied among the participants. Around 50% of the participants understood the results, while 19% were neutral and 13% found the explanation unclear. This discrepancy may be attributed to the diverse backgrounds and expertise of the workshop attendees. The results highlight the need for presenting the information in a more accessible manner. That feedback was useful to improve the communication of the results.

The next question was aimed to assess whether the participants considered whether the DT could replicate/simulate logistics operations accurately. In that respect, 34% of the participants marked neutral opinion. This could suggest that there is room for improvement regarding the accuracy of the DTs. Further investigation may be needed to identify specific aspects of the digital twin that may require refinement to improve its accuracy. Additionally, feedback from logistics operators and other stakeholders could help identify potential areas for improvement in the simulation model.

The last two questions were aimed to assess whether the DTs include most of the information and usefulness, respectively, needed by planners and policymakers to fulfil these objectives. Overall, 60% of participants agree or feel neutral with the information included in the digital twins. Additionally, the participants' feedback indicates that the digital twin is perceived as a helpful tool for achieving the goals of planners and logistics companies.

In conclusion, positive feedback was reported attributable to the digital twin's ability to provide data-driven insights that can help decision-making processes related to logistics operations. However, it is worth noting that some participants expressed neutral or negative opinions, suggesting that there may be areas for improvement.

At the end, participants were asked about aspects that were missing in the DTs or areas for improvement. One of the main issues was related to the user interface, which some felt could be improved with better graphical information for decision-making. There were also suggestions for incorporating operational and economic KPIs to track decision-making. Some participants also felt that there could be better cooperation models between stakeholders and the inclusion of other distribution typologies, such as HORECA (Hotel/Restaurant/Café), or B2B in the LLs were only B2C was model, or reverse operations. Finally, there were suggestions for better visualization of user results.

Table 44: Digital Twins validation in the final local LLs workshops

1. From a non-technical perspective, is the objective of the digital twin sound and understandable?						
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NR/DK**
Madrid LL	0%	3%	13,79%	31,03%	20,69%	31,03%
The Hague LL	0%	17%	16,67%	50,00%	16,67%	0%
Lyon LL	0,00%	9,52%	14,29%	47,62%	28,57%	0,00%
Budapest LL	4,00%	12,00%	40,00%	20,00%	12,00%	12,00%
Oslo LL						
Porto LL	0,00%	0,00%	25,00%	75,00%	0,00%	0,00%
LEAD LLs average	**0,67%**	**6,94%**	**18,29%**	**37,28%**	**12,99%**	**7,17%**
2. Is the output provided by the DT clear an easy to the understand by non-technical people?						
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NR/DK**
Madrid LL	0%	10%	20,69%	10,34%	20,69%	38%
The Hague LL	16,67%	16,67%	16,67%	33,33%	16,67%	0,00%
Lyon LL	0,00%	4,76%	23,81%	47,62%	23,81%	0,00%
Budapest LL	4%	24%	32%	16%	8%	16%

Oslo LL						
Porto LL	0%	0%	25%	75%	0%	0%
LEAD LLs average	**3,45%**	**9,30%**	**19,70%**	**30,38%**	**11,53%**	**8,99%**
3. In your opinion, does the DT replicate the logistic operations with enough accuracy?						
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NR/DK**
Madrid LL	0	6,90%	24,14%	20,69%	6,90%	41,38%
The Hague LL						
Lyon LL	0,00%	38,10%	42,86%	19,05%	0,00%	0%
Budapest LL	0%	16,00%	28%	40%	0%	16%
Oslo LL						
Porto LL	0%	0,00%	75%	25%	0%	0%
LEAD LLs average	**0,00%**	**12,20%**	**34,00%**	**20,95%**	**1,38%**	**11,48%**
4. Does the DT include most of the information needed by planners and policy makers?						
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NR/DK**
Madrid LL	0	6,90%	17,24%	20,69%	17,24%	**37,93%**
The Hague LL	0,00%	16,67%	50,00%	16,67%	16,67%	0,00%
Lyon LL	0,00%	38,10%	52,38%	9,52%	0,00%	0,00%
Budapest LL	8%	8%	20%	36%	8%	20%
Oslo LL						
Porto LL	0%	0%	50%	50%	0%	0%
LEAD LLs average	**1,33%**	**11,61%**	**31,60%**	**22,15%**	**6,99%**	**9,66%**
5. Will the DT be useful for planners and logistic companies to achieve their objectives?						
	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NR/DK**
Madrid LL	0	3,45%	6,90%	34,48%	13,79%	**41,38%**
The Hague LL	0,00%	16,67%	50,00%	16,67%	16,67%	0,00%
Lyon LL	0,00%	14,29%	23,81%	23,81%	38,10%	0,00%
Budapest LL	0%	12%	8%	44%	24%	12%
Oslo LL						
Porto LL	0%	0%	50%	50%	0%	0%
LEAD LLs average	**0,00%**	**7,74%**	**23,12%**	**28,16%**	**15,43%**	**8,90%**

5 Lessons learnt and conclusions

This Deliverable has shown the evaluation of LEAD solutions to achieve low-emission adaptive LML by applying the evaluation tool **“STAR Logistics Methodology”,** specifically developed for the LEAD project. Some lessons learnt coming up from the evaluation of such LML measures are worth to be highlighted and considered in forthcoming projects.

First, **sustainability** in last-mile logistics should be considered **from an overall perspective**. The successful implementation of sustainable LML solutions should respond to both the sustainability needs of the city and the criteria of key stakeholders. Every city requires specific measures to improve sustainability. There is not a single solution that is effective everywhere. Consequently, the decision-making process to adopt suitable solutions should be accompanied by an evaluation framework that engages expert stakeholders and considers the sustainability context of each city.

Secondly, policymakers can use the **sustainability rating**, defined in a transparent way, to prioritize and implement sustainable LML solutions that align with specific goals. In this respect, the **STAR Logistics Methodology** facilitates making tailor-made decisions according to the sustainability needs of each city. This approach makes a step forward in assessing sustainable LML solutions by combining expert’s perspectives with sensitive aspects of the city where the LL is implemented. Decision-makers can utilise the outcomes of this research to make sustainability-oriented decisions at the time of implementing LML solutions. STAR Logistics is also a valuable tool for logistics operators to optimize operations and enhance their sustainability performance. Consultants and researchers can leverage the methodology to conduct comprehensive evaluations and keep on advancing in the knowledge of sustainable urban logistics.

Thirdly, **setting the sustainability criteria** and discussing with stakeholders help acquiring knowledge about key aspects to characterize sustainability of last mile logistic solutions. Within LEAD project the establishment of KPIs has been an important part of the project. A set of KPIs are identified and quantified to characterize the sustainability of different LML solutions to be evaluated. The KPIs measure the impact of implementing the proposed LML strategies compared to the BAU scenario for each solution.

Fourthly, **Digital Twins Tools for synchronous last-mile planning** are able to provide KPIs for hypothetical scenarios, that would otherwise be very complicated to get. The LEAD project has developed Digital Twins for urban logistics networks in six cities to support experimentation and decision-making with on-demand logistics operations in a public-private urban setting. Digital Twin models can capture and analyse pertinent metrics based on sustainability criteria. DTs allows making simulations that estimate potential outcomes and associated KPIs based on parameters and configurations, such as equipment changes, operational process, or resource allocation. The LEAD project has demonstrated the potential of the Digital Twins to measure those impacts.

Last, **establishment of a Community of Practice (CoP)** in each LEAD LL has provided an effective and useful collaborative approach to assist in the validation of the solutions, the impact assessment tool and the Digital Twin.

6 References

Alvarez, S.M., Maheut, J., 2022. Protocol: Systematic literature review of the application of the multicriteria decision analysis methodology in the evaluation of urban freight logistics initiatives. WPOM-Working Pap. Oper. Manag. 13, 86–107. https://doi.org/10.4995/wpom.16780

Ayuntamiento de Madrid, 2023. Estrategia de distribución urbana de mercancías DUM [WWW Document]. Madrid 360. URL https://www.madrid360.es/movilidad-sostenible/distribucion-urbana-de-mercancias/ (accessed 5.15.23).

Bueno Cadena, P.C., Vassallo Magro, J.M., 2015. SETTING THE WEIGHTS OF SUSTAINABILITY CRITERIA FOR THE APPRAISAL OF TRANSPORT PROJECTS. TRANSPORT 30, 298–306. https://doi.org/10.3846/16484142.2015.1086890

European Commission, 2020. Quality of life in European cities [WWW Document]. Reg. Policy. URL https://ec.europa.eu/regional_policy/en/information/maps/quality_of_life/ (accessed 4.21.22).

European Environment Agency, 2021. European city air quality viewer [WWW Document]. URL https://www.eea.europa.eu/themes/air/urban-air-quality/european-city-air-quality-viewer (accessed 10.25.22).

European Environment Agency, 2020. 2021 country fact sheets [WWW Document]. URL https://www.eea.europa.eu/themes/air/country-fact-sheets/2021-country-fact-sheets (accessed 10.25.22).

Eurostat, 2022a. Unemployment rates by sex, age, educational attainment level and NUTS 2 regions (%) [WWW Document]. URL https://ec.europa.eu/eurostat/databrowser/view/lfst_r_lfu3rt/default/table?lang=en (accessed 4.21.22).

Eurostat, 2022b. Share of renewable energy in gross final energy consumption by sector [WWW Document]. URL https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en (accessed 4.21.22).

Eurostat, 2022c. Retail trade turnover - total [WWW Document]. URL https://ec.europa.eu/eurostat/databrowser/view/teiis200/default/table?lang=en (accessed 10.25.22).

Jamshidi, A., Jamshidi, F., Ait-Kadi, D., Ramudhin, A., 2019. A review of priority criteria and decision-making methods applied in selection of sustainable city logistics initiatives and collaboration partners. Int. J. Prod. Res. 57, 5175–5193. https://doi.org/10.1080/00207543.2018.1540892

Karbassi Yazdi, A., Abdi, F., 2017. Designing robust model for banks benchmarking based on Rembrandt method and DEA. Benchmarking 24, 431–444. https://doi.org/10.1108/BIJ-01-2015-0001

LEAD Project, 2020. About [WWW Document]. URL https://www.leadproject.eu/about/ (accessed 7.9.21).

Mardani, A., Jusoh, A., Zavadskas, E.K., 2015. Fuzzy multiple criteria decision-making techniques and applications - Two decades review from 1994 to 2014. Expert Syst. Appl. 42, 4126–4148.

https://doi.org/10.1016/j.eswa.2015.01.003

OECD, 2020. Jobs [WWW Document]. Better Life Index. URL https://www.oecdbetterlifeindex.org/topics/jobs/ (accessed 4.21.22).

Olson, D.L., Fliedner, G., Currie, K., 1995. Comparison of the REMBRANDT system with analytic hierarchy process. Eur. J. Oper. Res. 82, 522–539. https://doi.org/10.1016/0377-2217(93)E0340-4

The World Bank, 2020. Logistics performance index: Frequency with which shipments reach consignee within scheduled or expected time (1=low to 5=high) - Spain, Portugal, France, Netherlands, Hungary, Norway | Data [WWW Document]. URL https://data.worldbank.org/indicator/LP.LPI.TIME.XQ?locations=ES-PT-FR-NL-HU-NO (accessed 10.25.22).

TomTom, 2022. Traffic congestion ranking [WWW Document]. URL https://www.tomtom.com/traffic-index/ranking/ (accessed 10.25.22).

Vassallo, J.M., Bueno, P.C., 2021. Sustainability assessment of transport policies, plans and projects. Adv. Transp. Policy Plan. 7, 9–50. https://doi.org/10.1016/bs.atpp.2020.07.006

Vassallo, J.M., Gonzalez, J.N., Sobrino, N., 2023. Sustainable Expert Criteria Weights [WWW Document]. https://doi.org/10.5281/ZENODO.7695814

Watróbski, J., Małecki, K., Kijewska, K., Iwan, S., Karczmarczyk, A., Thompson, R.G., 2017. Multi-Criteria analysis of electric vans for city logistics. Sustain. 9. https://doi.org/10.3390/su9081453

Annex 1: Experts Survey for STAR Logistics Methodology

https://www.surveymonkey.com/r/starlogistics

STAR Logistics Methodology

SUSTAINABILITY CRITERIA WEIGHTS

Dear expert,

This questionnaire is part of the **STAR Logistics Model**, which is a methodological tool developed by UPM to come up with a sustainability rating of last mile logistics solutions. The methodology is based on multi-criteria decision analysis including a **weighting model**.

This questionnaire consists of identifying priorities among different sustainability criteria related to last mile logistics by using a pair-wise comparison method aimed at determining the weights for every criterion.

We would be grateful if you could indicate your opinion as an expert in mobility, logistics or sustainability. **Your response will be of great value** for the results of the sustainability impact assessment in the **LEAD project**. So, **please spend a 5-10 minutes answering the questionnaire**.

The questionnaire can be filled on a mobile phone, but it is preferable to complete it on a computer or tablet. If you have any questions, please contact us by email at: natalia.sobrino@upm.es or juannicolas.gonzalez@upm.es

Thank you very much for your cooperation!

In compliance with the provisions of the Organic Law 3/2018, of 5 December, on Personal Data Protection and Digital Guarantees, we inform you that the personal data you provide in this form will become part of a file, owned by UPM, which will be managed with your consent for purposes solely related to the objectives of the LEAD Project and with no commercial purposes.

Next

Annex 2: LEAD final LLs Local Workshops instructions and validation questionnaires.

GENERAL INSTRUCTIONS FOR LEAD FINAL LLs LOCAL WORKSHOPS

BACKGROUND

The **LEAD Solutions Validation** is an action included in ‘*Task 3.8. Impact Assessment, Solutions Validation and Learning Conclusions*’. The aim is to know whether the solutions developed and tested have accomplished the objectives originally set. The validation methodology includes the four items described below:

3. **LEAD value cases impact validation**. Each LL will include the report of the accomplishment of the LEAD KPIs originally set in the grant agreement. The results will be presented in the *Final LLs Local Workshops*.
   •
4. **LEAD Living Labs validation**
   •
   a. **LEAD pilots, scale-up and business value validation** based on a questionnaire at the end of the *Final LLs Local Workshops* (see “*Pilot Validation Survey”* document).
   •
   b. **LEAD Digital Twins validation**
      i. LLs partners should verify the accuracy of the results of the DTs' models
      ii. Validate DTs’ utility with the CoP and other players based on a questionnaire at the end of the *Final LLs Local Workshops* (see *“Digital Twin Validation Survey”* document).
      iii. Validate DTs’ users experience (TBD).

The following **instructions** are a set of guidelines for conducting the *Final LLs Local Workshop* focused on part of the validation of the LEAD Solutions and the Digital Twins.

PLANNING

The Local Organizing Team of each LL will be in-charge of:

- **Setting the Venue** and deciding whether it will be on-line, on-site or hybrid.
- **Recruiting Participants**. The Local Organizing Team will be in charge of inviting participants (CoP and local stakeholders) to the workshop. Organizers should ensure that all stakeholders are represented (public administrations, logistics operators, shippers, neighbours and citizens, consultancy, researchers and academia, etc.).
- **Ensure a good number of participants** (around 20 per LL).
- **Define the Workshop agenda** following the guidelines below.

PROPOSED WORKSHOP AGENDA

This is a proposed agenda for the workshop. The content can be adapted to the specific characteristics of each Living Lab. Feel free to adapt it according to your needs.

- **Welcome by the Living Lab Leader (5 min)**
- **Living Lab description (15 min) –** Ppt presentation describing the Living Lab in the context of LEAD project, challenges of the city, the pilot implemented, the business model developed, etc.
- **Technical visit / Video (30 min) –** Each Living Lab is free to decide whether a technical visit to the pilot is interesting and possible. If this is not possible, a good option would be to show an explanatory video.
- **Digital Twin (15 min) –** Presentation describing the sequence of models, data inputs and assumptions that formed the DT, simulate scenarios and calculate some impacts of the environmental / economic indicators.
- **LEAD Living Lab impact (10 min) –** Ppt presentation describing the results of the Living Lab: KPIs compared to the targets originally set in the grant agreement (AS IF vs. TO BE), and long-term impact assessment results (*the latter based on the Instructions for reporting KPIs and making future estimates of the LLs scalability document prepared by UPM)*.
- **Conducting workshop’s surveys (15 min) –** Explanation and distribution/completion of the different questionnaires (*surveys validations*).
- **Acknowledgments.** Idea: A thank you gift (*If the LLs have the budget perhaps a tote bag, notepad, pens, etc. with LEAD logos can be given to the attendees*).

DURING THE WORKSHOP

Don’t forget

- Making the Registration of attendees.
- Workshop agenda.
- Evaluation – Survey/Questionnaire forms.
- Take pictures of the workshop.

AFTER THE WORKSHOP

Don’t forget

- Reporting surveys to UPM.
- Summary Report of the Workshop with some pictures, etc.
- Send to the UPM (leader of T3.8) the results of the validation surveys as well as the workshop summary report.

[CITY] LL [PILOT] VALIDATION SURVEY

Dear participant, thank you very much for attending the workshop.

For the validation and acceptance of the solutions proposed in the [CITY] Living Lab aimed at achieving more sustainable and efficient last mile logistics operations, we need you to answer the following questions.

Please indicate the stakeholder you represent:

Public administration	
Shipper	
Logistic Operator	
Consultancy firm	
Research / University	
Lawyer	
Independent professional	
Citizens / Neighbour	
Other (NGO, etc.)	

Based on the results shown in the workshop and your personal expertise, rate the following items:

Perceived implementation and impacts of the pilot

1. Please rate how successful has been the **implementation** of [PILOT X] in the [CITY] Living Lab.

Poor	Fair	Good	Very Good	Excellent	NR/DK

2. According to your opinion, the **business model** presented to implement the [PILOT`X] in the [CITY] Living Lab is…

Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/DK

3. Please rate the degree of **performance** of the [PILOT X] KPIs **impact results compared to the KPIs objectives set** at the beginning of the LEAD project.

Poor performance	Fair performance	Good Performance	Very Good performance	Excellent performance	NR/DK

4. Please indicate whether you agree or disagree with the **medium- long-term impacts of last-mile logistics LEAD strategies presented?**

Strongly disagree	Disagree	Neutral	Agree	Strongly agree	NR/DK

Perceived scalability of the pilot

5. Do you consider that applying the [PILOT X] launched in the [CITY] Living Lab **on a larger scale** in the city (e.g. all logistics operators, other districts, etc.) is?

Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/DK

6. If the [PILOT X] presented in the [CITY] Living Lab were **applied on a larger scale** (e.g. other logistics operators, other districts, etc.), do you think it would have **positive impact on the quality of life city's inhabitants**?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

7. If the [PILOT X] presented in the [CITY] Living Lab were **applied on a larger scale** (e.g. all logistics operators, other districts, etc.), do you think it would have a **positive impact on the business performance of logistics operators**?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/ DK

Other questions

8. What aspect/s do you consider outstanding regarding the LEAD strategies presented at the Living Lab?

9. What aspect/s would you improve of the LEAD strategies presented at the Living Lab?

OTHER SPECIFIC QUESTIONS FOR EACH LIVING LAB – To be proposed by LLs’ partners

Example of specific questions for the Madrid Living Lab

Indicate your opinion regarding the **scalability of the public-private partnership/collaboration** business model implemented at the UCC in the Madrid Living Lab.

Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/DK

[CITY] DIGITAL TWIN VALIDATION SURVEY

Based on the presentation of the DIGITAL TWIN (DT) in [CITY] Living Lab,

10. From a non-technical perspective, is the objective of the digital twin sound and understandable?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

11. Is the output provided by the DT clear an easy to the understand by non-technical people?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

12. In your opinion, does the DT replicate the logistic operations with enough accuracy?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

13. Does the DT include most of the information needed by planners and policy makers?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

14. Will the DT be useful for planners and logistic companies to achieve their objectives?

Totally disagree	Disagree	Neutral	Agree	Totally agree	NR/DK

15. Point out what specific topics/aspects do you miss within the DT:

OTHER SPECIFIC QUESTIONS FOR EACH LIVING LAB – To be proposed by LLs’ partners

Example of specific questions for the Madrid Living Lab

Indicate your opinion on the **applicability of the DT implemented** for the UCC of the Madrid Living Lab to the whole city.

Not at all feasible	Slightly feasible	Moderately feasible	Very feasible	Extremely feasible	NR/DK

Annex 3: STAR Logistics Reports per Living Lab

Impact Assessment, Solutions Validation and Learning Conclusions for Madrid

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-22

1 Introduction

The overall goal of this document is to assess the potential of **LEAD** solutions to achieve Low-Emission adaptive Last Mile Logistics. To that end, this task will be in-charge of monitoring the impact of the measures implemented and what-if scenarios in each value case. The city studied in this document is **Madrid**.

The methodology used in this document is known as **STAR Logistics** developed by the **Universidad Politécnica de Madrid (UPM)**. It is an adaptation of the **STAR Methodology** developed by the **Universidad Politécnica de Madrid (UPM)** for assessing road projects. Basically the goal of this model is to measure sustainability given the fact that the impact factors of the project or certain measures have an opposite balance from the economic, social, and economic points of view. The model offers a multicriteria analysis using multiple inputs to do an appraisal of sustainability.

For more information see:

- Bueno P. C., Vassallo J. M. and Cheung K. (2015) Sustainability Assessment of Transport Infrastructure Projects: A Review of Existing Tools and Methods. Transport Reviews 35(5): 622–649. DOI: 10.1080/01441647.2015.1041435.
- Vassallo, J. M., & Bueno, P. C. (2021). Sustainability assessment of transport policies, plans and projects. Advances in Transport Policy and Planning, 7, 9–50. https://doi.org/10.1016/bs.atpp.2020.07.006.

The **STAR Logistic Methodology** is transferable as it is applicable to any spatial area where an innovative logistic solution is implemented or is planned to be implemented, though it may need a specific calibration of the weights for each context. **STAR Logistics** can be utilized on a large-scale basis by multiple end-users (policymakers, planners, logistics operators, consultants and researchers) who will be able to showcase and publicize the environmental, social and economic benefits of innovative last mile logistics solutions.

The **STAR Logistic Methodology** is composed by three steps:

- Step 1. Scenario definition and Identification of sustainability
- Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria
- Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

2 Step 1. Scenario definition and Identification of sustainability

This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **Madrid** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **Madrid**, the first being the base case.

Table 1: Scenarios definition

Scenarios	Description
Scenario 0	BAU: Diesel Van
Scenario 1	What if: BAU with E-van
Scenario 2	Pilot: UCC Hybrid van + E-scooter
Scenario 3	What if: UCC E-van + E-scooter
Scenario 4	What if: UCC Big E-van + E-scooter

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus "results based on exploiting the strategies". The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

Table 2: Key Performance Inicators

Component	**Label**	**Units**	**Direction**
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	gNO2e/delivery	-1
Environmental	PM emissions	gPM/delivery	-1
Environmental	Noise pollution	% Population affected	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	m2*h/day	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

[a] (+1) More is better, (-1) Less is better

3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

- Paola Carolina Bueno Cadena & José Manuel Vassallo Magro (2015). Setting the weights of sustainability criteria for the appraisal of transport projects, Transport, 30:3, 298-306, DOI: 10.3846/16484142.2015.1086890.

3.1 Experts Weights

Stakeholders were asked to express graded comparative judgments among the different sustainable criteria related to last-mile logistics through a pair-wise comparison questionnaire in a general way and without knowledge of the urban context. Their assessment of trade-offs involves a clear representation of the extent to which the worsening of another may offset the improvement of a criterion. For more details about the methodology Bueno Cadena & Vassallo Magro (2015). **Figure 1** shows the experts weights estimated for each sustainability component and criteria. The **survey** was disseminated online and stakeholders were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector.

3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

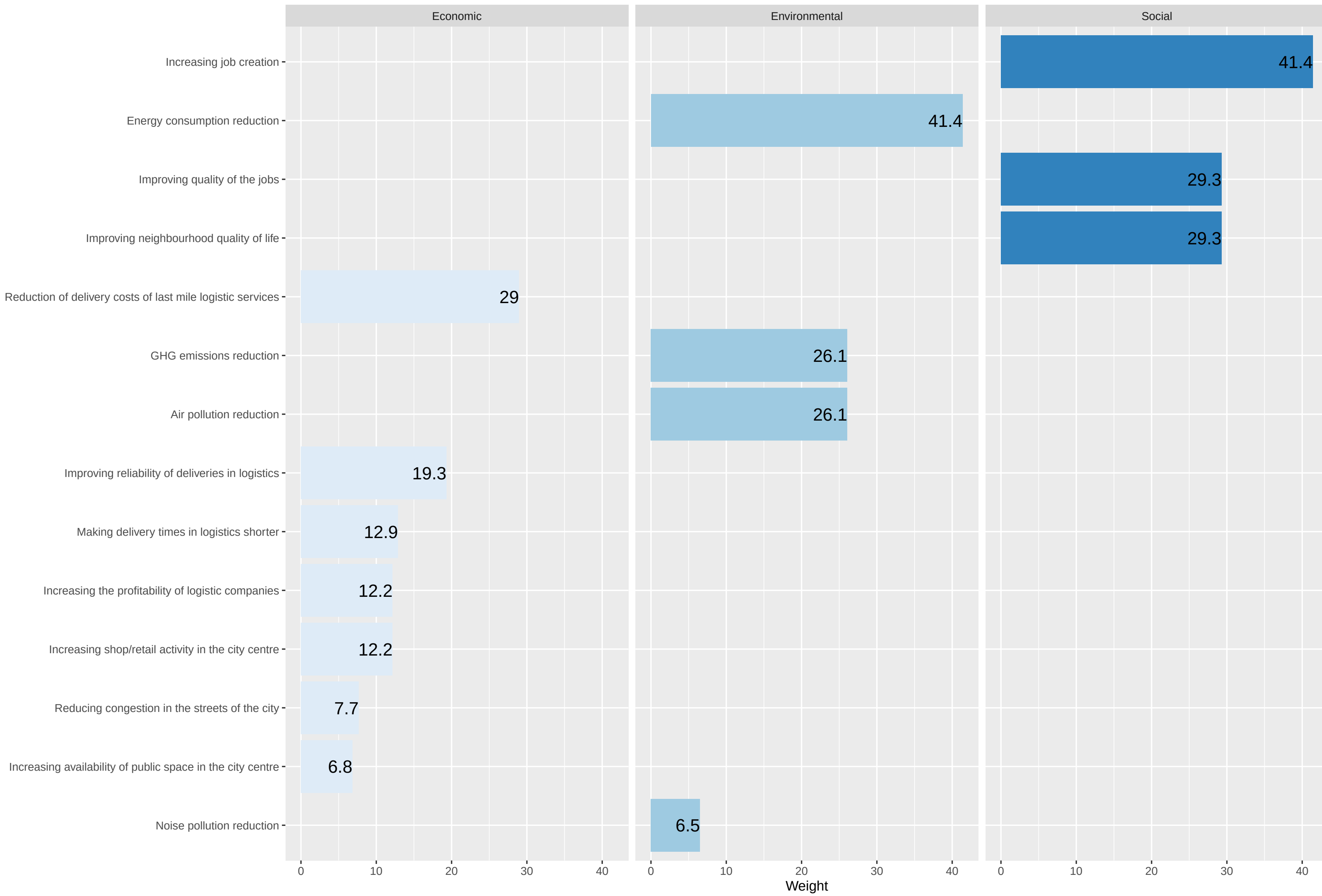

Figure 1: Experts Weights

Table 3: Severity Level for Madrid

KPI	Present Situation	Trend	Severity Index
Job Creation	5	0	5
Quality of the Jobs	5	1	6
Neighbourd Quality of Life	3	2	5
Energy consumption	5	0	5
GHG emissions	3	0	3
NOx emissions	2	0	2
PM emissions	1	1	2
Noise pollution	1	0	1
Average delivery cost of the business model	3	1	4
Congestion	1	1	2
Urban storage & parking space	4	1	5
FIRR	2	2	4
Shop retail benefits	4	2	6
Delivery time	3	0	3
Delivery reliability within the time windows	3	1	4

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Madrid

KPI	**Sustanability Weight**
Job Creation	207.10
Quality of the Jobs	175.74
Neighbourd Quality of Life	146.45
Energy consumption	206.85
GHG emissions	78.18
NOx emissions	52.12
PM emissions	52.12
Noise pollution	6.51
Average delivery cost of the business model	115.80
Congestion	15.34
Urban storage & parking space	34.15
FIRR	48.68
Shop retail benefits	73.02
Delivery time	38.67
Delivery reliability within the time windows	77.28

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Madrid

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Madrid

Component	Label	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Economic	Average delivery cost of the business model	2.3	2.4	2.5	2.6	2.4
Economic	Congestion	300.6	300.6	180.6	180.6	180.6
Economic	Urban storage & parking space	45.1	45.1	245.1	245.1	245.1
Economic	FIRR	4.0	3.0	2.0	1.0	2.0
Economic	Shop retail benefits	3.0	3.0	3.8	3.8	3.8
Economic	Delivery time	5.0	5.0	4.0	4.0	4.0
Economic	Delivery reliability within the time windows	0.8	0.8	0.9	0.9	0.9
Environmental	Energy consumption	1.3	0.1	0.3	0.1	0.1
Environmental	GHG emissions	357.0	0.0	63.6	0.0	0.0
Environmental	NOx emissions	0.4	0.0	0.0	0.0	0.0
Environmental	PM emissions	0.0	0.0	0.0	0.0	0.0
Environmental	Noise pollution	59.7	49.1	35.0	35.0	35.0
Social	Job Creation	5.0	5.0	10.0	10.0	10.0
Social	Quality of the Jobs	3.0	3.0	3.6	3.6	3.6
Social	Neighbourd Quality of Life	3.0	4.4	4.4	4.4	4.4

4.2 Change from baseline scenario for Madrid

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Economic	Average delivery cost of the business model	0.0	0.1	0.1	0.0
Economic	Congestion	0.0	-0.4	-0.4	-0.4
Economic	Urban storage & parking space	0.0	4.4	4.4	4.4
Economic	FIRR	-0.2	-0.5	-0.8	-0.5
Economic	Shop retail benefits	0.0	0.3	0.3	0.3
Economic	Delivery time	0.0	-0.2	-0.2	-0.2
Economic	Delivery reliability within the time windows	0.0	0.1	0.1	0.1
Environmental	Energy consumption	-0.9	-0.8	-0.9	-0.9
Environmental	GHG emissions	-1.0	-0.8	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0	-1.0
Environmental	PM emissions	-1.0	-0.7	-1.0	-1.0
Environmental	Noise pollution	-0.2	-0.4	-0.4	-0.4
Social	Job Creation	0.0	1.0	1.0	1.0
Social	Quality of the Jobs	0.0	0.2	0.2	0.2
Social	Neighbourd Quality of Life	0.5	0.5	0.5	0.5

4.3 Sustainable Performance for Madrid

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Madrid Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**	**Agg Scenario 4**
Economic	Average delivery cost of the business model	0.000	-11.580	-11.580	0.000
Economic	Congestion	0.000	6.136	6.136	6.136
Economic	Urban storage & parking space	0.000	-150.260	-150.260	-150.260
Economic	FIRR	-9.736	-24.340	-38.944	-24.340
Economic	Shop retail benefits	0.000	21.906	21.906	21.906
Economic	Delivery time	0.000	7.734	7.734	7.734
Economic	Delivery reliability within the time windows	0.000	7.728	7.728	7.728
Environmental	Energy consumption	186.165	165.480	186.165	186.165
Environmental	GHG emissions	78.180	62.544	78.180	78.180
Environmental	NOx emissions	52.120	52.120	52.120	52.120
Environmental	PM emissions	52.120	36.484	52.120	52.120
Environmental	Noise pollution	1.302	2.604	2.604	2.604
Social	Job Creation	0.000	207.100	207.100	207.100
Social	Quality of the Jobs	0.000	35.148	35.148	35.148
Social	Neighbourd Quality of Life	73.225	73.225	73.225	73.225

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Madrid Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 4	555.566	1
Agg Scenario 3	529.382	2
Agg Scenario 2	492.029	3
Agg Scenario 1	433.376	4

Impact Assessment, Solutions Validation and Learning Conclusions for The Hague

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-22

1 Introduction

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This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **The Hague** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **The Hague**, the first being the base case.

Table 1: Scenarios definition

Scenarios	**Description**
Scenario 0	Business as Usual
Scenario 1	Crowdshipping
Scenario 2	Parcel Lockers
Scenario 3	Parcel lockers + Crowdshipping

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus "results based on exploiting the strategies". The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

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Component	**Label**	**Units**	**Direction**
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Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
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Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	gNO2e/delivery	-1
Environmental	PM emissions	gPM/delivery	-1
Environmental	Noise pollution	% Population affected	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	m2*h/day	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

[a] (+1) More is better, (-1) Less is better

3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

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3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

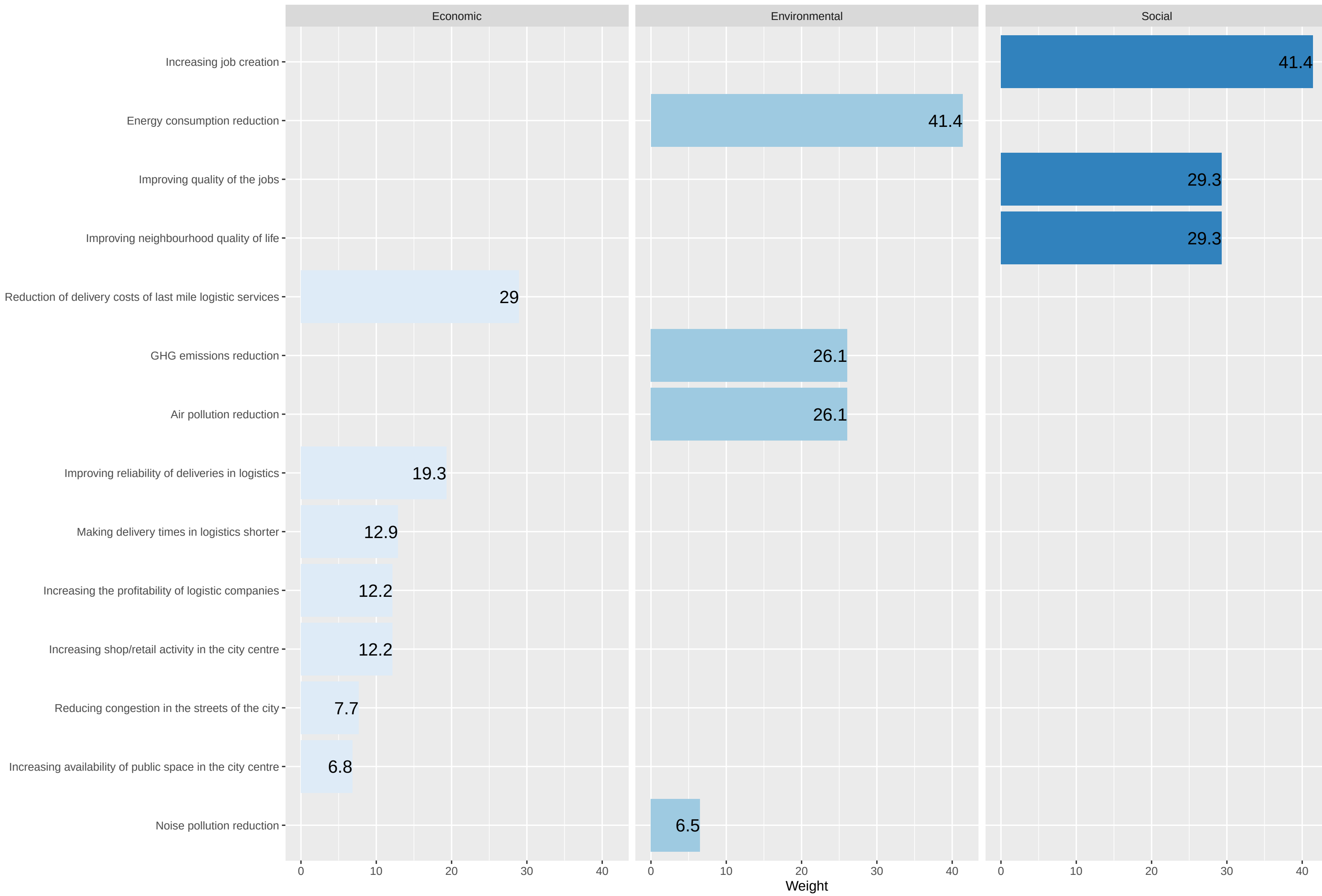

Figure 1: Experts Weights

Table 3: Severity Level for The Hague

KPI	**Present Situation**	**Trend**	**Severity Index**
Job Creation	1	0	1
Quality of the Jobs	1	1	2
Neighbourd Quality of Life	1	0	1
Energy consumption	3	0	3
GHG emissions	3	0	3
NOx emissions	5	0	5
PM emissions	1	0	1
Noise pollution	4	2	6
Average delivery cost of the business model	3	0	3
Congestion	4	1	5
Urban storage & parking space	4	0	4
FIRR	2	0	2
Shop retail benefits	4	0	4
Delivery time	3	0	3
Delivery reliability within the time windows	3	2	5

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for The Hague

KPI	**Sustanability Weight**
Job Creation	41.42
Quality of the Jobs	58.58
Neighbourd Quality of Life	29.29
Energy consumption	124.11
GHG emissions	78.18
NOx emissions	130.30
PM emissions	26.06
Noise pollution	39.06
Average delivery cost of the business model	86.85
Congestion	38.35
Urban storage & parking space	27.32
FIRR	24.34
Shop retail benefits	48.68
Delivery time	38.67
Delivery reliability within the time windows	96.60

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for The Hague

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for The Hague

Component	Label	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Economic	Average delivery cost of the business model	9.2	6.0	9.2	6.0
Economic	Congestion	343.5	310.5	308.3	308.3
Economic	Urban storage & parking space	1.0	1.0	1.0	2.0
Economic	FIRR	1.0	1.0	6.0	6.0
Economic	Shop retail benefits	3.0	3.8	3.8	3.8
Economic	Delivery time	1.0	1.0	1.0	1.0
Economic	Delivery reliability within the time windows	1.0	1.0	1.0	1.0
Environmental	Energy consumption	0.1	0.1	0.1	0.1
Environmental	GHG emissions	6.6	6.1	6.6	6.1
Environmental	NOx emissions	0.0	0.0	0.0	0.0
Environmental	PM emissions	0.0	0.0	0.0	0.0
Environmental	Noise pollution	100.0	100.0	100.0	100.0
Social	Job Creation	10.0	48.0	10.0	48.0
Social	Quality of the Jobs	3.0	3.0	3.0	3.0
Social	Neighbourd Quality of Life	3.0	4.1	4.1	4.1

4.2 Change from baseline scenario for The Hague

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3
Economic	Average delivery cost of the business model	-0.4	0.0	-0.4
Economic	Congestion	-0.1	-0.1	-0.1
Economic	Urban storage & parking space	0.0	0.0	1.0
Economic	FIRR	0.0	5.0	5.0
Economic	Shop retail benefits	0.3	0.3	0.3
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0
Environmental	Energy consumption	-0.1	0.0	-0.1
Environmental	GHG emissions	-0.1	0.0	-0.1
Environmental	NOx emissions	-0.1	0.0	-0.1
Environmental	PM emissions	-0.1	0.0	-0.1
Environmental	Noise pollution	0.0	0.0	0.0
Social	Job Creation	3.8	0.0	3.8
Social	Quality of the Jobs	0.0	0.0	0.0
Social	Neighbourd Quality of Life	0.4	0.4	0.4

4.3 Sustainable Performance for The Hague

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for The Hague Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**
Economic	Average delivery cost of the business model	34.740	0.000	34.740
Economic	Congestion	3.835	3.835	3.835
Economic	Urban storage & parking space	0.000	0.000	-27.320
Economic	FIRR	0.000	121.700	121.700
Economic	Shop retail benefits	14.604	14.604	14.604
Economic	Delivery time	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	0.000	0.000	0.000
Environmental	Energy consumption	12.411	0.000	12.411
Environmental	GHG emissions	7.818	0.000	7.818
Environmental	NOx emissions	13.030	0.000	13.030
Environmental	PM emissions	2.606	0.000	2.606
Environmental	Noise pollution	0.000	0.000	0.000
Social	Job Creation	157.396	0.000	157.396
Social	Quality of the Jobs	0.000	0.000	0.000
Social	Neighbourd Quality of Life	11.716	11.716	11.716

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for The Hague Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 3	352.536	1
Agg Scenario 1	258.156	2
Agg Scenario 2	151.855	3

Impact Assessment, Solutions Validation and Learning Conclusions for Lyon

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-22

1 Introduction

The overall goal of this document is to assess the potential of **LEAD** solutions to achieve Low-Emission adaptive Last Mile Logistics. To that end, this task will be in-charge of monitoring the impact of the measures implemented and what-if scenarios in each value case. The city studied in this document is **Lyon**.

The methodology used in this document is known as **STAR Logistics** developed by the **Universidad Politécnica de Madrid (UPM)**. It is an adaptation of the **STAR Methodology** developed by the **Universidad Politécnica de Madrid (UPM)** for assessing road projects. Basically the goal of this model is to measure sustainability given the fact that the impact factors of the project or certain measures have an opposite balance from the economic, social, and economic points of view. The model offers a multicriteria analysis using multiple inputs to do an appraisal of sustainability.

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The **STAR Logistic Methodology** is transferable as it is applicable to any spatial area where an innovative logistic solution is implemented or is planned to be implemented, though it may need a specific calibration of the weights for each context. **STAR Logistics** can be utilized on a large-scale basis by multiple end-users (policymakers, planners, logistics operators, consultants and researchers) who will be able to showcase and publicize the environmental, social and economic benefits of innovative last mile logistics solutions.

The **STAR Logistic Methodology** is composed by three steps:

- Step 1. Scenario definition and Identification of sustainability
- Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria
- Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

2 Step 1. Scenario definition and Identification of sustainability

This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **Lyon** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **Lyon**, the first being the base case.

Table 1: Scenarios definition

Scenarios	**Description**
Scenario 0	Business as usual with today's demand
Scenario 1	Impementation of UCCs in three underground parkings with cargo-bikes
Scenario 2	Business as usual with future predicted demand
Scenario 3	Implementation of UCCs in three underground parkings with cargo-bikes

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus "results based on exploiting the strategies". The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

Table 2: Key Performance Inicators

Component	Label	Units	Direction
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	mgNOx/delivery	-1
Environmental	PM emissions	mgPM2.5/delivery	-1
Environmental	Noise pollution	dB	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	km	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

[a] (+1) More is better, (-1) Less is better

3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

- Paola Carolina Bueno Cadena & José Manuel Vassallo Magro (2015). Setting the weights of sustainability criteria for the appraisal of transport projects, Transport, 30:3, 298-306, DOI: 10.3846/16484142.2015.1086890.

3.1 Experts Weights

Stakeholders were asked to express graded comparative judgments among the different sustainable criteria related to last-mile logistics through a pair-wise comparison questionnaire in a general way and without knowledge of the urban context. Their assessment of trade-offs involves a clear representation of the extent to which the worsening of another may offset the improvement of a criterion. For more details about the methodology Bueno Cadena & Vassallo Magro (2015). **Figure 1** shows the experts weights estimated for each sustainability component and criteria. The **survey** was disseminated online and stakeholders were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector.

3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

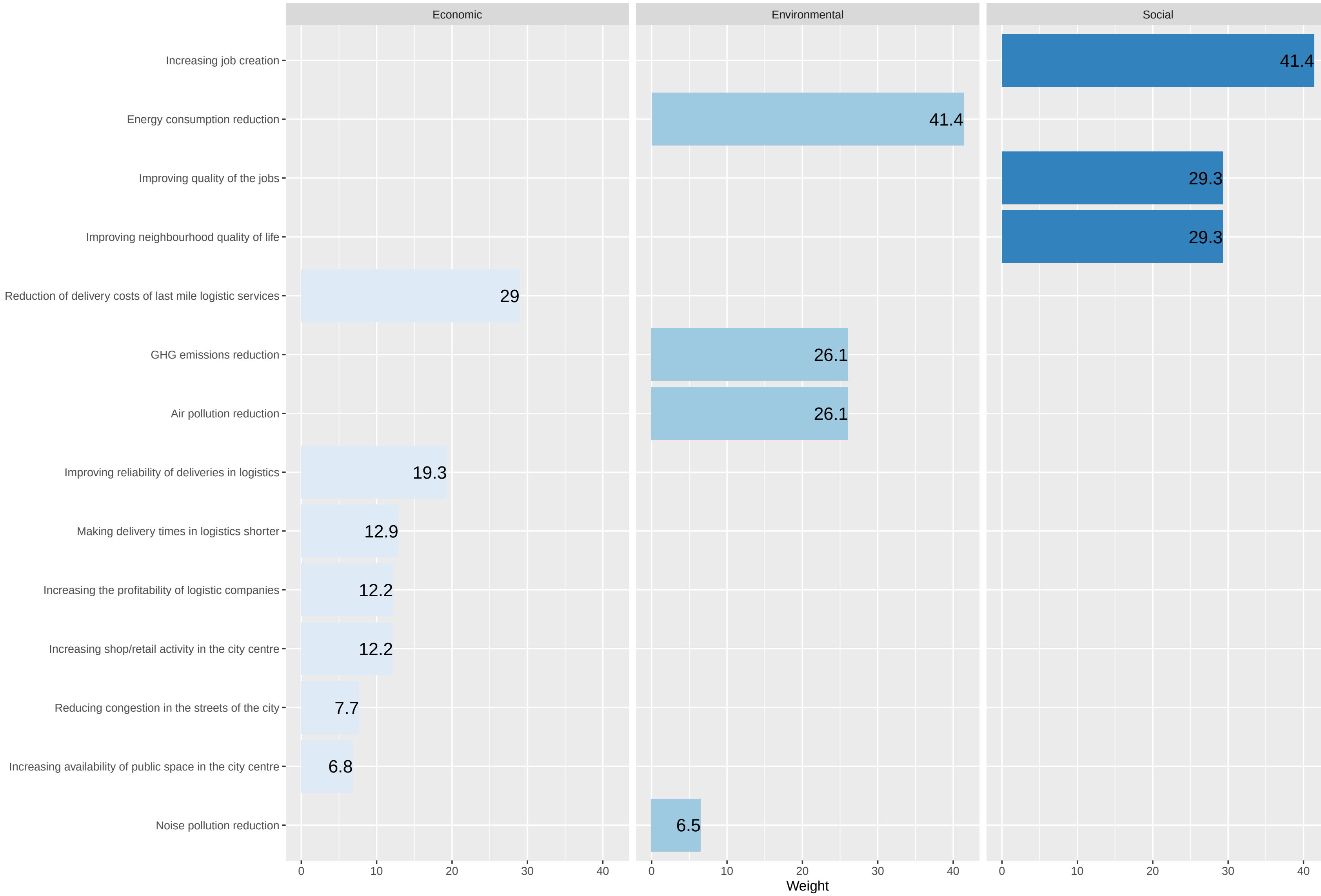

Figure 1: Experts Weights

Table 3: Severity Level for Lyon

KPI	Present Situation	Trend	Severity Index
Job Creation	3	0	3
Quality of the Jobs	2	2	4
Neighbourd Quality of Life	1	0	1
Energy consumption	5	0	5
GHG emissions	3	0	3
NOx emissions	2	0	2
PM emissions	3	0	3
Noise pollution	4	0	4
Average delivery cost of the business model	3	2	5
Congestion	5	1	6
Urban storage & parking space	3	0	3
FIRR	4	0	4
Shop retail benefits	4	0	4
Delivery time	3	0	3
Delivery reliability within the time windows	3	1	4

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Lyon

KPI	**Sustanability Weight**
Job Creation	124.26
Quality of the Jobs	117.16
Neighbourd Quality of Life	29.29
Energy consumption	206.85
GHG emissions	78.18
NOx emissions	52.12
PM emissions	78.18
Noise pollution	26.04
Average delivery cost of the business model	144.75
Congestion	46.02
Urban storage & parking space	20.49
FIRR	48.68
Shop retail benefits	48.68
Delivery time	38.67
Delivery reliability within the time windows	77.28

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Lyon

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Lyon

Component	**Label**	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**
Economic	Average delivery cost of the business model	2.1	2.1	1.8	1.8
Economic	Congestion	6.2	6.1	4.6	5.0
Economic	Urban storage & parking space	100.0	145.0	100.0	145.0
Economic	FIRR	1.0	1.0	1.0	1.0
Economic	Shop retail benefits	3.5	4.1	3.5	4.1
Economic	Delivery time	1.0	1.0	1.0	1.0
Economic	Delivery reliability within the time windows	1.0	1.0	1.0	1.0
Environmental	Energy consumption	1.5	1.4	1.3	1.3
Environmental	GHG emissions	107.7	99.6	91.8	91.6
Environmental	NOx emissions	0.6	0.5	0.5	0.5
Environmental	PM emissions	0.0	0.0	0.0	0.0
Environmental	Noise pollution	45.0	45.0	45.0	45.0
Social	Job Creation	10.0	11.0	10.0	11.0
Social	Quality of the Jobs	3.5	4.6	3.5	4.6
Social	Neighbourd Quality of Life	3.5	4.0	3.5	4.0

4.2 Change from baseline scenario for Lyon

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3
Economic	Average delivery cost of the business model	0.0	-0.2	-0.2
Economic	Congestion	0.0	-0.3	-0.2
Economic	Urban storage & parking space	0.4	0.0	0.4
Economic	FIRR	0.0	0.0	0.0
Economic	Shop retail benefits	0.2	0.0	0.2
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0
Environmental	Energy consumption	-0.1	-0.2	-0.2
Environmental	GHG emissions	-0.1	-0.1	-0.1
Environmental	NOx emissions	-0.1	-0.1	-0.1
Environmental	PM emissions	0.0	-0.2	-0.3
Environmental	Noise pollution	0.0	0.0	0.0
Social	Job Creation	0.1	0.0	0.1
Social	Quality of the Jobs	0.3	0.0	0.3
Social	Neighbourd Quality of Life	0.1	0.0	0.1

4.3 Sustainable Performance for Lyon

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Lyon Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**
Economic	Average delivery cost of the business model	0.000	28.950	28.950
Economic	Congestion	0.000	13.806	9.204
Economic	Urban storage & parking space	-8.196	0.000	-8.196
Economic	FIRR	0.000	0.000	0.000
Economic	Shop retail benefits	9.736	0.000	9.736
Economic	Delivery time	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	0.000	0.000	0.000
Environmental	Energy consumption	20.685	41.370	41.370
Environmental	GHG emissions	7.818	7.818	7.818
Environmental	NOx emissions	5.212	5.212	5.212
Environmental	PM emissions	0.000	15.636	23.454
Environmental	Noise pollution	0.000	0.000	0.000
Social	Job Creation	12.426	0.000	12.426
Social	Quality of the Jobs	35.148	0.000	35.148
Social	Neighbourd Quality of Life	2.929	0.000	2.929

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Lyon Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 3	168.051	1
Agg Scenario 2	112.792	2
Agg Scenario 1	85.758	3

Impact Assessment, Solutions Validation and Learning Conclusions for Lyon

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Table 1: Scenarios definition

Scenarios	**Description**
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Scenario 1	Implementation of UCCs in three underground parkings with cargo-bikes
Scenario 2	Restriction to only let electric vehicles enter the LEZ
Scenario 3	Comparative costs of thermic vehicles +20%
Scenario 4	Comparative costs of thermic vehicles +40%
Scenario 5	Comparative costs of thermic vehicles +60%

Key Performance Incators (KPIs)

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Table 2: Key Performance Inicators

Component	**Label**	**Units**	**Direction**
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	mgNOx/delivery	-1
Environmental	PM emissions	mgPM2.5/delivery	-1
Environmental	Noise pollution	dB	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	km	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

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$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

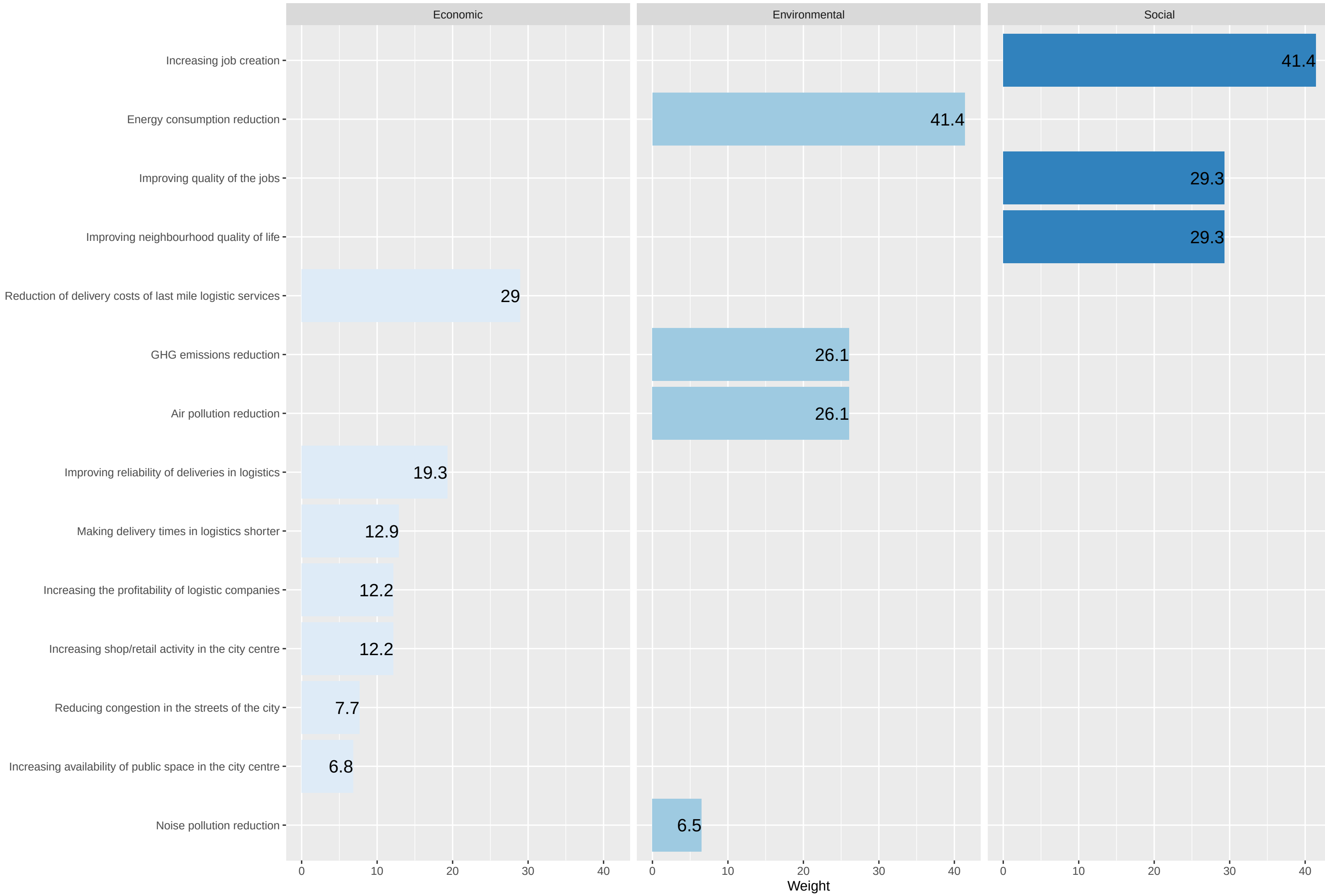

Figure 1: Experts Weights

Table 3: Severity Level for Lyon

KPI	Present Situation	Trend	Severity Index
Job Creation	3	0	3
Quality of the Jobs	2	2	4
Neighbourd Quality of Life	1	0	1
Energy consumption	5	0	5
GHG emissions	3	0	3
NOx emissions	2	0	2
PM emissions	3	0	3
Noise pollution	4	0	4
Average delivery cost of the business model	3	2	5
Congestion	5	1	6
Urban storage & parking space	3	0	3
FIRR	4	0	4
Shop retail benefits	4	0	4
Delivery time	3	0	3
Delivery reliability within the time windows	3	1	4

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Lyon

KPI	**Sustanability Weight**
Job Creation	124.26
Quality of the Jobs	117.16
Neighbourd Quality of Life	29.29
Energy consumption	206.85
GHG emissions	78.18
NOx emissions	52.12
PM emissions	78.18
Noise pollution	26.04
Average delivery cost of the business model	144.75
Congestion	46.02
Urban storage & parking space	20.49
FIRR	48.68
Shop retail benefits	48.68
Delivery time	38.67
Delivery reliability within the time windows	77.28

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Lyon

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Lyon

Component	**Label**	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Economic	Average delivery cost of the business model	1.8	1.8	1.8	1.8	1.8	1.9
Economic	Congestion	4.6	5.0	5.0	4.6	4.9	4.8
Economic	Urban storage & parking space	100.0	145.0	100.0	100.0	100.0	100.0
Economic	FIRR	1.0	1.0	1.0	1.0	1.0	1.0
Economic	Shop retail benefits	3.5	4.1	3.5	3.5	3.5	3.5
Economic	Delivery time	1.0	1.0	1.0	1.0	1.0	1.0
Economic	Delivery reliability within the time windows	1.0	1.0	1.0	1.0	1.0	1.0
Environmental	Energy consumption	1.3	1.3	1.0	1.2	1.1	0.5
Environmental	GHG emissions	91.8	91.6	65.1	87.0	69.9	12.2
Environmental	NOx emissions	0.5	0.5	0.3	0.5	0.3	0.0
Environmental	PM emissions	0.0	0.0	0.0	0.0	0.0	0.0
Environmental	Noise pollution	45.0	45.0	45.0	45.0	45.0	45.0
Social	Job Creation	10.0	11.0	10.0	10.0	10.0	10.0
Social	Quality of the Jobs	3.5	4.6	3.5	3.5	3.5	3.5
Social	Neighbourd Quality of Life	3.5	4.0	3.5	3.5	3.5	3.5

4.2 Change from baseline scenario for Lyon

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4	Ch
Economic	Average delivery cost of the business model	0.0	0.0	0.0	0.0	
Economic	Congestion	0.1	0.1	0.0	0.1	
Economic	Urban storage & parking space	0.4	0.0	0.0	0.0	
Economic	FIRR	0.0	0.0	0.0	0.0	
Economic	Shop retail benefits	0.2	0.0	0.0	0.0	
Economic	Delivery time	0.0	0.0	0.0	0.0	
Economic	Delivery reliability within the time windows	0.0	0.0	0.0	0.0	
Environmental	Energy consumption	0.0	-0.2	0.0	-0.2	
Environmental	GHG emissions	0.0	-0.3	-0.1	-0.2	
Environmental	NOx emissions	0.0	-0.3	-0.1	-0.3	
Environmental	PM emissions	0.0	0.0	0.0	0.0	
Environmental	Noise pollution	0.0	0.0	0.0	0.0	
Social	Job Creation	0.1	0.0	0.0	0.0	
Social	Quality of the Jobs	0.3	0.0	0.0	0.0	
Social	Neighbourd Quality of Life	0.1	0.0	0.0	0.0	

4.3 Sustainable Performance for Lyon

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Lyon Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**	**Agg Scenario 4**	**Agg Scenario 5**
Economic	Average delivery cost of the business model	0.000	0.000	0.000	0.000	-14.475
Economic	Congestion	-4.602	-4.602	0.000	-4.602	0.000
Economic	Urban storage & parking space	-8.196	0.000	0.000	0.000	0.000
Economic	FIRR	0.000	0.000	0.000	0.000	0.000
Economic	Shop retail benefits	9.736	0.000	0.000	0.000	0.000
Economic	Delivery time	0.000	0.000	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	0.000	0.000	0.000	0.000	0.000
Environmental	Energy consumption	0.000	41.370	0.000	41.370	124.110
Environmental	GHG emissions	0.000	23.454	7.818	15.636	70.362
Environmental	NOx emissions	0.000	15.636	5.212	15.636	52.120
Environmental	PM emissions	0.000	0.000	0.000	0.000	7.818
Environmental	Noise pollution	0.000	0.000	0.000	0.000	0.000
Social	Job Creation	12.426	0.000	0.000	0.000	0.000
Social	Quality of the Jobs	35.148	0.000	0.000	0.000	0.000
Social	Neighbourd Quality of Life	2.929	0.000	0.000	0.000	0.000

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Lyon Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 5	239.935	1
Agg Scenario 2	75.858	2
Agg Scenario 4	68.040	3
Agg Scenario 1	47.441	4
Agg Scenario 3	13.030	5

Impact Assessment, Solutions Validation and Learning Conclusions for Budapest

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-28

1 Introduction

The overall goal of this document is to assess the potential of **LEAD** solutions to achieve Low-Emission adaptive Last Mile Logistics. To that end, this task will be in-charge of monitoring the impact of the measures implemented and what-if scenarios in each value case. The city studied in this document is **Budapest**.

The methodology used in this document is known as **STAR Logistics** developed by the **Universidad Politécnica de Madrid (UPM)**. It is an adaptation of the **STAR Methodology** developed by the **Universidad Politécnica de Madrid (UPM)** for assessing road projects. Basically the goal of this model is to measure sustainability given the fact that the impact factors of the project or certain measures have an opposite balance from the economic, social, and economic points of view. The model offers a multicriteria analysis using multiple inputs to do an appraisal of sustainability.

For more information see:

- Bueno P. C., Vassallo J. M. and Cheung K. (2015) Sustainability Assessment of Transport Infrastructure Projects: A Review of Existing Tools and Methods. Transport Reviews 35(5): 622–649. DOI: 10.1080/01441647.2015.1041435.
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The **STAR Logistic Methodology** is transferable as it is applicable to any spatial area where an innovative logistic solution is implemented or is planned to be implemented, though it may need a specific calibration of the weights for each context. **STAR Logistics** can be utilized on a large-scale basis by multiple end-users (policymakers, planners, logistics operators, consultants and researchers) who will be able to showcase and publicize the environmental, social and economic benefits of innovative last mile logistics solutions.

The **STAR Logistic Methodology** is composed by three steps:

- Step 1. Scenario definition and Identification of sustainability
- Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria
- Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

2 Step 1. Scenario definition and Identification of sustainability

This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **Budapest** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **Budapest**, the first being the base case.

Table 1: Scenarios definition

Scenarios	**Description**
Scenario 0	Business as Usual
Scenario 1	LNG vehicle from BILK to the minihub. Permanent regional service warehouse operating 24 hours a day. B2B. Between minihub and shops: electric van
Scenario 2	Electric 16t vehicle from BILK. Permanent regional warehouse open from 7 a.m. to 12 p.m. B2B. Between minihub and shops: electric van
Scenario 3	LNG vehicle from BILK to the minihub. 24-hour transshipment point. B2B. Between minihub and shops: electric van
Scenario 4	16t electric vehicle from BILK to the minihub. Transshipment point open from 7 a.m. to 12 p.m. B2B. Between minihub and shops: electric van

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus "results based on exploiting the strategies". The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

Table 2: Key Performance Inicators

Component	Label	Units	Direction
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	liter/delivery	-1
Environmental	GHG emissions	tCO2e/partner	-1
Environmental	NOx emissions	gNO2e/partner	-1
Environmental	PM emissions	gPM/partner	-1
Environmental	Noise pollution	dB	-1
Economic	Average delivery cost of the business model	€	-1
Economic	Congestion	m2/day	-1
Economic	Urban storage & parking space	m2/day	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/partner	-1
Economic	Delivery reliability within the time windows	%	1

[a] (+1) More is better, (-1) Less is better

3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

- Paola Carolina Bueno Cadena & José Manuel Vassallo Magro (2015). Setting the weights of sustainability criteria for the appraisal of transport projects, Transport, 30:3, 298-306, DOI: 10.3846/16484142.2015.1086890.

3.1 Experts Weights

Stakeholders were asked to express graded comparative judgments among the different sustainable criteria related to last-mile logistics through a pair-wise comparison questionnaire in a general way and without knowledge of the urban context. Their assessment of trade-offs involves a clear representation of the extent to which the worsening of another may offset the improvement of a criterion. For more details about the methodology Bueno Cadena & Vassallo Magro (2015). **Figure 1** shows the experts weights estimated for each sustainability component and criteria. The **survey** was disseminated online and stakeholders were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector.

3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

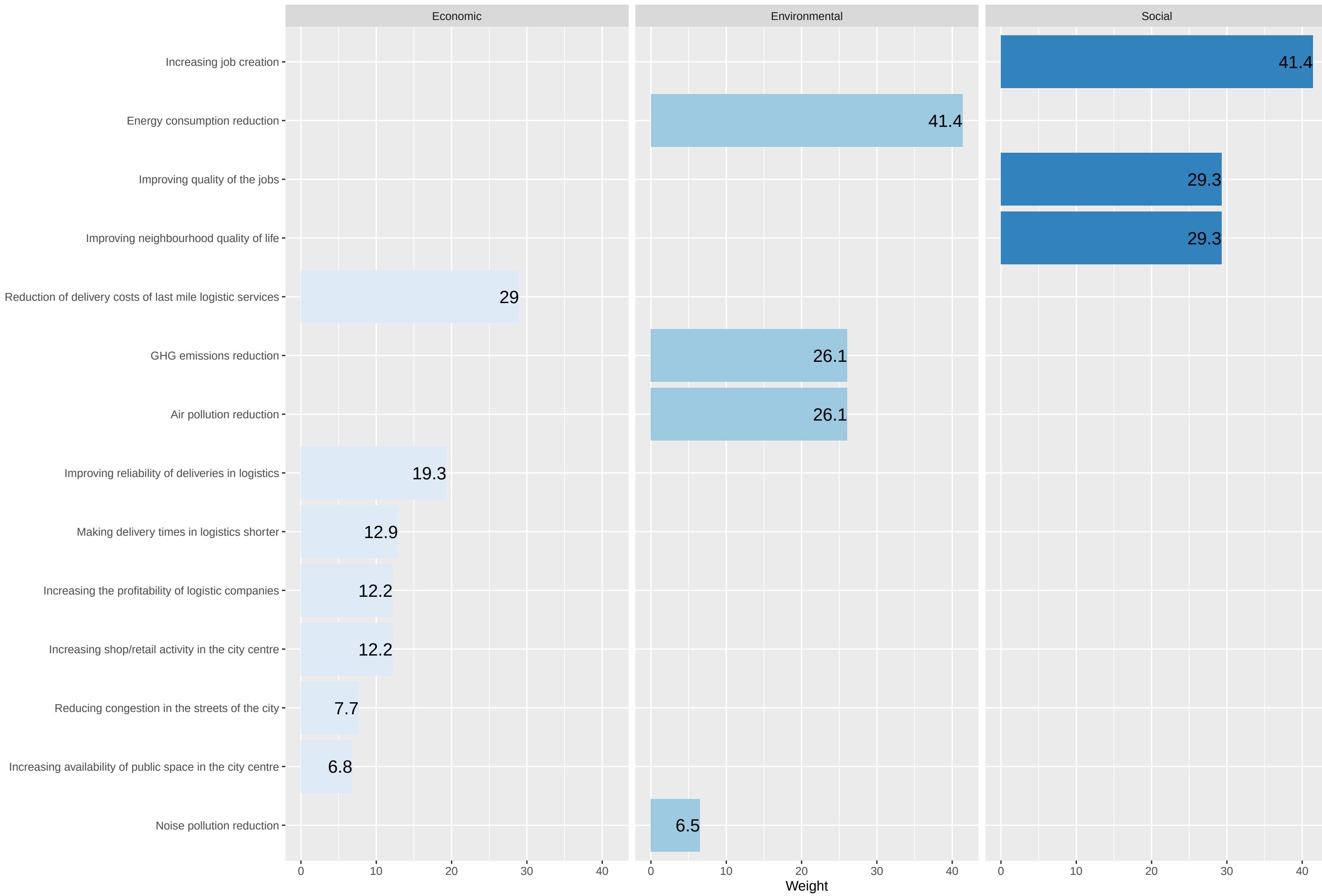

Figure 1: Experts Weights

Table 3: Severity Level for Budapest

KPI	**Present Situation**	**Trend**	**Severity Index**
Job Creation	1	1	2
Quality of the Jobs	2	2	4
Neighbourd Quality of Life	3	2	5
Energy consumption	3	1	4
GHG emissions	3	0	3
NOx emissions	3	1	4
PM emissions	3	0	3
Noise pollution	4	2	6
Average delivery cost of the business model	4	2	6
Congestion	5	0	5
Urban storage & parking space	4	0	4
FIRR	3	0	3
Shop retail benefits	1	0	1
Delivery time	3	0	3
Delivery reliability within the time windows	3	2	5

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Budapest

KPI	**Sustanability Weight**
Job Creation	82.84
Quality of the Jobs	117.16
Neighbourd Quality of Life	146.45
Energy consumption	165.48
GHG emissions	78.18
NOx emissions	104.24
PM emissions	78.18
Noise pollution	39.06
Average delivery cost of the business model	173.70
Congestion	38.35
Urban storage & parking space	27.32
FIRR	36.51
Shop retail benefits	12.17
Delivery time	38.67
Delivery reliability within the time windows	96.60

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Budapest

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Budapest

Component	**Label**	**Scenario 0**	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
Economic	Average delivery cost of the business model	630.0	722.6	720.9	715.7	718.8
Economic	Congestion	863.2	322.8	354.7	322.8	354.7
Economic	Urban storage & parking space	742.5	209.1	240.9	113.1	144.9
Economic	FIRR	1.0	1.0	1.0	1.0	1.0
Economic	Shop retail benefits	3.5	3.5	3.5	3.5	3.5
Economic	Delivery time	2400.0	1728.0	1728.0	1728.0	1728.0
Economic	Delivery reliability within the time windows	90.0	90.0	90.0	90.0	90.0
Environmental	Energy consumption	69.3	8.5	0.0	8.5	0.0
Environmental	GHG emissions	1.1	0.0	0.0	0.0	0.0
Environmental	NOx emissions	581.1	5.9	0.0	5.9	0.0
Environmental	PM emissions	8.3	0.8	0.0	0.2	0.0
Environmental	Noise pollution	400.0	400.0	400.0	400.0	400.0
Social	Job Creation	13.0	18.0	15.0	18.0	15.0
Social	Quality of the Jobs	4.0	4.5	5.0	4.5	5.0
Social	Neighbourd Quality of Life	3.0	3.5	4.0	4.5	4.5

4.2 Change from baseline scenario for Budapest

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Economic	Average delivery cost of the business model	0.1	0.1	0.1	0.1
Economic	Congestion	-0.6	-0.6	-0.6	-0.6
Economic	Urban storage & parking space	-0.7	-0.7	-0.8	-0.8
Economic	FIRR	0.0	0.0	0.0	0.0
Economic	Shop retail benefits	0.0	0.0	0.0	0.0
Economic	Delivery time	-0.3	-0.3	-0.3	-0.3
Economic	Delivery reliability within the time windows	0.0	0.0	0.0	0.0
Environmental	Energy consumption	-0.9	-1.0	-0.9	-1.0
Environmental	GHG emissions	-1.0	-1.0	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0	-1.0
Environmental	PM emissions	-0.9	-1.0	-1.0	-1.0
Environmental	Noise pollution	0.0	0.0	0.0	0.0
Social	Job Creation	0.4	0.2	0.4	0.2
Social	Quality of the Jobs	0.1	0.2	0.1	0.2
Social	Neighbourd Quality of Life	0.2	0.3	0.5	0.5

4.3 Sustainable Performance for Budapest

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Budapest Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**	**Agg Scenario 4**
Economic	Average delivery cost of the business model	-17.370	-17.370	-17.370	-17.370
Economic	Congestion	23.010	23.010	23.010	23.010
Economic	Urban storage & parking space	19.124	19.124	21.856	21.856
Economic	FIRR	0.000	0.000	0.000	0.000
Economic	Shop retail benefits	0.000	0.000	0.000	0.000
Economic	Delivery time	11.601	11.601	11.601	11.601
Economic	Delivery reliability within the time windows	0.000	0.000	0.000	0.000
Environmental	Energy consumption	148.932	165.480	148.932	165.480
Environmental	GHG emissions	78.180	78.180	78.180	78.180
Environmental	NOx emissions	104.240	104.240	104.240	104.240
Environmental	PM emissions	70.362	78.180	78.180	78.180
Environmental	Noise pollution	0.000	0.000	0.000	0.000
Social	Job Creation	33.136	16.568	33.136	16.568
Social	Quality of the Jobs	11.716	23.432	11.716	23.432
Social	Neighbourd Quality of Life	29.290	43.935	73.225	73.225

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Budapest Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 4	578.402	1
Agg Scenario 3	566.706	2
Agg Scenario 2	546.380	3
Agg Scenario 1	512.221	4

Impact Assessment, Solutions Validation and Learning Conclusions for Oslo

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-22

1 Introduction

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This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **Oslo** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **Oslo**, the first being the base case.

Table 1: Scenarios definition

Scenarios	**Description**
Scenario 0	Business as Usual
Scenario 1	Deliver with electrical vehicles
Scenario 2	Deliver using a microhub and electric vehicles
Scenario 3	Deliver using a microhub, electric vehicles and crowdshippers
Scenario 4	Deliver using a microhub, electric vehicles, crowdshippers and doing returns

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus “results based on exploiting the strategies”. The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

Table 2: Key Performance Inicators

Component	**Label**	**Units**	**Direction**
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	gNO2e/delivery	-1
Environmental	PM emissions	gPM/delivery	-1
Environmental	Noise pollution	dBA*h/day	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	%	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	%	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

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3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

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Stakeholders were asked to express graded comparative judgments among the different sustainable criteria related to last-mile logistics through a pair-wise comparison questionnaire in a general way and without knowledge of the urban context. Their assessment of trade-offs involves a clear representation of the extent to which the worsening of another may offset the improvement of a criterion. For more details about the methodology Bueno Cadena & Vassallo Magro (2015). **Figure 1** shows the experts weights estimated for each sustainability component and criteria. The **survey** was disseminated online and stakeholders were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector.

3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

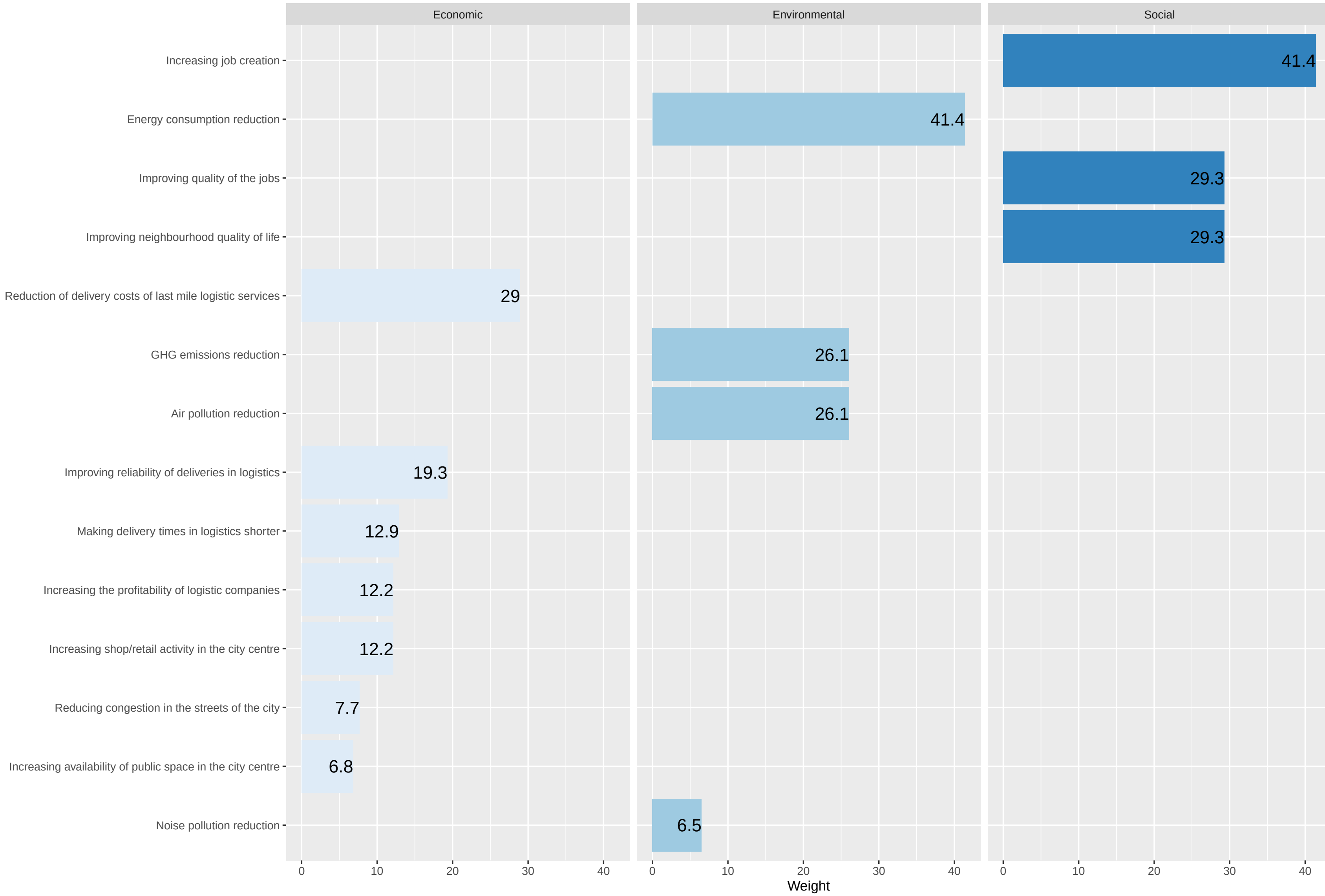

Figure 1: Experts Weights

Table 3: Severity Level for Oslo

KPI	Present Situation	Trend	Severity Index
Job Creation	1	1	2
Quality of the Jobs	1	1	2
Neighbourd Quality of Life	1	2	3
Energy consumption	1	0	1
GHG emissions	3	0	3
NOx emissions	3	0	3
PM emissions	1	0	1
Noise pollution	5	1	6
Average delivery cost of the business model	3	2	5
Congestion	2	1	3
Urban storage & parking space	4	2	6
FIRR	2	0	2
Shop retail benefits	3	0	3
Delivery time	3	1	4
Delivery reliability within the time windows	3	1	4

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Oslo

KPI	**Sustanability Weight**
Job Creation	82.84
Quality of the Jobs	58.58
Neighbourd Quality of Life	87.87
Energy consumption	41.37
GHG emissions	78.18
NOx emissions	78.18
PM emissions	26.06
Noise pollution	39.06
Average delivery cost of the business model	144.75
Congestion	23.01
Urban storage & parking space	40.98
FIRR	24.34
Shop retail benefits	36.51
Delivery time	51.56
Delivery reliability within the time windows	77.28

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Oslo

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Oslo

Component	Label	Scenario 0	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Economic	Average delivery cost of the business model	275.0	261.0	210.0	246.0	246.0
Economic	Congestion	0.2	0.2	0.2	0.3	0.3
Economic	Urban storage & parking space	201458.5	114542.6	122031.3	55617.3	55617.3
Economic	FIRR	1.0	1.0	1.0	1.0	1.0
Economic	Shop retail benefits	1.0	1.0	1.0	1.0	1.0
Economic	Delivery time	51.0	40.0	41.0	27.0	27.0
Economic	Delivery reliability within the time windows	0.8	0.8	0.8	0.9	0.9
Environmental	Energy consumption	126.6	56.0	43.3	21.1	21.1
Environmental	GHG emissions	11.9	0.1	0.1	0.0	0.0
Environmental	NOx emissions	18.4	0.0	0.0	0.0	0.0
Environmental	PM emissions	0.0	0.0	0.0	0.0	0.0
Environmental	Noise pollution	1.0	1.0	1.0	1.0	1.0
Social	Job Creation	1.0	1.0	1.0	1.0	1.0
Social	Quality of the Jobs	1.0	1.0	1.0	1.0	1.0
Social	Neighbourd Quality of Life	3.4	3.4	3.4	3.4	3.4

4.2 Change from baseline scenario for Oslo

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3	Change Scenario 4
Economic	Average delivery cost of the business model	-0.1	-0.2	-0.1	-0.1
Economic	Congestion	0.0	0.0	0.1	0.1
Economic	Urban storage & parking space	-0.4	-0.4	-0.7	-0.7
Economic	FIRR	0.0	0.0	0.0	0.0
Economic	Shop retail benefits	0.0	0.0	0.0	0.0
Economic	Delivery time	-0.2	-0.2	-0.5	-0.5
Economic	Delivery reliability within the time windows	0.0	-0.1	0.1	0.1
Environmental	Energy consumption	-0.6	-0.7	-0.8	-0.8
Environmental	GHG emissions	-1.0	-1.0	-1.0	-1.0
Environmental	NOx emissions	-1.0	-1.0	-1.0	-1.0
Environmental	PM emissions	-1.0	-1.0	-1.0	-1.0
Environmental	Noise pollution	0.0	0.0	0.0	0.0
Social	Job Creation	0.0	0.0	0.0	0.0
Social	Quality of the Jobs	0.0	0.0	0.0	0.0
Social	Neighbourd Quality of Life	0.0	0.0	0.0	0.0

4.3 Sustainable Performance for Oslo

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Oslo Last-Mile alternatives

Component	Label	Agg Scenario 1	Agg Scenario 2	Agg Scenario 3	Agg Scenario 4
Economic	Average delivery cost of the business model	14.475	28.950	14.475	14.475
Economic	Congestion	0.000	0.000	-2.301	-2.301
Economic	Urban storage & parking space	16.392	16.392	28.686	28.686
Economic	FIRR	0.000	0.000	0.000	0.000
Economic	Shop retail benefits	0.000	0.000	0.000	0.000
Economic	Delivery time	10.312	10.312	25.780	25.780
Economic	Delivery reliability within the time windows	0.000	-7.728	7.728	7.728
Environmental	Energy consumption	24.822	28.959	33.096	33.096
Environmental	GHG emissions	78.180	78.180	78.180	78.180
Environmental	NOx emissions	78.180	78.180	78.180	78.180
Environmental	PM emissions	26.060	26.060	26.060	26.060
Environmental	Noise pollution	0.000	0.000	0.000	0.000
Social	Job Creation	0.000	0.000	0.000	0.000
Social	Quality of the Jobs	0.000	0.000	0.000	0.000
Social	Neighbourd Quality of Life	0.000	0.000	0.000	0.000

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Oslo Last-Mile alternatives

Alternative	Total	Rating
Agg Scenario 3	289.884	1
Agg Scenario 4	289.884	2
Agg Scenario 2	259.305	3
Agg Scenario 1	248.421	4

Impact Assessment, Solutions Validation and Learning Conclusions for Porto

Juan Nicolas Gonzalez[1] Natalia Sobrino[2] José Manuel Vassallo[3]

2023-09-22

1 Introduction

The overall goal of this document is to assess the potential of **LEAD** solutions to achieve Low-Emission adaptive Last Mile Logistics. To that end, this task will be in-charge of monitoring the impact of the measures implemented and what-if scenarios in each value case. The city studied in this document is **Porto**.

The methodology used in this document is known as **STAR Logistics** developed by the **Universidad Politécnica de Madrid (UPM)**. It is an adaptation of the **STAR Methodology** developed by the **Universidad Politécnica de Madrid (UPM)** for assessing road projects. Basically the goal of this model is to measure sustainability given the fact that the impact factors of the project or certain measures have an opposite balance from the economic, social, and economic points of view. The model offers a multicriteria analysis using multiple inputs to do an appraisal of sustainability.

For more information see:

- Bueno P. C., Vassallo J. M. and Cheung K. (2015) Sustainability Assessment of Transport Infrastructure Projects: A Review of Existing Tools and Methods. Transport Reviews 35(5): 622–649. DOI: 10.1080/01441647.2015.1041435.
- Vassallo, J. M., & Bueno, P. C. (2021). Sustainability assessment of transport policies, plans and projects. Advances in Transport Policy and Planning, 7, 9–50. https://doi.org/10.1016/bs.atpp.2020.07.006.

The **STAR Logistic Methodology** is transferable as it is applicable to any spatial area where an innovative logistic solution is implemented or is planned to be implemented, though it may need a specific calibration of the weights for each context. **STAR Logistics** can be utilized on a large-scale basis by multiple end-users (policymakers, planners, logistics operators, consultants and researchers) who will be able to showcase and publicize the environmental, social and economic benefits of innovative last mile logistics solutions.

The **STAR Logistic Methodology** is composed by three steps:

- Step 1. Scenario definition and Identification of sustainability
- Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria
- Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

2 Step 1. Scenario definition and Identification of sustainability

This step consists of identifying and quantifying project criteria related to sustainability. Items are grouped into the economic, social and environmental component of sustainability. Firstly, it is necessary to define the scenarios to assess and then which Key Performance Indicators (KPIs) will be measured.

Scenario definition

Different strategies have been assessed in **Porto** in order to achieve a more sustainable Last Mile Logistic. **Table 1** shows the scenarios assessed for **Porto**, the first being the base case.

Table 1: Scenarios definition

Scenarios	Description
Scenario 0	Business as Usual
Scenario 1	Deliver with 75% electrical vehicles
Scenario 2	Deliver with 50% electrical vehicles
Scenario 3	Deliver with 25% electrical vehicles

Key Performance Incators (KPIs)

The impacts of the scenarios will be measured by monitoring a set of common KPIs applicable to all of them. These KPIs will compare the impact of conducting the scenarios with the baseline scenario (Scenario 0) that will be defined as results based on business-as-usual (i.e. not implementing the strategies tested) versus "results based on exploiting the strategies". The KPIs will be measured using a twofold approach: via simulation before the interventions; and, as far as possible, empirically during the projects period. **Table 2** shows the KPIs assessed in the **STAR Logistic Methodology**.

Table 2: Key Performance Inicators

Component	Label	Units	Direction
Social	Job Creation	employee	1
Social	Quality of the Jobs	Value between 1 to 5	1
Social	Neighbourd Quality of Life	Value between 1 to 5	1
Environmental	Energy consumption	MJ/delivery	-1
Environmental	GHG emissions	gCO2e/delivery	-1
Environmental	NOx emissions	gNO2e/delivery	-1
Environmental	PM emissions	gPM/delivery	-1
Environmental	Noise pollution	dB	-1
Economic	Average delivery cost of the business model	€/delivery	-1
Economic	Congestion	m2*h/day	-1
Economic	Urban storage & parking space	Square meters	-1
Economic	FIRR	€	1
Economic	Shop retail benefits	Value between 1 to 5	1
Economic	Delivery time	minutes/delivery	-1
Economic	Delivery reliability within the time windows	%	1

[a] (+1) More is better, (-1) Less is better

3 Step 2. Assignment of Weighting Coefficients to the Sustainability Criteria

This step addresses the relatively limited number of real and standard applications to determine the relative impact of each criterion on sustainability. The proposed weighting process directly addresses the issues surrounding the use of weights and how these might be obtained in practice. The procedure to be developed is based on a combination of the Ratio Estimation in Magnitudes or decibels to Rate Alternatives, which are Non-Dominated system (REMBRANDT system), the Delphi method, and an objective value defined as the Level of Severity. Then, the assignment of weighting coefficients to the sustainability criteria proposed in this method is based on the urban context and evaluation judgments –preferences for pairwise comparisons of sustainability criteria by decision-makers and experts in the field. A detailed description of the estimation of weights is presented in the following paper:

- Paola Carolina Bueno Cadena & José Manuel Vassallo Magro (2015). Setting the weights of sustainability criteria for the appraisal of transport projects, Transport, 30:3, 298-306, DOI: 10.3846/16484142.2015.1086890.

3.1 Experts Weights

Stakeholders were asked to express graded comparative judgments among the different sustainable criteria related to last-mile logistics through a pair-wise comparison questionnaire in a general way and without knowledge of the urban context. Their assessment of trade-offs involves a clear representation of the extent to which the worsening of another may offset the improvement of a criterion. For more details about the methodology Bueno Cadena & Vassallo Magro (2015). **Figure 1** shows the experts weights estimated for each sustainability component and criteria. The **survey** was disseminated online and stakeholders were invited to answer it from May to June 2022. In the end, 54 experts answered the survey, well-distributed by years of experience in the logistics sector.

3.2 Severity Level

To evaluate the context of a city, the Severity Level (SL) index is used, which compares the context value of each criterion in a city with the average value in other similar cities. The Present Situation (PS) and Trend (T) are considered for each criterion to determine the SL index, with the Present Situation evaluated on a scale of 0 to 5 points based on how it compares to the average in the context. The Trend is classified as "improving," "stable," or "worsening" and allocated 0 to 2 points accordingly. The SL index is the sum of the Present Situation and Trend, with a range of 0 to 7.

$$SL_i = CI_i + TI_i$$

Where,

SL_i = Severity Level for criterion i

PS_i = Present Situation for criterion i

T_i = Trend for criterion i

Table 3 shows the Severity Level estimated for the city and its respective value for their Present Situation and Trend.

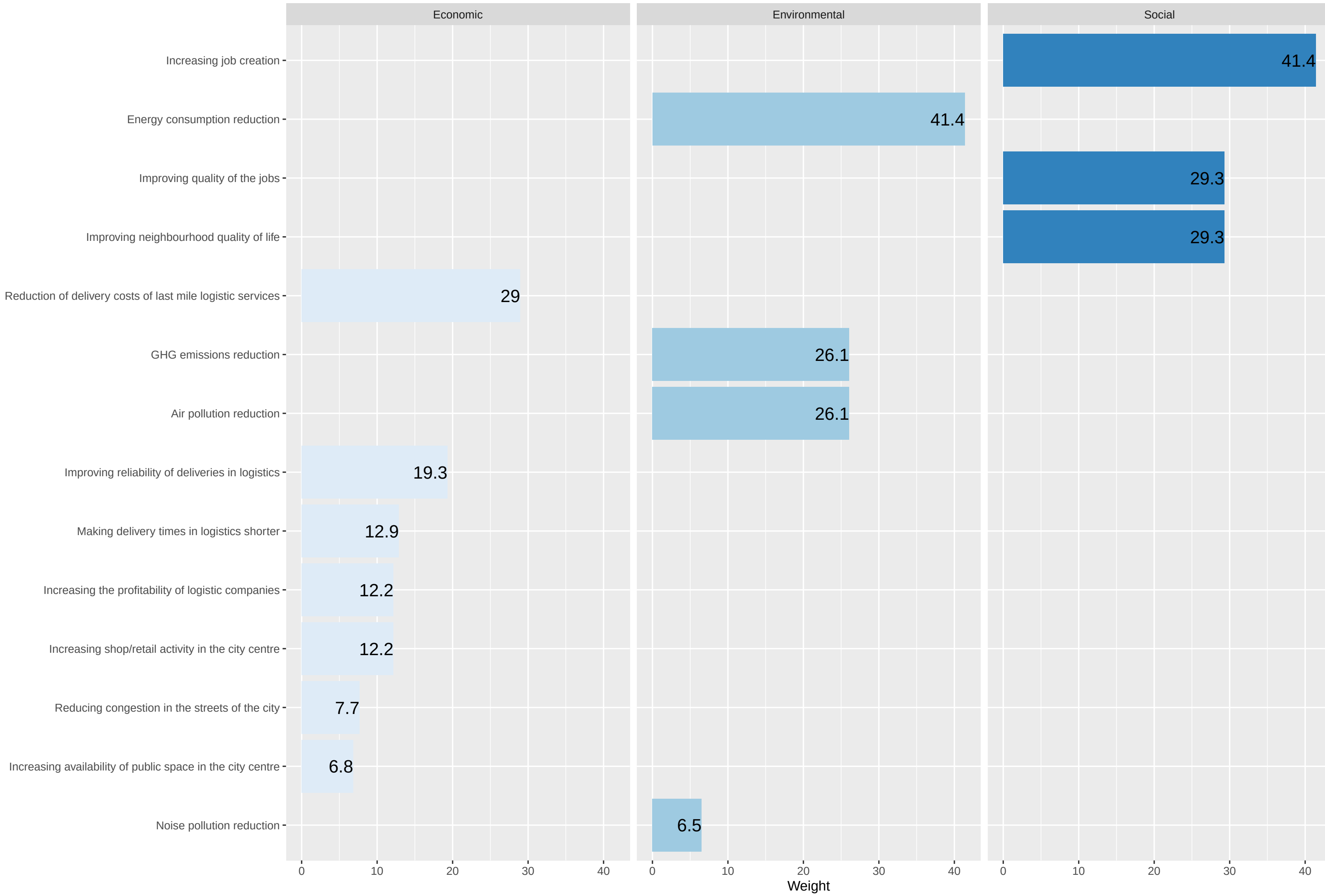

Figure 1: Experts Weights

Table 3: Severity Level for Porto

KPI	**Present Situation**	**Trend**	**Severity Index**
Job Creation	2	1	3
Quality of the Jobs	3	1	4
Neighbourd Quality of Life	1	1	2
Energy consumption	5	0	5
GHG emissions	3	0	3
NOx emissions	3	1	4
PM emissions	1	1	2
Noise pollution	1	2	3
Average delivery cost of the business model	3	2	5
Congestion	2	0	2
Urban storage & parking space	4	2	6
FIRR	2	1	3
Shop retail benefits	4	0	4
Delivery time	3	1	4
Delivery reliability within the time windows	3	0	3

3.3 Sustainability Weight

The Sustainability Weight for the sustainability criterion i is defined by the equation:

$$SW_i = CW_i * SL_i$$

Where,

SW_i = Sustainability Weight for sustainability criterion i

CW_i = Convergent Weight for sustainability criterion i

SL_i = Severity Level for sustainability criterion i

Table 4 shows the Sustainability Weight (SW) for each criterion. For this analysis, SW can vary between 0 – 290 (considering an SL of 7 and the highest obtained Experts' Weights).

Table 4: Sustainability Weight for Porto

KPI	**Sustanability Weight**
Job Creation	124.26
Quality of the Jobs	117.16
Neighbourd Quality of Life	58.58
Energy consumption	206.85
GHG emissions	78.18
NOx emissions	104.24
PM emissions	52.12
Noise pollution	19.53
Average delivery cost of the business model	144.75
Congestion	15.34
Urban storage & parking space	40.98
FIRR	36.51
Shop retail benefits	48.68
Delivery time	51.56
Delivery reliability within the time windows	57.96

4 Step 3. Sustainability Evaluations of Last-Mile Solutions Alternatives

The main objective of this step is to assess the last-mile solution alternatives according to their sustainability performance. Firstly, KPIs in each scenario are estimated. Then, there is calculated the percentage change of each of the scenarios with respect to the baseline scenario (scenario 0). Finally, the sustainability performance of each scenario is estimated by obtaining the sustainability rate.

4.1 Key Performance Indicators for Porto

Table 5 presents the values obtained for each KPIs (see **Table 2**) and scenarios assessed (see **Table 1**). It is important to clarify at this point that several of the indicators were obtained through the Digital Twin and other are from real data from operators, and other are survey-based.

Table 5: KPIs for Porto

Component	Label	Scenario 0	Scenario 1	Scenario 2	Scenario 3
Economic	Average delivery cost of the business model	2.1	1.2	1.6	1.8
Economic	Congestion	610.0	189.7	333.1	471.0
Economic	Urban storage & parking space	1.0	1.0	1.0	1.0
Economic	FIRR	775000.0	390577.0	547383.0	639791.0
Economic	Shop retail benefits	3.5	3.5	3.5	3.5
Economic	Delivery time	6.3	6.5	6.6	6.5
Economic	Delivery reliability within the time windows	0.9	0.9	0.9	0.9
Environmental	Energy consumption	3.2	1.9	2.5	2.8
Environmental	GHG emissions	150.4	93.4	116.3	135.9
Environmental	NOx emissions	0.0	0.0	0.0	0.0
Environmental	PM emissions	0.0	0.0	0.0	0.0
Environmental	Noise pollution	70.0	66.2	67.5	68.8
Social	Job Creation	31.0	32.0	33.0	32.0
Social	Quality of the Jobs	3.5	4.1	4.1	4.1
Social	Neighbourd Quality of Life	4.7	4.9	4.8	4.7

4.2 Change from baseline scenario for Porto

In order to compare all the KPIs and consider them in the same order of magnitude, the percentage change of each of the scenarios with respect to the base scenario was estimated (see **Table 6**).

Table 6: Change from baseline scenario

Component	Label	Change Scenario 1	Change Scenario 2	Change Scenario 3
Economic	Average delivery cost of the business model	-0.4	-0.2	-0.1
Economic	Congestion	-0.7	-0.5	-0.2
Economic	Urban storage & parking space	0.0	0.0	0.0
Economic	FIRR	-0.5	-0.3	-0.2
Economic	Shop retail benefits	0.0	0.0	0.0
Economic	Delivery time	0.0	0.0	0.0
Economic	Delivery reliability within the time windows	0.0	0.0	0.0
Environmental	Energy consumption	-0.4	-0.2	-0.2
Environmental	GHG emissions	-0.4	-0.2	-0.1
Environmental	NOx emissions	-0.6	-0.4	-0.2
Environmental	PM emissions	-0.7	-0.5	-0.2
Environmental	Noise pollution	-0.1	0.0	0.0
Social	Job Creation	0.0	0.1	0.0
Social	Quality of the Jobs	0.2	0.2	0.2
Social	Neighbourd Quality of Life	0.0	0.0	0.0

4.3 Sustainable Performance for Porto

In order to measure the Sustainable Performance of each scenario, the multiplication between the Sustainability Weight for sustainability and the change rate was performed. In addition, the sign was changed according to its effect of sustainability ((+1) More is better, (-1) Less is better). **Table 7** presents the aggregate values obtaine for each scenario.

Table 7: Sustainable Performance for Porto Last-Mile alternatives

Component	**Label**	**Agg Scenario 1**	**Agg Scenario 2**	**Agg Scenario 3**
Economic	Average delivery cost of the business model	57.900	28.950	14.475
Economic	Congestion	10.738	7.670	3.068
Economic	Urban storage & parking space	0.000	0.000	0.000
Economic	FIRR	-18.255	-10.953	-7.302
Economic	Shop retail benefits	0.000	0.000	0.000
Economic	Delivery time	0.000	0.000	0.000
Economic	Delivery reliability within the time windows	0.000	0.000	0.000
Environmental	Energy consumption	82.740	41.370	41.370
Environmental	GHG emissions	31.272	15.636	7.818
Environmental	NOx emissions	62.544	41.696	20.848
Environmental	PM emissions	36.484	26.060	10.424
Environmental	Noise pollution	1.953	0.000	0.000
Social	Job Creation	0.000	12.426	0.000
Social	Quality of the Jobs	23.432	23.432	23.432
Social	Neighbourd Quality of Life	0.000	0.000	0.000

Finally, for each scenario, all aggregate values were added and arranged from highest to lowest. **Table 8** shows the sustainable rating obtained for each scenario.

Table 8: Sustainable Rating for Porto Last-Mile alternatives

Alternative	**Total**	**Rating**
Agg Scenario 1	288.808	1
Agg Scenario 2	186.287	2
Agg Scenario 3	114.133	3