



# ASSESSMENT FRAMEWORK FOR ZERO-EMISSION DELIVERY OPTIONS

**Project deliverable D3.1**

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## List of abbreviations and acronyms

Acronym	Meaning
AHP	Analytic Hierarchy Process
CINEA	European Climate, Infrastructure and Environment Executive Agency
CO <sub>2</sub>	Carbon dioxide
dB(A)	A-weighted decibels
EU	European Union
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
KPI	Key Performance Indicator
MCA	Multi Criteria Analysis
NO <sub>x</sub>	Nitric Oxides
PM	Particulate Matter
WP	Work Package

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## Abstract

Released within WP3 “**CodeZERO assessment framework**”, Deliverable D3.1 proposes a methodological approach to assess the impact of sustainable delivery options from the perspective of all stakeholders involved in last-mile e-commerce logistics, including consumers, e-tailers, logistics operators, and local authorities.

It defines an assessment framework that translates delivery attributes into quantitative key performance indicators (KPIs) to evaluate sustainability across environmental, social, and economic dimensions.

The framework employs a Multi Criteria Analysis (MCA) and an Analytic Hierarchy Process (AHP) to determine the relative importance of indicators, ensuring a balanced perspective among stakeholders. Insights from an online pairwise comparison survey further refine the weighting of delivery attributes.

**This deliverable is to be approved by the European Commission**

## Executive Summary

CodeZERO is a three-year Horizon Europe research project aiming to co-create **sustainable and zero-emission last-mile delivery and return solutions for ecommerce** that align with **consumers’** preferences while being sustainable for **retailers, logistics operators** and **local authorities**. Additionally, the project is focused on providing clear, consumer-friendly communication and developing tools for local authorities to promote eco-friendly behaviour.

Released within WP3 ‘CodeZERO assessment framework’, deliverable D3.1 presents the methodological framework for assessing the impacts of zero-emission delivery options from the perspective of all stakeholders involved in last-mile e-commerce deliveries and returns i.e. consumers, e-tailers, logistics operators and local authorities.

Forthcoming deliverable D3.2 ‘Assessment framework for consumers’ behaviour change’<sup>1</sup> will provide a set of quantitative and qualitative key performance indicators assessing the effects on consumers of retailer communications about zero-emission delivery and return options.

These two deliverables build in the **CodeZERO assessment framework**, intended not only to be used for the evaluation and comparison of the performance and effectiveness of last-mile sustainable logistics solutions (including the co-created pilots), but also to enable “shared” decision-making by accounting for the point of view of all stakeholders to the definition of sustainable solutions in WP4.

Building on the definitions developed in D1.1 ‘Delivery options analysis framework’, a delivery option can be described by the combination of different delivery attributes and – as such – can be evaluated from the ‘values’ used to quantify these attributes. Therefore, the development of the assessment framework requires as first step, to ‘operationalise’ the attributes. This means specifying the states or levels (i.e. the ‘values’) that each attribute can assume. To this aim, in D3.1 delivery attributes are reformulated in terms of quantitative key performance indicators (KPIs) to be used for evaluating and comparing delivery options from multiple criteria assessing the sustainability of last-mile solutions in the environmental, social, and economic domains.

The relative importance of indicators and criteria within the assessment framework has been based on a Multi Criteria Analysis (MCA) involving multiple stakeholders (i.e. consumers, retailers, transport

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<sup>1</sup> To be released in April 2025.

operators and local authorities) in jointly establishing the relative importance of indicators through an Analytic Hierarchy Process (AHP).

Results from on-line pairwise comparison survey carried by CodeZERO provide an indication of the relative importance of delivery attributes for the different stakeholders.

**This deliverable is to be approved by the European Commission**

## TABLE OF CONTENTS

<b>ABSTRACT</b> .....	<b>5</b>
<b>EXECUTIVE SUMMARY</b> .....	<b>5</b>
<b>1 INTRODUCTION</b> .....	<b>9</b>
<b>1.1 ABOUT CODEZERO</b> .....	<b>9</b>
<b>1.2 AIM OF THIS DOCUMENT</b> .....	<b>9</b>
<b>2 CODEZERO ASSESSMENT FRAMEWORK FOR ZERO-EMISSION DELIVERY OPTIONS</b> 11	
<b>3 KEY PERFORMANCE INDICATORS</b> .....	<b>15</b>
<b>3.1 DEMAND-SIDE ATTRIBUTE INDICATORS</b> .....	<b>15</b>
3.1.1 COST INDICATORS .....	16
3.1.2 FLEXIBILITY INDICATORS .....	17
3.1.3 DELIVERY TIME INDICATORS .....	22
3.1.4 DELIVERY METHOD INDICATORS .....	27
3.1.5 INFORMATION INDICATORS .....	30
3.1.6 RELIABILITY INDICATORS .....	33
<b>3.2 SUPPLY-SIDE ATTRIBUTE INDICATORS</b> .....	<b>35</b>
3.2.1 SERVICE ORGANISATION INDICATORS .....	36
3.2.2 IMPACT MONITORING SYSTEM INDICATORS.....	40
3.2.3 SIZE AND COMPOSITION OF THE VEHICLE FLEET INDICATORS .....	42
3.2.4 WORKFORCE ARRANGEMENT INDICATORS .....	45
3.2.5 DISTRIBUTION NETWORK INDICATORS.....	47
<b>3.3 SPATIAL CONTEXT ATTRIBUTE INDICATORS</b> .....	<b>51</b>
3.3.1 SPATIAL ARRANGEMENT INDICATORS .....	52
<b>3.4 IMPACT ATTRIBUTE INDICATORS</b> .....	<b>58</b>
3.4.1 SERVICE EFFICIENCY INDICATORS .....	59
3.4.2 ENVIRONMENTAL IMPACTS INDICATORS .....	68
3.4.3 TRANSPORT IMPACTS INDICATORS .....	74
3.4.4 LABOUR IMPACTS INDICATORS .....	77
<b>4 EVALUATION OF THE DELIVERY OPTIONS</b> .....	<b>84</b>
<b>4.1 DEFINITION OF THE RELEVANCE OF EACH KPI</b> .....	<b>84</b>
<b>4.2 CALCULATION OF WEIGHTS FOR THE KPIS</b> .....	<b>85</b>
<b>4.3 CALCULATION OF THE NORMALISED SCORES OF EACH KPI</b> .....	<b>88</b>
<b>4.4 CALCULATION OF THE AGGREGATED SCORES</b> .....	<b>89</b>
<b>4.5 AN EXAMPLE OF APPLICATION</b> .....	<b>90</b>
4.5.1 DEFINITION OF THE FICTITIOUS DELIVERY OPTIONS .....	90
4.5.2 QUANTIFICATION OF THE KPIS .....	91
4.5.3 NORMALISATION OF KPIS SCORES .....	96
4.5.4 CALCULATION OF THE AGGREGATED SCORE AND COMPARISON .....	99
<b>5 CODEZERO PAIRWISE COMPARISON SURVEY RESULTS</b> .....	<b>103</b>
<b>6 CONCLUSIONS</b> .....	<b>107</b>
<b>7 REFERENCES</b> .....	<b>108</b>
<b>8 ANNEX: PAIRWISE COMPARISONS</b> .....	<b>109</b>

<b>8.1 DEMAND-SIDE ATTRIBUTES PAIRWISE COMPARISONS.....</b>	<b>109</b>
8.1.1 FIRST LEVEL (COMPARISON BETWEEN ATTRIBUTE TYPES).....	109
8.1.2 SECOND LEVEL (COMPARISON BETWEEN ATTRIBUTES).....	110
<b>8.2 SUPPLY-SIDE AND CONTEXT ATTRIBUTES PAIRWISE COMPARISONS .....</b>	<b>112</b>
8.2.1 FIRST LEVEL (COMPARISON BETWEEN ATTRIBUTE TYPES).....	112
8.2.2 SECOND LEVEL (COMPARISON BETWEEN ATTRIBUTES).....	113
<b>8.3 IMPACT ATTRIBUTES PAIRWISE COMPARISONS .....</b>	<b>115</b>
8.3.1 FIRST LEVEL (COMPARISON BETWEEN ATTRIBUTE TYPES).....	115
8.3.2 SECOND LEVEL (COMPARISON BETWEEN ATTRIBUTES).....	115

## LIST OF FIGURES

Figure 1: Categories and types of attributes .....	11
Figure 2: Demand-side delivery attributes and types.....	15
Figure 3: Supply-side delivery attributes and types.....	35
Figure 4: Spatial context delivery attributes and types.....	51
Figure 5: Impact delivery attributes and types.....	58
Figure 6: Delivery option A.....	90
Figure 7: Delivery option B.....	91
Figure 8: Composition of respondents .....	103

## LIST OF TABLES

Table 2-1: Phases of the evaluation process .....	13
Table 4-1: Initial weights associated to comparisons results .....	86
Table 4-2: Quantification of the KPIs.....	92
Table 4-3: Example: KPIs normalised .....	96
Table 4-4: Options aggregated scores from the consumers' perspective .....	100
Table 4-5: Options aggregated scores from the logistics operators' perspective.....	100
Table 4-6: Options aggregated scores from the retailers' perspective.....	101
Table 4-7: Options aggregated scores from the Public Authorities perspective.....	101
Table 4-8: Consumer overall score .....	102
Table 4-9: Logistics operator overall score .....	102
Table 4-10: Retailer overall score .....	102
Table 4-11: Overall score.....	102
Table 5-1: Demand-side attributes weights.....	104
Table 5-2: Supply-side and context attributes weights.....	105
Table 5-3: Private impacts attributes weights.....	106
Table 5-4: Social impacts attributes weights .....	106

# 1 Introduction

## 1.1 About CodeZERO

CodeZERO is a three-year Horizon Europe research project aiming to co-create **sustainable and zero-emission last-mile delivery and return solutions for ecommerce** that align with **consumers'** preferences while being sustainable for **retailers, logistics operators** and **local authorities**. Additionally, the project is focused on providing clear, consumer-friendly communication and developing tools for local authorities to promote eco-friendly behaviour.

CodeZERO is articulated in four phases:

- An **ANALYSIS** phase which provides (1) an analysis of existing delivery and return options and an understanding of how they are shaped by the needs and constraints of all involved stakeholders; (2) an in-depth intersectional analysis of various groups of on-line consumers to understand what are the features of delivery and return options making them attractive, with the aim to identify mechanisms to incentivize behaviour changes; and (3) develops an assessment framework to measure the impacts in the environmental, economic and social domains of new solutions.
- A **DESIGN** phase, in which CodeZERO engages in a co-design process involving retailers, transport operators, consumers and local authorities in developing (1) guidelines for retailers to raise awareness among customers; (2) a set of zero-emission and sustainable delivery and return options for retailers and transport operators; and (3) a toolset for local authorities to accelerate the transition towards sustainable solutions in last mile consignments in e-commerce.
- A **TEST** phase running 4 pilots in 4 different European cities in Italy, Netherlands, Belgium, and Norway to test a set of sustainable solutions identified in the previous phase with the aim to prove their feasibility, to fine-tune their design and to assess their impacts from the perspective of all stakeholders.
- A **CONSOLIDATION** phase where (1) CodeZERO outcomes are fine-tuned based on the lessons learned from real life applications, (2) requirements for up-scaling of solutions at European level are discussed (3) recommendations are formulated and (4) directions for future research are outlined.

Engagement with consumers and retailers' associations, industry stakeholders, cities and researchers contributes to shaping project results.

Running from June 2024 to May 2027, CodeZERO is organized along eight WPs:

- WP1 Analysis of current delivery models
- WP2 Analysis of consumers' behaviour
- WP3 CodeZERO assessment framework
- WP4 Design of CodeZERO solutions
- WP5 Testing solutions: CodeZERO living labs
- WP6 Conclusions and recommendations
- WP7 Dissemination, communication and exploitation
- WP8 Project management.

## 1.2 Aim of this document

Released within WP3 'CodeZERO assessment framework', deliverable D3.1 presents the methodological framework for assessing the impacts of zero-emission delivery options from the

perspective of all stakeholders involved in last-mile e-commerce deliveries and returns: consumers, e-tailers, logistics operator and local authorities.

Forthcoming deliverable D3.2 'Assessment framework for consumers' behaviour change<sup>2</sup> will provide a set of quantitative and qualitative key performance indicators assessing the effects on consumers of retailer communications about zero-emission delivery and return options.

These two deliverables build in the **CodeZERO assessment framework**, intended not only to be used for the evaluation and comparison of the performance and effectiveness of last-mile sustainable logistics solutions, but also to enable “shared” decision-making by accounting for the point of view of all stakeholders to the definition of sustainable solutions in WP4.

The document is structured as follows:

- Chapter 2 provides an overview of the proposed assessment framework and its linkage with previous and forthcoming project activities.
- Chapter 3 includes a set of factsheets illustrating the key performance indicators identified to measure delivery options from multiple criteria and perspectives.
- Chapter 4 describes the key phases of the evaluation process and provides an example of application.
- Chapter 5 reports the weights obtained from the pairwise comparison exercise performed in CodeZERO.
- Conclusions are presented in Chapter 6
- Annex in Chapter 8 provides the full list of pairwise comparisons supporting the calculation of weights.

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<sup>2</sup> To be released in April 2025.

## 2 CodeZERO assessment framework for zero-emission delivery options

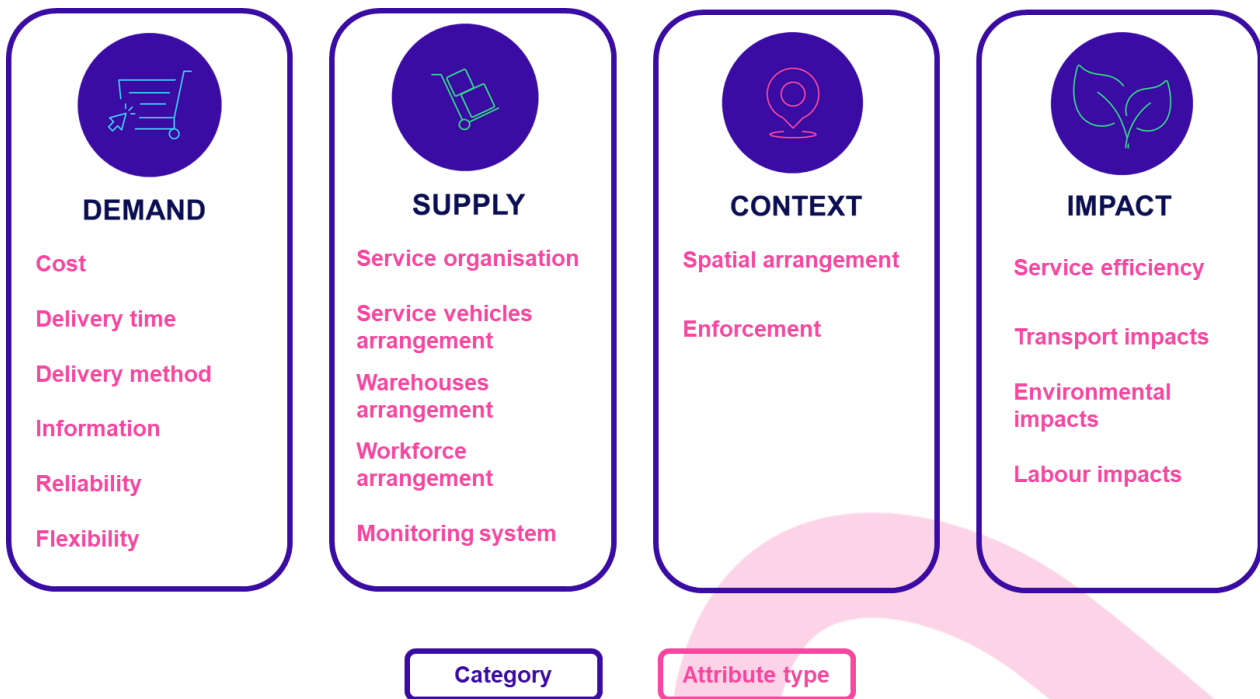
The CodeZERO assessment frameworks builds on some concepts presented and discussed in the CodeZERO deliverable D1.1 ‘Delivery options analysis framework’ released in November 2024. The key definitions are herewith mentioned:

**Delivery option** is defined as one configuration of the delivery process of a product purchased online. As such, one delivery option represents several deliveries with the same features (and not a single delivery).

**Delivery option attribute** is one elementary aspect of the delivery process, i.e. one of the features distinguishing the delivery options.

Delivery attributes are classified according to four categories: **demand-side, supply-side, spatial context and impact**. Each category groups different types of attributes, as shown in Figure 1.

Figure 1: Categories and types of attributes



**Demand-side** attributes are intended to describe customers’ experience both during the purchase process (e.g. by measuring the degree of flexibility in the choice that customers can make to customize their delivery) as well as after the delivery has occurred (e.g. by measuring to what extent the delivery has met their expectations). They are defined while looking at delivery options from the customer’s perspective.

**Supply-side** attributes describe the organisational requirements needed to fulfil customers’ expectations on deliveries. These attributes are defined from the perspectives of on-line retailers and logistics operators and consider elements like the organization of the service, the structure of the distribution network, the workforce arrangement, the size and composition of the delivery fleet etc.

**Spatial context** attributes describe the physical space in which delivery options are operated e.g. in terms of street accessibility, availability of parking lots etc. In many cases, these attributes are affected by decisions of the local authorities which not only regulate land use but can facilitate desirable situations through the adoption of certain policies.

**Impact attributes** refer to the various types of impacts stemming from delivery options. Two categories of impacts have been defined. The first category refers to “private” impacts i.e., those mainly affecting logistics operators (or own account transporting retailers) and look at the efficiency and the cost<sup>3</sup> of the service. The second category of impacts is that of “social” impacts i.e., those affecting the society as a whole and refer to environmental effects (e.g., GHG emissions, polluting emissions, noise) as well as transport impacts (e.g., congestion) and working conditions for drivers and workers in the logistics sector.

Building on the definitions developed in D1.1, a delivery option can be described by the level or state of each delivery attribute. The CodeZERO assessment framework is a methodology for summarising the information provided by the indicators and comparing alternative delivery options considering different perspectives (e.g., the point of view of consumers, the point of view of retailers, the point of view of the authorities).

The application of the assessment framework should allow to identify preferable options among alternative ones. It should also help analysing the preferences of different stakeholders and building innovative options that can represent a balance between conflicting priorities. Therefore, its scope is not limited to the existing delivery options, nor it is limited to the analysis of the delivery options of CodeZERO pilot cases.

In CodeZERO the assessment framework will be applied for comparing the delivery options of the pilot cases against comparable references (e.g. an option representing the current “standard” for delivering a given category of products in a certain context). In these applications several inputs can be derived from the observation/measurement of the delivery process. Nevertheless, the framework includes inputs that might not be directly measured from the pilots for one reason or another and require assumptions. Also, the outcomes of the pilots might suggest that variants or adaptations of the experimented options could enhance the level of sustainability from some perspectives. The assessment framework can be applied to theoretical options of this kind.

The methodology used in the framework is based on a Multi Criteria Analysis (MCA) approach involving multiple stakeholders, namely on an Analytic Hierarchy Process (AHP). The evaluation process involves all categories of stakeholders playing a role in last-mile e-commerce logistics (i.e. consumers, e-tailers, logistics operator and local authorities) as well as analysts performing the evaluation. It is organised according to the seven phases summarized in Table 2-1.

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<sup>3</sup> In CodeZERO assessment framework, the cost of delivery is defined twice. On the one hand, it is included within the demand-side attributes in terms of “delivery price” i.e., the amount of money asked to the customer to cover, entirely or partially, the delivery costs. On the other hand, the delivery cost – meant as production cost – is included among the “private” impacts for operators.

Table 2-1: Phases of the evaluation process

Phase	Content	Roles
1	Definition of KPIs reflecting the level or state of attributes	<ul style="list-style-type: none"> <li>Analysts to define KPIs values based on various sources and methods</li> </ul>
2	Definition of the relevance of each KPI (demand; supply/context; impacts)	<ul style="list-style-type: none"> <li>Analysts to arrange the collection of evaluations</li> <li>Demand-side stakeholders to provide responses according to the defined methodology</li> <li>Supply-side stakeholders (retailers, logistics operators) to provide responses according to the defined methodology</li> <li>Authority stakeholders to provide responses according to the defined methodology</li> <li>Labour stakeholders to provide responses according to the defined methodology</li> </ul>
3	Calculation of weights for the KPIs	<ul style="list-style-type: none"> <li>Analysts to apply the defined methodology</li> </ul>
4	Quantification of all KPIs for each delivery option	<ul style="list-style-type: none"> <li>Analysts to define KPIs values based on various sources and methods</li> <li>Supply-side stakeholders to provide information supporting the definition of values for supply-side and impact KPIs</li> </ul>
5	Calculation of the normalised scores of each KPI for each delivery option	<ul style="list-style-type: none"> <li>Analysts to apply the defined methodology</li> </ul>
6	Calculation of the overall score for each category and for each stakeholders' group	<ul style="list-style-type: none"> <li>Analysts to apply the defined methodology</li> </ul>
7	Calculation of aggregated overall scores across dimensions and/or stakeholders' groups	<ul style="list-style-type: none"> <li>Analysts to apply the defined methodology</li> </ul>

As for the first step, the delivery attributes identified in D1.1 are reformulated in terms of quantitative key performance indicators (KPIs). The indicators can be considered a sort of “operational” version of the attributes. They need to be representative of the attribute they refer to but, at the same time, should be reasonably quantifiable by one single number, so that they can be later used in the following steps. The KPIs are described in detail in section 3.

The definition of the relative relevance of attributes in step 2 consists of explicitly ranking each indicator with respect to the others (within each category). This phase has been carried out by means of a pairwise comparison survey involving a sample of stakeholders belonging to different groups (consumers, logistics operators, local authorities, etc.). The features and the results of the survey are presented in section 5.

The following step 3 consists of processing the results of step 2 according to specific rules in order to transform the collected judgment in sets of weights. At the end of this phase, each indicator is associated

to at least one weight. As different stakeholder groups can have different ideas regarding the relevance of attributes, an independent set of weight is defined for each stakeholder group. Each set covers all attributes of interest for that specific group (e.g., the set of weights for consumers does not consider supply-side attributes). The calculation of weights is explained in section 4.2.

Step 4 refers to the definition of numeric values for all KPIs of the delivery options under evaluation. This step should be solved case by case, there are not general rules or methods defined as part of the CodeZERO evaluation framework. When the options under analysis are existing ones, it is expected that several KPIs can be quantified building on observed data. Notwithstanding, even for existing delivery options, the data required to quantify some KPIs might not be observable. As an example, some KPIs related to the supply side do not refer to elements of a specific given option but to the overall organisation (i.e., warehouses, staff, vehicles, etc.) supporting a range of delivery options. In this and other cases, and when the options under analysis are theoretical ones, the quantification of the KPIs is not just a matter of measurements but includes assumptions and guess based on other experience, literature and professional judgment. An exemplification of the outcome of this phase is shown in section 4.5.

Step 5 addresses the issue of comparing different KPIs. KPIs refer to several different dimensions, therefore they are expressed in several different forms like indexes, shares, averages and, when absolute values are used, various units of measurement are used. Since the evaluation requires that KPIs are considered together, their values should be made comparable. In this way, the contribution of each KPI to the evaluation depends on its weight and not on its unit of measurement. The definition of normalised scores from KPIs values is presented in section 4.3.

The two final steps 6 and 7 refer to the application of the assessment framework to specific delivery options. The assessment framework includes rules for computing overall scores by integrating the different KPIs. These rules have been defined with the aim of providing a transparent process where the overall scores are initially produced independently for each category (e.g., demand, supply) and for each stakeholder group. Subsequent integrations across categories and stakeholder groups are made in separate steps according to explicit parameters. The aggregation of scores is explained in section 4.4.

### 3 Key Performance Indicators

This section presents the Key Performance Indicators (KPIs) interpreting the attributes used for defining the delivery options. The KPIs are structured according to the analytical categories: demand, supply, spatial contexts and impacts, which are explicitly considered in the hierarchical evaluation process described in section 4. For each KPI a dedicate factsheet reports its definition and provides a description, including, where relevant, the mathematical equation expressing the value of the indicators and the input elements of the equation itself. The unit of measure is also provided as well as whether higher or lower values of the indicator are preferable (when different perspectives exist, this is explicitly mentioned).

#### 3.1 Demand-side attribute indicators

Within this category, 18 **attributes** are identified and clustered in six **types**: cost, flexibility, delivery time, delivery method, information and reliability.

Factsheets describing demand-side KPIs are provided on this section.

Figure 2: Demand-side delivery attributes and types



3.1.1 Cost indicators

3.1.1.1 Delivery price

<b>Attribute type</b>	
Cost	
<b>Attribute</b>	
Delivery price	
<b>Attribute definition</b>	
Charge applied to cover shipment costs.	
<b>Indicator</b>	
Average price per delivery.	
<b>Description</b>	
<p>The delivery price is the cost paid by the consumer for the transportation service of the item purchased online. The price of delivery is defined as 'average' because it can be different case by case. The price of one delivery can also be free e.g. when based on a minimum purchase volume, part of a loyalty programme or determined by other customer characteristics.</p> <p>As in any other sector, e-commerce delivery pricing is a commercial decision driven by a number of demand and supply factors. Demand factors include consumers' willingness to pay and bargaining power of e-retailers, while supply factors include volume flows and organization and efficiency of delivery networks.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
€/delivery	Downwards

### 3.1.2 Flexibility indicators

#### 3.1.2.1 Choice of delivery date

Attribute type	
Flexibility	
Attribute	
Choice of delivery date	
Attribute definition	
The option for the customer to choose the delivery date.	
Indicator	
<p>Delivery date choice index:</p> <ul style="list-style-type: none"> <li>- The delivery date can be chosen and can be even the same day: 4</li> <li>- The delivery date can be chosen and can be any day since the day after the purchase: 3</li> <li>- The delivery date can be chosen and can be any day since three days after the purchase: 2</li> <li>- The delivery date can be chosen and can be any day since seven days after the purchase: 1</li> <li>- The delivery date cannot be chosen: 0</li> </ul>	
Description	
<p>The possibility to choose the delivery date during the purchase process is generally highly valued by customers as it gives more flexibility in deciding when their orders are received. Indeed, the top delivery concern for customers in 2023 was the risk of failed delivery due to no one being home to receive the item (53.8%) (IMRG, nShift, 2004).</p> <p>With this option, customers can pick a date that fit their personal and professional agenda without worrying about missing personal commitments or missing the delivery.</p> <p>The indicator is formulated as an index summarizing two elements: the availability of the choice and the time constraints applied to the choice.</p>	
Measurement unit	Desired direction
Dimensionless	Upwards

3.1.2.2 Choice of delivery time slot

<b>Attribute type</b>	
Flexibility	
<b>Attribute</b>	
Choice of delivery time slot	
<b>Attribute definition</b>	
The option for the customer to choose the time slot.	
<b>Indicator</b>	
<p>Delivery time slot choice index:</p> <ul style="list-style-type: none"> <li>- One out 1 hour delivery time slots can be chosen: 4</li> <li>- One out 2 hours delivery time slots can be chosen: 3</li> <li>- One out 3 hours delivery time slots can be chosen: 2</li> <li>- One out 4 hours delivery time slots can be chosen: 1</li> <li>- The delivery time slot cannot be chosen: 0</li> </ul>	
<b>Description</b>	
<p>The possibility to choose the delivery time slot during the purchase process is generally highly valued by customers as it allows them to choose a convenient time window for receiving their orders (especially the groceries).</p> <p>They can pick a slot that fits their personal and professional schedule and plan their day around the delivery.</p> <p>Several studies have shown that consumers have a preference for short delivery time slots.</p> <p>Most people are willing to wait within 2 hours of their timeslot, whilst the second most popular option is 1 hour. Very few people would be willing to wait for more than 4 hours (IMRG, nShift, 2004).</p> <p>The indicator is formulated as an index summarizing two elements: the availability of the choice and the time constraints applied to the choice.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.1.2.3 Choice of products consolidation

<b>Attribute type</b>	
Flexibility	
<b>Attribute</b>	
Choice of products consolidation (in one order)	
<b>Attribute definition</b>	
The option for the customer to choose if receiving all items in a single delivery.	
<b>Indicator</b>	
<p>Product consolidation choice index:</p> <ul style="list-style-type: none"> <li>- Receiving all items in a single delivery can be chosen: 1</li> <li>- Receiving all items in a single delivery cannot be chosen: 0</li> </ul>	
<b>Description</b>	
<p>The possibility to choose that all items of an order are grouped into a single delivery can be highly valued by customers as it allows them to attend only one delivery rather than multiple ones.</p> <p>The indicator is formulated as an index expressing the possibility to choose.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.1.2.4 Choice of point of delivery

<b>Attribute type</b>	
Flexibility	
<b>Attribute</b>	
Choice of point of delivery	
<b>Attribute definition</b>	
The option for the customer to choose the point of delivery.	
<b>Indicator</b>	
<p>Delivery point choice index:</p> <ul style="list-style-type: none"> <li>- The point of delivery can be chosen and can be even at floor: 2</li> <li>- The point of delivery can be chosen but not at floor: 1</li> <li>- The point of delivery cannot be chosen: 0</li> </ul>	
<b>Description</b>	
<p>When placing an order, online shoppers expect to be able to choose from multiple points of delivery which include not only the delivery at the customer's chosen address (home or at work) but also the possibility to collect the order from retailer's physical shops, pick-up points or automated parcel stations (lockers), which can offer customers the option to collect their package outside of opening hours.</p> <p>Generally customers prefer home delivery over any other option.</p> <p>The index is a summary of two elements: the availability of the choice between multiple options and the constraints applied to the choice (e.g. delivery at the floor). Delivery at floor might be relevant for certain type of goods and can be combined with installation or assembly services, which are often essential when delivering furniture or household appliances.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.1.2.5 Choice of vehicle type

Attribute type	
Flexibility	
Attribute	
Choice of vehicle type	
Attribute definition	
The option for the customer to choose the type of vehicle used for the delivery.	
Indicator	
Vehicle type choice index: - Vehicle type can be chosen: 1 - Vehicle type cannot be chosen: 0	
Description	
<p>The possibility to choose the delivery vehicle can be relevant for customers living in zones with specific accessibility requirements e.g. due to road infrastructure limitations (narrow streets in historic city centres) and / or regulations (low or zero emission zones, pedestrian zones etc.).</p> <p>It can be relevant as well for customers preferring eco-friendly deliveries by cargobikes or electric vehicles.</p> <p>The indicator is formulated as an index expressing the possibility to choose.</p>	
Measurement unit	Desired direction
Dimensionless	Upwards

### 3.1.3 Delivery time indicators

#### 3.1.3.1 Delivery date

<b>Attribute type</b>	
Delivery time	
<b>Attribute</b>	
Delivery date	
<b>Attribute definition</b>	
Time needed to receive the ordered products.	
<b>Indicator</b>	
Average number of days required for the delivery.	
<b>Description</b>	
<p>To meet most customers' expectations, retailers should aim to complete their deliveries within three days, or even better, two days (IMRG, nShift, 2004). But some orders, such as spare parts or health products, are more urgent than others, and are preferred to being delivered quickly.</p> <p>The average consumer is prepared to wait under 24 hours until they receive their online grocery order.</p> <p>The indicator is defined as the average number of days required for the delivery as it varies case by case.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Number of days	Downwards

3.1.3.2 Delivery time slot

<b>Attribute type</b>	
Delivery time	
<b>Attribute</b>	
Delivery time slot	
<b>Attribute definition</b>	
The size of the period of the day announced for delivering the product to the customer.	
<b>Indicator</b>	
Delivery time slot length.	
<b>Description</b>	
<p>Several studies have shown that, when it comes to the length of the delivery slot, consumers have a preference for short delivery time slots.</p> <p>Most people are willing to wait within 2 hours of their timeslot, whilst the second most popular option is 1 hour. Very few people would be willing to wait for more than 4 hours (IMRG, nShift, 2004).</p> <p>This indicator measures the length in hours of the time slot.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
hours	Downwards

3.1.3.3 Delivery date punctuality

		<b>Attribute type</b>
		Delivery time
<b>Attribute</b>		
Delivery date punctuality		
<b>Attribute definition</b>		
The product is delivered in the day announced at the purchase.		
<b>Indicator</b>		
Share of deliveries made in the chosen/announced day.		
<b>Description</b>		
<p>Punctuality plays a crucial role in the world of deliveries, significantly impacting customer satisfaction, business reputation, and operational efficiency.</p> <p>This indicator is defined as an index measuring the average punctuality of deliveries by computing the share of deliveries actually made in the day chosen/announced during the on-line purchase process out of total deliveries.</p>		
<b>Measurement unit</b>	<b>Desired direction</b>	
%	Upwards	

3.1.3.4 Delivery time slot punctuality

		<b>Attribute type</b>
		Delivery time
<b>Attribute</b>		
Delivery time slot punctuality		
<b>Attribute definition</b>		
The product is delivered in the time slot chosen/announced.		
<b>Indicator</b>		
Share of deliveries made in the announced/chosen time slot.		
<b>Description</b>		
<p>Time slot punctuality is the time lag in hours between the time slot chosen/announced during the purchase process and the actual time slot of the delivery.</p> <p>Punctuality plays a crucial role in the world of deliveries, significantly impacting customer satisfaction, business reputation, and operational efficiency.</p> <p>This indicator measures the average punctuality of deliveries by considering the share of deliveries actually made in the time slot chosen/announced during the on-line purchase process.</p>		
<b>Measurement unit</b>		<b>Desired direction</b>
%		Upwards

3.1.3.5 Products consolidation

		<b>Attribute type</b>
		Delivery time
<b>Attribute</b>		
Products consolidation		
<b>Attribute definition</b>		
All purchased items are delivered together as requested.		
<b>Indicator</b>		
Share of deliveries including all ordered products as requested.		
<b>Description</b>		
<p>Receiving all items of an order into a single delivery can be highly valued by customers as it allows to attend the delivery only once rather than multiple times.</p> <p>The choice of products consolidation can be offered by retailers to customers during the purchase process.</p> <p>Intended to measure the quality of the experienced delivery, this indicator is formulated as the share of deliveries received by the customers actually grouping all purchased items.</p>		
<b>Measurement unit</b>		<b>Desired direction</b>
%		Upwards

### 3.1.4 Delivery method indicators

#### 3.1.4.1 Point of delivery

<b>Attribute type</b>	
Delivery method	
<b>Attribute</b>	
Point of delivery	
<b>Attribute definition</b>	
Share of deliveries made at the chosen point	
<b>Indicator</b>	
Share of deliveries made at the chosen point.	
<b>Description</b>	
<p>This indicator applies only when the delivery point can be chosen by the customer during the purchase process (which is the normal condition).</p> <p>Intended to measure the quality of the experienced delivery, this indicator is formulated as the share of deliveries actually received by the customer at the chosen delivery point.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

3.1.4.2 Vehicle type

Attribute type	
Delivery method	
Attribute	
Vehicle type	
Attribute definition	
The type of vehicle used for the delivery.	
Indicator	
<p>Vehicle type index:</p> <ul style="list-style-type: none"> <li>- Conventional ICE vehicle: 1</li> <li>- Zero emission motorised vehicle: 2</li> <li>- Bike/Cargo bike: 3</li> <li>- Driverless vehicle (bot, drone): 4</li> </ul>	
Description	
<p>The type of vehicle used for the delivery plays an important role when deliveries are in zones with specific accessibility requirements e.g. due to road infrastructure limitations (narrow streets in historic city centers) and / or regulations (low or zero emission zones, pedestrian zones etc.).</p> <p>It can be relevant as well for customers preferring eco-friendly deliveries by cargobikes or electric vehicles.</p> <p>Intended to measure the quality of the experienced delivery, the indicator is formulated as an index expressing the type of vehicle actually used for the delivery.</p>	
Measurement unit	Desired direction
Dimensionless	According to consumer preferences

3.1.4.3 Vehicle type - Share of deliveries

Attribute type	
Delivery method	
Attribute	
Vehicle type - Share of deliveries	
Attribute definition	
Share of deliveries made with the chosen vehicle type	
Indicator	
Share of deliveries made with the chosen vehicle type.	
Description	
<p>This indicator applies only when the vehicle type can be chosen by the customer during the purchase process.</p> <p>Intended to measure the quality of the experienced delivery, this indicator is formulated as the share of deliveries actually received by the customer with the chosen vehicle type.</p>	
Measurement unit	Desired direction
%	Upwards

3.1.5 Information indicators

3.1.5.1 Tracking of shipment

Attribute type	
Information	
Attribute	
Tracking of shipment	
Attribute definition	
Access to tracking interface to follow the status of the delivery	
Indicator	
Tracking index: - No tracking: 0 - Tracking for the last-mile (consignment): 1 - Tracking from the warehouse (last-leg): 2	
Description	
<p>The majority of customers want access to online order tracking (80%, 2023). They want to know where their order is at all times, and in fulfilling this, retailers can reduce the amount of 'Where is my order' (WISMO) queries they receive, saving time and resources (IMRG, nShift, 2004).</p> <p>Expressed as an index, this indicator combines the availability of tracking function and its quality (i.e. tracking for the whole journey or for the last-mile only).</p>	
Measurement unit	Desired direction
Dimensionless	Upwards

3.1.5.2 Delivery reminder

Attribute type	
Information	
Attribute	
Delivery reminder	
Attribute definition	
Message sent in advance to remind of the delivery	
Indicator	
<p>Reminder index:</p> <ul style="list-style-type: none"> <li>- Reminder message sent on the morning of delivery with time window specification: 3</li> <li>- Reminder message sent the day before the delivery without time window specification: 2</li> <li>- Reminder message sent 1-2 hours before the delivery:1</li> <li>- No reminder message: 0</li> </ul>	
Description	
<p>The majority of on-line customers want an in-transit SMS or email that advises them on when to expect delivery.</p> <p>Mostly, customers want a pre-delivery alert on the morning of delivery, with the time window specified (64%) (IMRG, nShift, 2004). This option will enable customers to be prepared to accept the item, limiting the number of reattempted deliveries and thus reducing the retailers' carbon footprint.</p> <p>Receiving an alert the day before delivery with no time specified also proves popular (47.6%) (IMRG, nShift, 2004). Having enough pre-warning will allow customers, if the option is there, to redirect their deliveries or change their delivery date if needed.</p> <p>Some customers (28.3%) would like an alert within the hour of delivery, which can showcase that the retailer values transparency and the customer experience (IMRG, nShift, 2004).</p> <p>This indicator refers to the case of receiving a delivery message according to preferences of consumers as emerging from literature.</p>	
Measurement unit	Desired direction
Dimensionless	Upwards

3.1.5.3 Impact of purchase

<b>Attribute type</b>	
Information	
<b>Attribute</b>	
Impact of purchase	
<b>Attribute definition</b>	
Detail on social impacts of deliveries (e.g., emissions, working conditions of delivery personnel, etc.)	
<b>Indicator</b>	
<p>Impact information index:</p> <ul style="list-style-type: none"> <li>- No information: 0</li> <li>- Information on CO2 emissions: 1</li> <li>- Information on working conditions of drivers and warehouse workers: 2</li> <li>- Information on CO2 emissions AND working conditions of drivers and warehouse workers: 3</li> </ul>	
<b>Description</b>	
<p>Disclosing sustainability impact information associated with delivery options is considered steering consumer choice of deliveries as information disclosure implies that trade-offs between sustainability and delivery convenience become explicit for consumers.</p> <p>As an example, consumers with a high sustainability concern likely experience discomfort if they are confronted with a discrepancy between their preference for speedy delivery and the negative sustainability effects of this option.</p> <p>This indicator measures the availability of information on environmental impacts, on labour impacts and on both types of impacts stemming from delivery options.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

### 3.1.6 Reliability indicators

#### 3.1.6.1 Products safety

<b>Attribute type</b>	
Reliability	
<b>Attribute</b>	
Products safety	
<b>Attribute definition</b>	
Products and original packages are not damaged	
<b>Indicator</b>	
Share of deliveries without damaged products	
<b>Description</b>	
<p>According to various studies, anywhere from 7% to 11% of customers' online orders arrive broken or damaged, a scenario that's even more likely if products are large (when delivery damages climb to 21%).</p> <p>This can cause a poor consumer experience and negatively impacts an e-tailer reputation. One study found that 73% of customers would be unlikely to purchase from the company again after receiving a damaged item (Pregis&amp;PackageInsight, 2016).</p> <p>On top of this, damaged items create a sustainability issue as many products cannot be fixed, or repurposed and are often discarded or destroyed.</p> <p>Intended to measure the quality of the experienced delivery, the indicator is formulated as an index expressing the share of deliveries without damaged products of original package on total deliveries made.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

3.1.6.2 Actual delivery

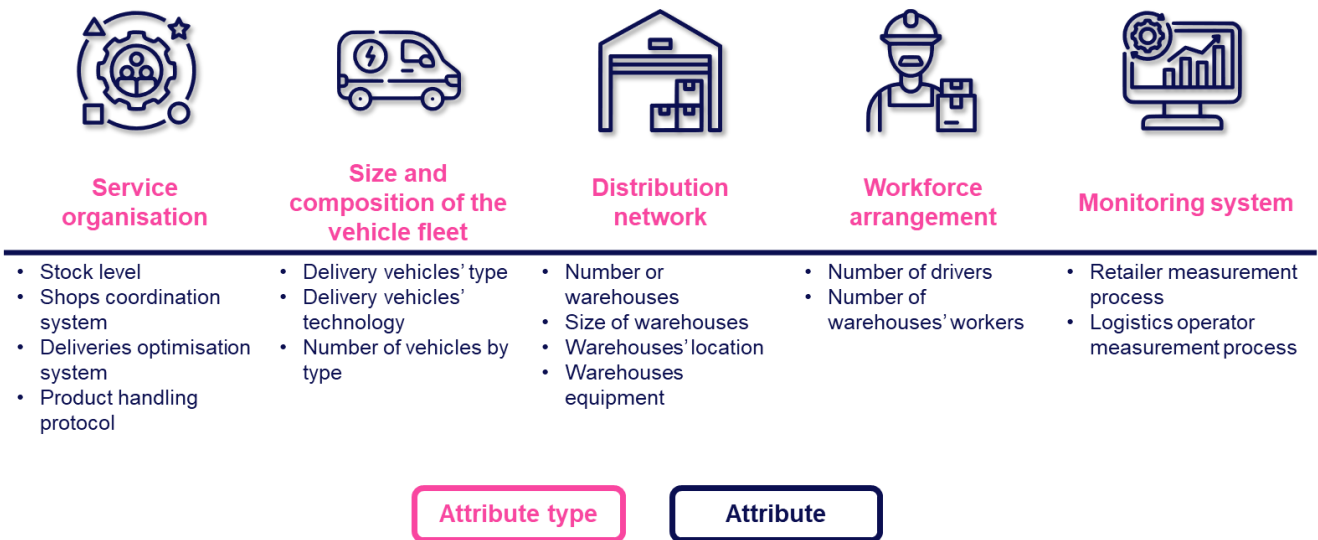
		<b>Attribute type</b>
		Reliability
<b>Attribute</b>		
Actual delivery		
<b>Attribute definition</b>		
Unfounded communications of failed delivery attempt		
<b>Indicator</b>		
Number of reported unfounded communications per 100 deliveries.		
<b>Description</b>		
<p>The majority of customers want to be informed in case of non-delivery (89.3%) (IMRG, nShift, 2004). Sometimes, however, non-delivery notifications are made even when no delivery attempt has been made.</p> <p>This indicator is intended to measure customers' experience with unfounded communications of failed deliveries attempts.</p>		
<b>Measurement unit</b>	<b>Desired direction</b>	
%	Downwards	

### 3.2 Supply-side attribute indicators

Supply-side attributes are defined looking at delivery options from the perspective of **logistics operators and e-tailers**. Within this category, 15 **attributes** are identified and clustered in five **types**: **service organization, impact monitoring systems, size and composition of the vehicle fleet, workforce arrangements** and **distribution network**.

Factsheets describing supply-side KPIs are provided in this section.

Figure 3: Supply-side delivery attributes and types



3.2.1 Service organisation indicators

3.2.1.1 Stock level

Attribute type
Service organisation
Stakeholder
Retailer

Attribute	
Stock level	
Attribute definition	
Number of products available for order.	
Indicator	
Share of products on sale on the retailer online shop that cannot be ordered.	
Description	
<p>Customers shopping online today expect products to be in stock and available for rapid delivery, and so there is a direct connection between stock level and delivery time.</p> <p>The adequate level of stock can be different for each e-tailer as it depends on three main variables: the delivery lead time offered by retailers to customers, the stability of demand (i.e. variation of orders over the year) and the lead times the product suppliers can guarantee to retailers.</p> <p>The indicator is defined as the share of products on sale on the retailer online shop that cannot be ordered.</p>	
Measurement unit	Desired direction
%	Downwards

3.2.1.2 Shops coordination system

<b>Attribute type</b>	
Service organisation	
<b>Stakeholder</b>	
Retailer	
<b>Attribute</b>	
Shops coordination system	
<b>Attribute definition</b>	
The organisation used to assemble e-commerce deliveries with products available in different physical shops.	
<b>Indicator</b>	
Ratio between the average number of days required for the delivery of orders including products available in different shops and the average number of days required for the delivery of orders including only products available in one shop.	
<b>Description</b>	
<p>The omnichannel retail strategy promotes e-commerce integration with physical stores. With omnichannel solutions, retailers fulfill orders from the most convenient and efficient location, which reduces waiting times and delivery costs. Omnichannel strategies also enable retailers to spread the stock levels across all sales channels. That way, they can manage their supply chain better and not overstock their products. It also helps them save storage costs and restock quicker, especially for popular products.</p> <p>If retained, the formulation of the indicator could be:</p> $I = \frac{D1 * Sh1 + D2 * Sh2 + D3m * Sh3m}{D1}$ <p>Where:</p> <p>D1 = number of days required to deliver products available in one shop  D2 = number of days required to deliver products available in two shops  D3m = number of days required to deliver products available in three or more shops  Sh1 = share of deliveries with all products available in one shop  Sh2 = share deliveries with products available in two shops  Sh3m = share of deliveries with products available in three or more shops</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Downwards

3.2.1.3 Delivery optimisation system

<b>Attribute type</b>	
Service organisation	
<b>Stakeholder</b>	
Logistics operator	
<b>Attribute</b>	
Delivery optimisation system	
<b>Attribute definition</b>	
Organisation and rules applied to arrange deliveries in an efficient manner.	
<b>Indicator</b>	
<p>Delivery optimisation system index:</p> <ul style="list-style-type: none"> <li>- Delivery optimization systems in place (e.g. optimized load/route planning software) : 1</li> <li>- No systems: 0</li> </ul>	
<b>Description</b>	
<p>Delivery optimization systems can enable faster and more effective last-mile delivery by decreasing distance traveled and optimizing the order of stops. To optimize delivery routes, sophisticated algorithms and machine learning techniques can be used to identify the most effective sequence of deliveries based on real-time traffic information, delivery density, and client preferences.</p> <p>To consolidate several orders into a single delivery route and save down on trips and transportation expenses, load/trip planning algorithms can be used. The best delivery operations are also guaranteed by selecting the most appropriate mode of transportation depending on variables like distance, urgency, and cost-effectiveness.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.2.1.4 Products handling protocols

<b>Attribute type</b>	
Service organisation	
<b>Stakeholder</b>	
Logistics operator	
<b>Attribute</b>	
Products handling protocols	
<b>Attribute definition</b>	
Organisation and rules applied to ensure integrity of delivered products	
<b>Indicator</b>	
<p>Products handling protocols index:</p> $I = ITP + LUP + WSP$ <p>Where:</p> <p>ITP = 1 if In-Transit Procedures are in place; 0 if they are not.</p> <p>LUP = 1 if Loading and Unloading Procedures are in place; 0 if they are not.</p> <p>WSP = 1 if Warehousing and Storage Procedures are in place; 0 if they are not.</p>	
<b>Description</b>	
<p>Products handling protocols generally encompass:</p> <ul style="list-style-type: none"> <li>- In Transit Procedures: ensuring items are properly packaged and the best transportation method is selected;</li> <li>- Loading and Unloading Procedures: ensuring personnel is well-trained and uses specialized equipment;</li> <li>- Warehousing and Storage Procedures: ensuring warehouses are properly organized, storage conditions adequate and special requirements are met, for example for perishables, pharmaceuticals, and other temperature and humidity-sensitive items.</li> </ul> <p>This indicator accounts for how many of the three different types of procedures are in place.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.2.2 Impact monitoring system indicators

3.2.2.1 Impact measurement process – Logistics operator

Attribute type
Impact monitoring system
Stakeholder
Logistics operator

Attribute	
Impact measurement process	
Attribute definition	
Internal data collection and elaboration system to measure indicators for customers (e.g. on emissions per delivery)	
Indicator	
<p>Impact measurement process index:</p> <ul style="list-style-type: none"> <li>- No measurement: 0</li> <li>- Estimation of CO<sub>2</sub> emissions: 1</li> <li>- Monitoring of working conditions of drivers and warehouse workers: 2</li> <li>- Estimation of CO<sub>2</sub> emissions AND monitoring of working conditions of drivers and warehouse workers: 3</li> </ul>	
Description	
<p>Providing transparent information to consumers on the impacts of their delivery choice is a first step to steering consumer behaviour as information disclosure implies that trade-offs between sustainability and delivery convenience become explicit for them.</p> <p>As an example, consumers with a high sustainability concern likely experience discomfort if they are confronted with a discrepancy between their preference for speedy delivery and the negative sustainability effects of this option.</p> <p>This indicator measures the capability of logistics operator to measure environmental impacts, labour impacts and both types of impacts stemming from their deliveries.</p>	
Measurement unit	Desired direction
Dimensionless	Downwards

3.2.2.2 Impact measurement process - Retailer

<b>Attribute type</b>	
Impact monitoring system	
<b>Stakeholder</b>	
Retailer	
<b>Attribute</b>	
Impact measurement process	
<b>Attribute definition</b>	
Internal data collection and elaboration systems to measure indicators for transparent communication with customers (e.g. on emissions per delivery)	
<b>Indicator</b>	
<p>Impact measurement process index:</p> <ul style="list-style-type: none"> <li>- No measurement: 0</li> <li>- Estimation of CO<sub>2</sub> emissions: 1</li> <li>- Monitoring of working conditions of drivers and warehouse workers: 2</li> <li>- Estimation of CO<sub>2</sub> emissions AND monitoring of working conditions of drivers and warehouse workers: 3</li> </ul>	
<b>Description</b>	
<p>Actually, the impact measurement process needs information from the logistics operators. If not performing own-account deliveries, the online retailer will likely receive and extend information from logistics operators. The additional value added by retailer would then be summarising information from the different used logistics operators.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Upwards

3.2.3 Size and composition of the vehicle fleet indicators

3.2.3.1 Delivery vehicles - Total vehicles

Attribute type
Size and composition of the vehicle fleet
Stakeholder
Logistics operator

Attribute	
Delivery vehicles - Total number of vehicles	
Attribute definition	
The size of the fleet available for deliveries	
Indicator	
Number of vehicles required to complete N deliveries per week in an area of X square km	
Description	
<p>The size and composition of the fleet is more an attribute of the logistics operator than an attribute of the delivery option. Referring to the fleet required to complete a certain number of deliveries allows to associate the size of the fleet to the requirements of the delivery option.</p> <p>The number of deliveries (N) and the size (X) of the area can be set to different values (to be defined in advance).</p>	
Measurement unit	Desired direction
N° of vehicles	Downwards

3.2.3.2 Delivery vehicles by type and technology

Attribute type
Size and composition of the vehicle fleet
Stakeholder
Logistics operator

Attribute
Delivery vehicles by type and technology
Attribute definition
<p>The composition of the fleet available for deliveries in terms of both:</p> <ul style="list-style-type: none"> <li>- the type of vehicles used for delivering (trucks, vans, cargo-bikes, drones, etc.)</li> <li>- the energy source they use (fossil fuels, electricity, human activity, etc.)</li> </ul>
Indicator
$I = \frac{\sum_t(Weight^t * Share^t)}{Max(Weight^t) * 100}$
<p>where:</p> <p>ICE_Share: Share of internal combustion engine vehicles (trucks and vans) on total vehicles used to complete N deliveries per week in an area of X square km</p> <p>EV_Share: Share of electric vehicles (trucks and vans) on total vehicles used to complete N deliveries per week in an area of X square km</p> <p>B&amp;CB_Share: Share of non motorised vehicles (bikes and cargobikes) on total vehicles used to complete N deliveries per week in an area of X square km</p> <p>AUT_Share: Share of driverless vehicles (drones, bot) on total vehicles used to complete N deliveries per week in an area of X square km</p> <p>Weight<sup>v</sup>: weight measuring the level of preference of operators for vehicle type v</p> <p>Share<sup>v</sup>: share of vehicle type v on total vehicles used to complete N deliveries per week in an area of X square km</p>
Description
<p>This indicator refers to the composition of the vehicle fleet used to complete N deliveries per week in an area of X square km (see attribute 'Delivery vehicles - Total vehicles').</p> <p>Formulated as an index, the indicator combines information on the type of vehicles used for deliveries (i.e. trucks, vans, cargo-bikes, drones, etc.) with information on the energy source they use (fossil fuels, electricity, human activity, etc.). It assumes a hierarchy based on the occupation of public space</p>

(smaller vehicles are preferable to bigger ones) and on the sustainability of energy source (electric vehicles are preferable to ICE ones). Driverless vehicles rank high in the hierarchy as they are smaller and do not need exploitation of human workforce.

Measurement unit	Desired direction
Dimensionless	Upwards

3.2.4 Workforce arrangement indicators

3.2.4.1 Number of drivers - Total

Attribute type
Workforce arrangement
Stakeholder
Logistics operator

Attribute	
Number of drivers - Total	
Attribute definition	
Number of drivers - Total	
Indicator	
Number of driver units required to complete N deliveries per week in an area of X square km	
Description	
<p>"Driver units" are defined as drivers working full time for the contractual working time. Driver units allows to account for seasonal and part-time drivers employed during peak periods only.</p> <p>This indicator refers to the drivers of all vehicles.</p> <p>The number of deliveries (N) and the size (X) of the area can be set to different values (to be defined in advance).</p>	
Measurement unit	Desired direction
N° of drivers	Downwards

3.2.4.2 *Number of warehouses workers*

<b>Attribute type</b>	
Workforce arrangement	
<b>Stakeholder</b>	
Logistics operator	
<b>Attribute</b>	
Number of warehouses workers	
<b>Attribute definition</b>	
Number of workers in the warehouses from which last-mile deliveries start	
<b>Indicator</b>	
Number of working units in the warehouses required to process N deliveries per week in an area of X square km.	
<b>Description</b>	
<p>E-commerce has become increasingly automated in its operations with robots moving inventory and assisting pickers. But picking, packing and shipping are still labor-intensive processes requiring many workers in warehouses.</p> <p>This indicator accounts for the warehouse workforce needed to process the average weekly amount of orders of a certain catchment area.</p> <p>"Working units" are defined as workers working full time for the contractual working time. Working units allows to account for seasonal and part-time workers employed during peak periods only.</p> <p>The number of deliveries (N) and the size (X) of the area can be set to different values (to be defined in advance).</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Number of workers	Downwards

3.2.5 Distribution network indicators

3.2.5.1 Number of warehouses

Attribute type
Distribution network
Stakeholder
Logistics operator
Retailer

Attribute	
Number of warehouses	
Attribute definition	
Number of the warehouses from which last-mile deliveries start	
Indicator	
Number of warehouses required to process N deliveries per week in an area of X square km	
Description	
<p>This indicator accounts for the number of warehouses needed to process the average weekly amount of orders of a certain catchment area.</p> <p>This indicator is meaningful when used together with the one regarding the size of warehouses because the number of warehouses in itself does not provide a full idea of the storing and orders processing capacity. One or two big warehouses could serve the service area better than several small warehouses.</p> <p>The number of deliveries (N) and the size (X) of the area can be set to different values (to be defined in advance).</p>	
Measurement unit	Desired direction
N° of warehouses	Downwards

3.2.5.2 Size of warehouses

<b>Attribute type</b>	
Distribution network	
<b>Stakeholder</b>	
Logistics operator	
<b>Attribute</b>	
Size of warehouses	
<b>Attribute definition</b>	
Size of the warehouses from which last-mile deliveries start	
<b>Indicator</b>	
Average size of warehouses required to process N deliveries per week in an area of X square km	
<b>Description</b>	
<p>This indicator accounts for the average size of warehouses needed to process the average weekly amount of orders of a certain catchment area.</p> <p>This indicator is meaningful when used together with the one regarding the number of warehouses because the average size of warehouses in itself does not provide a full idea of the storing and orders processing capacity. A lower average size associated to several warehouses can serve better than a higher size of just one warehouse.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Squared meters (sqm)	Downwards

3.2.5.3 Warehouses organization and equipment

<b>Attribute type</b>	
Distribution network	
<b>Stakeholder</b>	
Logistics operator	
<b>Attribute</b>	
Warehouses organization and equipment	
<b>Attribute definition</b>	
Efficiency of the warehouses from which last-mile deliveries start.	
<b>Indicator</b>	
Pallets/parcels processed per hour in the warehouse	
<b>Description</b>	
<p>Optimizing the organization and design of warehouse entails carefully placing products that move quickly, making effective use of storage space, and clearly identifying and directing internal warehouse traffic to reduce trips' lengths.</p> <p>By effectively sorting and routing parcels, the employment of robotic picking, conveyor belts, and automated sorting systems technologies can cut down on manual labor and speed up order processing.</p> <p>Robotic help in warehouse operations can automate labor-intensive, repetitive jobs, improving operational efficiency and lowering the possibility of mistakes.</p> <p>Optimising the organization and equipment of warehouses will result in increasing the number of pallets/parcels processed per hour in the warehouses.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Pallets (or parcels) per hour	Upwards

3.2.5.4 Warehouses location

<b>Attribute type</b>	
Distribution network	
<b>Stakeholder</b>	
Logistics operator	
Local authority	
<b>Attribute</b>	
Warehouses location	
<b>Attribute definition</b>	
Spatial distribution of warehouses from which last-mile deliveries start	
<b>Indicator</b>	
Share of warehouses - from which last-mile deliveries start - located within the area.	
<b>Description</b>	
<p>The location of last-mile warehouses should be ideally as close as possible to final consumers as this will make deliveries faster and minimise travelled distances and related transport externalities. The problem that a lot of retailers are facing, however, is that their warehouses and distribution centres are located outside heavily populated areas, and they must transport their goods over longer distances. This effectively makes deliveries slower.</p> <p>This indicator considers the share of warehouses from which last-mile deliveries start located within the main urban area, assuming the main urban areas as a proxy for denser consumer market.</p> <p>The indicator is relevant also for local authorities as new urban and regional planning approaches could consider the (re)introduction of logistics spaces and logistics facilities within inner urban areas of cities.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

### 3.3 Spatial context attribute indicators

Spatial context attributes describe the physical space in which delivery. In many cases, these attributes are affected by decisions of the **local authorities** which not only regulate land use but can facilitate desirable situations through the adoption of certain policies.

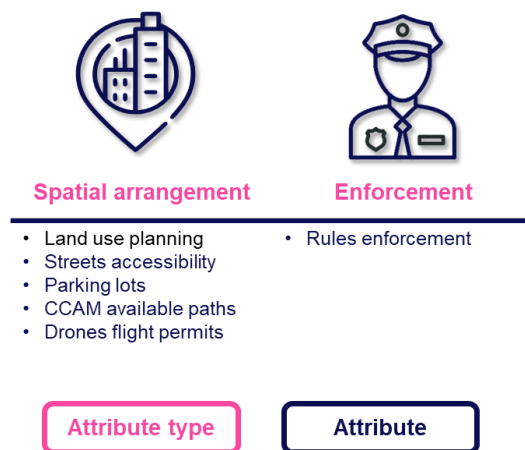
Within this category, six **attributes** are identified and clustered in two **types: spatial arrangement and enforcement.**

The enforcement activity can deal with very different types of regulations (e.g. parking, pedestrian areas, delivery hours, emissions of vehicles, and so on). A meaningful indicator covering all aspects is hard to define and therefore no KPIs have been defined for this attribute.

As per land use planning, this attribute is a sort of pre-condition for other attributes, namely warehouses location, number of warehouses and warehouses size. Therefore, this delivery attribute does not need an indicator.

Factsheets describing remaining spatial arrangement KPIs are provided in this section.

Figure 4: Spatial context delivery attributes and types



3.3.1 Spatial arrangement indicators

3.3.1.1 Streets accessibility – Bikes and cargobikes

Attribute type
Spatial arrangement
Stakeholder
Local authority

Attribute	
Streets accessibility	
Attribute definition	
Vehicle types admitted in each street of a given area (e.g., pedestrian areas, low emissions zones)	
Indicator	
Share of the road network in a given zone where motorised vehicles are not allowed (e.g. pedestrian areas).	
Description	
This indicator measures the share of the road network in a given zone where motorised vehicles (both ICE and electric) are not allowed. It measures the share of the network where deliveries can be made only by bikes and cargobikes.	
Measurement unit	Desired direction
%	Upwards

3.3.1.2 Streets accessibility – Zero emission vehicles

<b>Attribute type</b>	
Spatial arrangement	
<b>Stakeholder</b>	
Local authority	
<b>Attribute</b>	
Streets accessibility	
<b>Attribute definition</b>	
Vehicle types admitted in each street of a given area (e.g., pedestrian areas, low emissions zones)	
<b>Indicator</b>	
Share of the road network in a given zone where only zero or low-emissions vehicles are allowed.	
<b>Description</b>	
This indicator measures the share of the road network in a given zone where vehicles above certain levels of emissions are not allowed. It measures the share of the network where deliveries can be made only by low-emissions vehicles, electric vehicles, bikes and cargobikes.	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

3.3.1.3 *Parking lots*

<b>Attribute type</b>	
Spatial arrangement	
<b>Stakeholder</b>	
Local authority	
<b>Attribute</b>	
Parking lots	
<b>Attribute definition</b>	
Availability of lots for parking commercial vehicles during delivery tours	
<b>Indicator</b>	
Average number of parking lots reserved for deliveries per km of road network in the urban area.	
<b>Description</b>	
<p>The availability of lots for parking commercial vehicles during delivery tours can increase the efficiency of operations and minimise the impacts of e-commerce on traffic congestion and irregular parking by reducing double-parking and cruising for parking.</p> <p>The lack of parking spaces near delivery locations has also an impact on the working conditions of delivery personnel given the limited time they have to complete their assigned routes. After spending significant time searching or cruising for parking, drivers often decide to double park or re-schedule a delivery (if possible) thus impacting on consumers' experience and service efficiency.</p> <p>Illegal parking is also an option delivery drivers use when they have spent time searching for parking without success and are forced to make on-time deliveries.</p> <p>This indicator refers to the average number of parking lots reserved for deliveries per km of road network in the urban area.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Parking lots/km	Upwards

3.3.1.4 Micro-hubs

<b>Attribute type</b>	
Spatial arrangement	
<b>Stakeholder</b>	
Local authority	
<b>Attribute</b>	
Micro-hubs	
<b>Attribute definition</b>	
Availability of micro-hubs in urban area	
<b>Indicator</b>	
Number of micro-hubs/Urban area in km <sup>2</sup> .	
<b>Description</b>	
<p>As per the definition of the Urban Freight Lab (Urbanfreightlab.com, 2020) micro-hubs are “logistics facilities inside the urban area boundaries where goods are bundled to allow a mode shift to low (or zero) emission vehicles or soft transportation modes (e.g., walking) for last yard deliveries”.</p> <p>Micro-hubs, which serve a limited number of destinations within a bounded spatial range (within 1 to 5 km from the final destination), are considered to be a potential solution to increase the consolidation of inner-city deliveries.</p> <p>Retailers and logistics operators are increasingly relying on micro-hubs located in major cities and towns to reach customers in the shortest possible time. However, loading and unloading, overnight replenishment of stock and automated sequencing processes may be disruptive to residents, and low-emission zones, access restrictions and congestion charges may apply in some inner-city areas. These factors must be kept in mind when setting up a micro-hub and companies must work closely with local governments to find the right place.</p> <p>This indicator accounts for the density of micro-hubs in the urban area.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Sites/squared kilometers	Upwards

3.3.1.5 CCAM available paths

<b>Attribute type</b>	
Spatial arrangement	
<b>Stakeholder</b>	
Local authority	
<b>Attribute</b>	
CCAM available paths	
<b>Attribute definition</b>	
Places where driverless vehicles used for delivery can be operated (streets, platforms, etc.)	
<b>Indicator</b>	
Share of urban network on which driverless vehicles can be operated.	
<b>Description</b>	
<p>Autonomous vehicles have the potential to transform last mile delivery. Self-driving vehicles will have the most immediate impact on this sector by mitigating ongoing shortages of delivery personnel.</p> <p>The shift to autonomous last-mile deliveries will also lead to lower operating costs. Many of these savings stem from the added efficiency that automation enables. More deliveries in less time translates into lower relative costs per delivery.</p> <p>While autonomous delivery isn't a viable reality yet, it won't be long before it becomes one and city authorities should work closely with logistics operator to plan the transition.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

3.3.1.6 Drones flight permits

Attribute type
Spatial arrangement
Stakeholder
Local authority

Attribute	
Drones flight permits	
Attribute definition	
Areas where remote-controlled drones can fly (banned areas, corridors, minimum altitude, etc.)	
Indicator	
<p>Drones regulation index:</p> <ul style="list-style-type: none"> <li>- Drones cannot be used for deliveries: 0</li> <li>- Drones can be used for deliveries only in limited special cases: 1</li> <li>- Drones can be used for deliveries only in some areas/periods: 2</li> <li>- Drones can be used for deliveries without limitations: 3</li> </ul>	
Description	
<p>Drones offer an environmentally-friendly way to deliver goods quickly and affordably. These smaller vehicles can avoid road traffic that causes delays and are expected to become an integral part of the last-mile industry . Their speed, accessibility and relatively low operating costs are key driving factors for this change. Drone delivery services can provide on-demand goods to customers from a local delivery hub.</p> <p>Sending products through drones or autonomous carts will also leave more trucks and vans available for other deliveries. All these factors combine to create a future of more deliveries completed in less time.</p> <p>It will not be long before delivery by drones becomes a reality and local authorities should work closely with logistics operator to plan the transition.</p>	
Measurement unit	Desired direction
Dimensionless	Upwards

### 3.4 Impact attribute indicators

**Impact attributes** refer to the various types of impacts stemming from delivery options as a consequence of decisions made by logistics operators and e-tailers to satisfy customers' expectations.

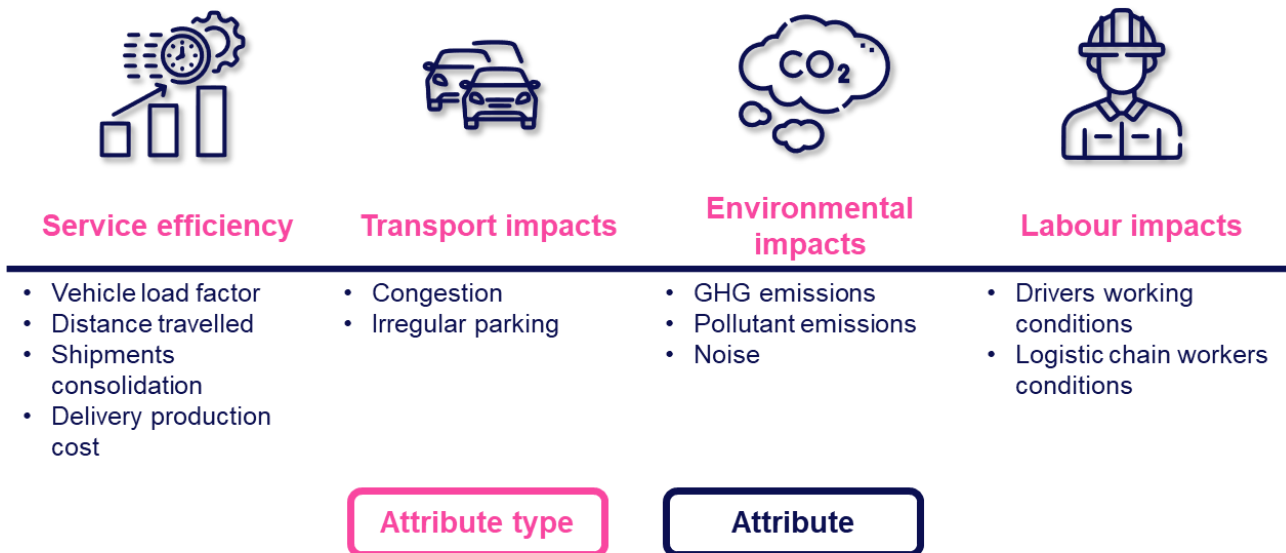
Within this category, 11 indicators are clustered in **two categories** (private and social) and **four attribute types**.

The category 'private impacts' cover the type of attributes related to **service efficiency**, as it looks at impacts for **logistics operators** (or own account transporting retailers).

The category 'social impacts' cover the types: **transport impacts**, **environmental impacts** and **labour impacts**.

Factsheets describing KPIs for **impact attributes** are provided in this section.

Figure 5: Impact delivery attributes and types



### 3.4.1 Service efficiency indicators

#### 3.4.1.1 Vehicles load factor

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Vehicles load factor	
<b>Attribute definition</b>	
Loaded tonnes per vehicle	
<b>Indicator</b>	
Share of vehicles used for delivery departing from warehouses with a load factor equal or above 75% of the carrying capacity	
<b>Description</b>	
<p>The load factor describes the ratio of the actual load to the maximum possible load of the transport means. It is a measure of the utilisation of a transport means and is therefore an indicator of transport efficiency.</p> <p>Vehicles load factor is considered an impact because operators can define the load of a vehicle only to a certain extent as this load will change case by case under the requirements emerging in specific circumstances (number of clients and their location, nature and size of products, delivery time to be respected, accessibility of the areas where customers live, and so on).</p> <p>Different delivery options can result in different average load factors (for different vehicle types).</p> <p>Therefore the indicator makes reference to both a load factor equal or above 75% representative of a good consolidation, and to the share of vehicles used for delivery departing from the warehouse with a load factor in this range.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Upwards

3.4.1.2 Travelled distance

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Travelled distance	
<b>Attribute definition</b>	
Distance travelled for delivering products	
<b>Indicator</b>	
<p>Travelled distance to complete D deliveries in an area of X square km</p> $I = \sum_v Dist_{Dv}^v$ <p>Where:</p> <p>Dist<sub>Dv</sub><sup>v</sup>: Distance travelled by vehicle type v to complete D<sub>v</sub> deliveries in an area of X square km under the condition that :</p> $\sum_v Dv = D$	
<b>Description</b>	
<p>As for load factor, the travelled distance is considered an impact as delivery tours are planned by operators according to specific circumstances (number of clients and their location, nature and size of products, delivery time to be respected, accessibility of the areas where customers live, and so on). Therefore they will change case by case and different delivery options may lead to different distances travelled by different type of vehicles.</p> <p>The indicator refers to the distance travelled to complete D deliveries in an area of X square km. The numbers D and X should be defined consistently with those defined for the the size of the fleet available for deliveries (see supply side attributes).</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
km	Downwards

3.4.1.3 Travelled distance by vehicle type

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Travelled distance by vehicle type	
<b>Attribute definition</b>	
Distance travelled by vehicle tipe v for delivering products	
<b>Indicator</b>	
Distance travelled by vehicle type v to complete Dv deliveries in an area of X square km	
<b>Description</b>	
This indicators refer to the distance travelled by each vehicle type v to complete Dv deliveries in an area of X square km	
<b>Measurement unit</b>	<b>Desired direction</b>
km	Downwards

3.4.1.4 Shipments consolidation

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Shipments consolidation	
<b>Attribute definition</b>	
Use of the same vehicle/delivery tour to serve more clients	
<b>Indicator</b>	
Average deliveries per tour	
$I = \sum_v Av\_Del^v$	
Where:	
Av_Del <sup>v</sup> : Average deliveries per tour per vehicle type v	
<b>Description</b>	
<p>Consolidation of shipments is enhanced by setting in place methods and rules to arrange deliveries in an efficient manner. Therefore the attribute 'Shipments consolidation' is highly interlinked with the supply side attribute 'Delivery optimisation system' .</p> <p>The number of deliveries per tour is affected by several factors including the location of the clients, the size of the vehicles as well as by the average size of packages.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Number/tour	Upwards

3.4.1.5 Shipments consolidation by type of vehicle

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Shipments consolidation by type of vehicle	
<b>Attribute definition</b>	
Use of the same vehicle/delivery tour to serve more clients	
<b>Indicator</b>	
Average deliveries per tour per type v vehicle	
<b>Description</b>	
<p>The number of deliveries per tour is affected by several factors including the location of the clients, the size of the vehicles as well as by the average size of packages.</p> <p>In case of electric vehicles, it is affected as well by the distance range of the vehicle.</p> <p>Due to their reduced load factor, non-motorised vehicles (bikes and cargobikes) can complete a reduced number of deliveries in a tour in comparison to motorised vehicles. Driverless vehicles (drones, bot) can complete an even lower number of deliveries per tour.</p> <p>This indicator is intended to reflect that different types of vehicles can have different performances in relation of the deliveries per tour.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Number/tour	Upwards

3.4.1.6 Total delivery time

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Total delivery time	
<b>Attribute definition</b>	
Time needed for delivering products	
<b>Indicator</b>	
Time needed to complete D deliveries in an area of X square km by all types of vehicles.	
$I = \sum_v Time_{Dv}^v$	
Where:	
Time <sub>Dv</sub> <sup>v</sup> : Time needed by vehicle type v to complete D <sub>v</sub> deliveries in an area of X square km under the condition that	
$\sum_v Dv = D$	
<b>Description</b>	
This indicators refer to the time needed by all vehicles to complete D deliveries in an area of X square km.	
<b>Measurement unit</b>	<b>Desired direction</b>
Hours	Downwards

3.4.1.7 Total delivery time by vehicle type

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Total delivery time by vehicle type	
<b>Attribute definition</b>	
Time needed for delivering products by vehicle type v	
<b>Indicator</b>	
Time needed by vehicle type v to complete Dv deliveries in an area of X square km	
<b>Description</b>	
This indicators refer to the time needed by each vehicle type v to complete Dv deliveries in an area of X square km	
<b>Measurement unit</b>	<b>Desired direction</b>
Hours	Downwards

3.4.1.8 Delivery production cost

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Delivery production cost	
<b>Attribute definition</b>	
Cost of the last-mile delivery	
<b>Indicator</b>	
Average cost per delivery	
<b>Description</b>	
Defined as average because it can be variable case by case. Basically, the indicator is the ratio between total delivery production cost and total number of deliveries	
<b>Measurement unit</b>	<b>Desired direction</b>
€/delivery	Downwards

3.4.1.9 Delivery production cost - Distribution and warehouse cost

<b>Domain</b>
Economic sustainability
<b>Attribute type</b>
Service efficiency
<b>Impact type</b>
Private

<b>Attribute</b>	
Delivery production cost - Distribution and warehouse cost	
<b>Attribute definition</b>	
Cost of the last-mile delivery	
<b>Indicator</b>	
Share of distribution network and warehouses cost per delivery	
<b>Description</b>	
Proportion of delivery costs attributable to the costs for managing last-mile distribution network and warehouses	
<b>Measurement unit</b>	<b>Desired direction</b>
%	Downwards

### 3.4.2 Environmental impacts indicators

#### 3.4.2.1 GHG emissions

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Environmental impacts
<b>Impact type</b>
Public

<b>Attribute</b>
GHG emissions
<b>Attribute definition</b>
Amount of GHG emissions generated during the last-mile delivery
<b>Indicator</b>
Average quantity of CO2 emissions per delivery
<b>Description</b>
<p>Parcel deliveries to people's homes imply a significant travelled distance, and this means that they are a huge contributor of greenhouse gas emissions. This is increased when deliveries fail and must be rescheduled, or when products are returned.</p> <p>This indicator refers to the amount of carbon dioxide emissions per delivery. The calculation could be based on actual fuel/energy consumption data or on consumption estimates and should be compliant with the EU framework for harmonised measurement of transport and logistics emissions (CountEmissions EU). The regulation establishes a voluntary EU methodology for the measurement of greenhouse gas emissions from freight and passenger transport. Nonetheless, if an organisation decides to calculate and disclose information on GHG emissions from transport services it needs to use the methodology provided.</p> <p>The methodology builds on the international standard ISO 14083, so that it can also be applied to transport chains which are partly outside the EU territory. The European Committee for Standardisation (CEN) has transposed it as an equivalent European standard EN ISO 14083:2023 establishing a common methodology for the quantification and reporting of GHG emissions from the operation of transport chains of passengers and freight, while also setting out requirements and guidance for the quantification, assignment, allocation and reporting of those GHG emissions. The standard covers all modes of land, water and air transport, and the operational emissions from transport hubs, and is applicable along the entire transport chain. The new EN ISO 14083:2023 standard allows for both energy- and activity-based emissions measurement, depending on whether or not accurate primary emissions data are available for all steps of the freight process. It uses a well-to-wheel approach for measuring emissions and prioritises the use of primary data. It establishes a</p>

database of default values to be used in case that primary data are not available. (European Parliament, 2025)

Measurement unit	Desired direction
g/delivery	Downwards

3.4.2.2 Pollutant emissions - PM

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Environmental impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Pollutant emissions	
<b>Attribute definition</b>	
Amount of PM pollutant emissions generated during the last-mile delivery	
<b>Indicator</b>	
Average quantity of PM emissions per delivery	
<b>Description</b>	
<p>This indicator refers to the amount of particulate matter (PM) emissions per delivery. As a general rule, GHG emissions are directly proportional to fuel consumption. NOx and PM vehicle emissions are different as they depend on combustion processes in engines and are therefore related to the engine design, exhaust gas cleaning systems applied, and the driving conditions such as cold start, speed, or type of road. Therefore, computing this indicator requires detailed information on the fleet and on the driving conditions.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
g/delivery	Downwards

3.4.2.3 Pollutant emissions - NOx

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Environmental impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Pollutant emissions	
<b>Attribute definition</b>	
Amount of NOx pollutant emissions generated during the last-mile delivery	
<b>Indicator</b>	
Average quantity of NOx emissions per delivery	
<b>Description</b>	
<p>This indicator refers to the amount of nitrogen oxide (NOx) emissions per delivery. As a general rule, GHG emissions are directly proportional to fuel consumption. NOx and PM vehicle emissions are different as they depend on combustion processes in engines and are therefore related to the engine design, exhaust gas cleaning systems applied, and the driving conditions such as cold start, speed, or type of road. Therefore, computing this indicator requires detailed information on the fleet and on the driving conditions.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
g/delivery	Downwards

3.4.2.4 Noise

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Environmental impacts
<b>Impact type</b>
Public

<b>Attribute</b>
Noise
<b>Attribute definition</b>
Noise generated during the last-mile delivery
<b>Indicator</b>
<p>Index obtained as weighted average of noise level of vehicle types using the shares of usage of each vehicle type as weights.</p> $I = \frac{\sum_v (NL^v * Dist\_Dv^v)}{\sum_v Dist\_Dv^v}$ <p>Where:</p> <ul style="list-style-type: none"> <li>- NL<sup>v</sup> is the average noise emission level of the specific vehicle type v in dB(A);</li> <li>- Dist_Dv<sup>v</sup> is the distance travelled by the specific vehicle type v to complete Dv deliveries in an area of X square km (see also indicators for "Travelled distance by vehicle type")</li> </ul> <p>under the condition that</p> $\sum_v Dv = D$
<b>Description</b>
<p>In 2011 the World Health Organisation (WHO) has identified noise from transport as the second most significant environmental cause of ill health in Western Europe, the first being air pollution from fine particulate matter . This type of pollution, caused by excessive sounds in the environment, is largely to blame for disorders such as stress, hearing loss or insomnia.</p> <p>The most efficient, sustainable solution to avoid contributing to this type of pollution in the delivery sector, is to commit to vehicles such as cargo bikes or bicycles with assisted pedalling or to electric vehicles in general. These are silent vehicles which greatly reduce noise in urban and interurban areas.</p>

Regulation (EU) No. 540/2014 of the European parliament and of the Council on the sound level of motor vehicles sets maximum values for noise emissions from road vehicles, including trucks and vans, applicable as of 2016, 2022 and 2026. Limit values for noise arising from contact between tires and road surfaces were introduced by Directive 2001/43/EC in 2001 and progressively made applicable.

Measuring noise from last mile deliveries is unfeasible as it depends on many local conditions and is mixed with noise generated by other vehicles.

An index considering the usage of various types of vehicles seems a reasonable measure for this attribute when comparing alternative delivery options.

The index could also include a factor to take into account the time distribution of deliveries, assuming that noise in early morning or in the evening is more annoying than noise during the day.

Measurement unit	Desired direction
dB(A)	Downwards

3.4.3 Transport impacts indicators

3.4.3.1 Congestion

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Transport impacts
<b>Impact type</b>
Public

<b>Attribute</b>
Congestion
<b>Attribute definition</b>
Contribution of last-mile delivery to traffic congestion
<b>Indicator</b>
<p>Index obtained as combination of:</p> <ul style="list-style-type: none"> <li>- the time needed for delivering products by each vehicle type</li> <li>- the road occupancy of each vehicle type.</li> </ul> $I = \sum_v (Time\_Dv^v * Road\_Occ^v)$ <p><math>I = \sum(i) Ti*OccVi</math></p> <p>where:</p> <p>Time_Dv<sup>v</sup>: Time needed by vehicle type v to complete Dv deliveries in an area of X square km</p> <p>Road_Occ<sup>v</sup>: road occupancy of vehicle type v</p> <p>under the condition that</p> $\sum_v Dv = D$
<b>Description</b>
<p>In addition to emissions, last mile delivery can also lead to traffic congestion, particularly in urban areas where there are more delivery destinations and less space for vehicles. Traffic congestion can cause delays and increase the time it takes for delivery vehicles to complete their routes. This results in more fuel consumption and emissions, as well as increased wear and tear on vehicles, which can lead to higher maintenance costs and lower fuel efficiency.</p>

Measuring congestion is however even more context-dependent than measuring noise.

An index based on the space occupied by vehicles during their delivery activity looks a feasible and meaningful way to describe that some delivery options can be more or less impactful on congestion when they are compared.

Measurement unit	Desired direction
hours*sqm	Downwards

3.4.3.2 Irregular parking

<b>Domain</b>
Environmental sustainability
<b>Attribute type</b>
Transport impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Irregular parking	
<b>Attribute definition</b>	
Contribution of transport activity for last-mile delivery to vehicles irregularly parked	
<b>Indicator</b>	
n.a.	
<b>Description</b>	
The contribution of last-mile delivery to vehicles irregularly parked cannot be quantified a-priori without on-field data collection in real cases e.g. from the analysis of GPS data from vehicles related to geo-location of stops and their duration in relation with the geo-location of dedicated parking lots in the delivery area.	
<b>Measurement unit</b>	<b>Desired direction</b>
n.a.	Downwards

### 3.4.4 Labour impacts indicators

Worker exploitation is defined as the “harmful, merely instrumental, utilization of an individual or her capacities for one’s own advantage or ends in a transaction” (Buchanan A., 1988). Although a transaction - such as the one between workers and delivery companies - benefits both parties involved, one party might not benefit sufficiently by some applied standard of equity or equality (Arnold D. G. & Bowie N. E., 2003).

In delivery companies, worker exploitation is associated with the classification of workers as independent contractors who are only paid on demand for each delivery (Cachon G. P. Daniels K. M. & Lobel R., 2017). Thus, companies have been accused to externalize the costs of flexibility to workers.

In addition, worker exploitation stems from unfair working conditions, such as work instability, low earnings, and limited rights and protections. Large e-commerce platforms generally rely on a network of thousands of drivers. Rather than keeping these workers on their books, they manage them through what are called delivery service providers, small companies that handle groups of drivers, who work as self-employed independent contractors with no right to holiday pay, sick pay or the “national living wage” (Longoni A. & al., 2024).

Since working conditions involve various elements, more indicators are needed to describe them. One indicator only would be risky as some aspects (e.g. lower working time) could be compensated by others (e.g. more intensive work). Indicators presented in this section refer to both working conditions of drivers and warehouse workers.

3.4.4.1 Drivers labour conditions – Fair salary

<b>Domain</b>
Social sustainability
<b>Attribute type</b>
Labour impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Drivers labour conditions	
<b>Attribute definition</b>	
Fair salary for drivers	
<b>Indicator</b>	
Average net hourly wage of drivers	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>This indicator accounts for fair wages for drivers.</p> <p>If considering the hours actually worked and their expenses, drivers' income might fall below the decent minimum wage.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
€/h	<p>Upwards for workers</p> <p>Downwards for operators</p>

3.4.4.2 Drivers labour conditions – Fair working time

<b>Domain</b>
Social sustainability
<b>Attribute type</b>
Labour impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Drivers labour conditions	
<b>Attribute definition</b>	
Fair working time for drivers	
<b>Indicator</b>	
Ratio between the actual average weekly working time of drivers and average contractual weekly working time	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>This indicator accounts for the average weekly working time of drivers. Too often the working time of delivery personnel is longer than the hours they are paid as they are committed to complete a certain number of deliveries and they are likely to spend more hours on the road due to re-deliveries and hold-ups such as traffic jams and parking.</p> <p>This indicator accounts for the ratio between the actual average weekly working time of drivers and average contractual weekly working time.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Not above 1 (for workers)

3.4.4.3 Drivers labour conditions – Sustainable workload

<b>Domain</b>
Social sustainability
<b>Attribute type</b>
Labour impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Drivers labour conditions	
<b>Attribute definition</b>	
Sustainable workload for delivery personnel	
<b>Indicator</b>	
Number of deliveries per hour requested to drivers	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>Drivers working for some worldwide e-commerce platforms have reported delivering 250-300 packages a day and that, according to the number of stops they need to make, traffic and wether conditions, this turns out they can't afford to spend more then 30 sec to a min per stop. This workload is clearly unsustainable and couriers are too often pushed beyond their limits chasing unrealistic targets.</p> <p>To account for a sustainable workload for delivery personnell, this indicator refers to the number of deliveries per hour requested to drivers.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
deliveries/hour*worker	<p>Downwards for workers</p> <p>Upwards for operators.</p>

3.4.4.4 Logistic chain labour conditions – Fair salary

<b>Domain</b>
Social sustainability
<b>Attribute type</b>
Labour impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Logistic chain labour conditions	
<b>Attribute definition</b>	
Fair labour practices	
<b>Indicator</b>	
Average net hourly wage of warehouses workers	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>This indicator accounts for the average net hourly wage of warehouse workers.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
%	<p>Upwards for workers</p> <p>Downwards for operators.</p>

3.4.4.5 Logistic chain labour conditions – Fair working time

<b>Domain</b>	
Social sustainability	
<b>Attribute type</b>	
Labour impacts	
<b>Impact type</b>	
Public	
<b>Attribute</b>	
Logistic chain labour conditions	
<b>Attribute definition</b>	
Fair working time for warehouse personnel	
<b>Indicator</b>	
Ratio between the actual average weekly working time of warehouse personnel and average contractual weekly working time	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>Long, gruelling shifts with unreasonable productivity targets and unfair shift patterns are commonly reported by personnel working in fulfilment centres of some worldwide known e-commerce platforms.</p> <p>Some evidence indicate that pickers might be expected to pick and pack around 300 items per hour, and working weeks average around 55 hours/ 10-hour days, especially over the peak Christmas period (<a href="https://www.tuc.org.uk/node/523929">https://www.tuc.org.uk/node/523929</a>).</p> <p>This indicator accounts for a fair working time of warehouse workers by considering the ratio between the actual average weekly working time of drivers and average contractual weekly working time.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
Dimensionless	Not above 1 (for workers)

3.4.4.6 Logistic chain labour conditions – Sustainable workload

<b>Domain</b>
Social sustainability
<b>Attribute type</b>
Labour impacts
<b>Impact type</b>
Public

<b>Attribute</b>	
Logistic chain labour conditions	
<b>Attribute definition</b>	
Sustainable workload for warehouse personnel	
<b>Indicator</b>	
Number of prepared parcels per hour requested to warehouse workers	
<b>Description</b>	
<p>Fair labour conditions encompass a broad range of elements, including fair wages, reasonable working hours, reasonable workload etc.</p> <p>To account for a sustainable workload for warehouse workers, this indicator refers to the number of parcels per hour requested to be processed by them.</p>	
<b>Measurement unit</b>	<b>Desired direction</b>
parcels/hour*worker	<p>Downwards for workers</p> <p>Upwards for operators.</p>

## 4 Evaluation of the delivery options

The KPIs represent one element of the CodeZERO assessment framework, allowing to describe the features of the delivery options in an operational manner. Using the KPIs, different options can be assessed and compared to each other. The other elements of the assessment framework are the methods to use the KPIs to provide summary measures, namely:

- A measure of the relative relevance of each KPI
- Methods for aggregating the KPIs

Once these elements are defined, the assessment framework can be applied for the evaluation of delivery options. As already mentioned, it should be noted that the CodeZERO assessment framework is conceived to compare two or more alternative delivery options, not to define an absolute “measure” of one delivery option in itself. The following paragraphs describe the different steps.

### 4.1 Definition of the relevance of each KPI

Since delivery options are defined as combinations of values/levels of several KPIs concerning various aspects, the first step of the evaluation process is deriving a measure of the relevance of each KPI.

The definition of the relative importance of each attribute is obtained by means of an Analytic Hierarchy Process (AHP). More specifically, a two-levels procedure of pairwise comparisons is used:

- In the **first level**, pairwise comparisons involve the **attribute types**.
- In the **second level**, pairwise comparisons involve the single **attributes** within the same type.

The two-levels procedure is applied separately for the demand-side attributes, the supply-side attributes (together the context attributes) and the impact attributes.

Pairwise comparisons means that all elements of one group (e.g. all attributes belonging to a certain attribute type) are compared in pairs (e.g. “A” vs “B”; “A” vs “C”; “B” vs “C”, etc.) and, for each pair, a judgment is provided regarding their relative importance (i.e. if “A” is more important of “B” or vice-versa). In this way, all elements are compared to each other.

Given the high number of attributes and types considered in CodeZERO analytical framework, a **seven-levels judgment** is proposed to allow for a higher differentiation in KPIs weights values.

For each pairwise comparison, one of the following options should be selected:

- **A is much more relevant than B**
- **A is more relevant than B**
- **A is slightly more relevant than B**
- **A and B are equally relevant**
- **B is slightly more relevant than A**
- **B is more relevant than A**
- **B is much more relevant than A**

#### Box - Example of pairwise comparisons

There are **18 attributes** demand-side attributes classified under **6 types**. Furthermore, an additional classification looks useful, i.e., KPIs related to the **purchase experience** and KPIs related to the **delivery experience** (still from the customer perspective).

**In the first level**, separately for the attributes related to the purchase experience and for the KPIs related to the delivery experience, **attribute types** are compared to each other, pairwise. For instance, for the purchase experience, pairwise comparisons are:

- Delivery price vs Flexibility
- Delivery price vs Delivery time
- Delivery price vs Information
- Flexibility vs Delivery time
- Flexibility vs Information
- Delivery time vs Information

**The second level** of the procedure works like the first level, but it is applied to the single attributes belonging to one type. For instance, the attributes related to the attribute type “flexibility” are: Choice of delivery date; Choice of delivery time slot; Choice of time optimisation; Choice of point of delivery; Choice of vehicle type. Therefore, the following pairwise comparisons should be made:

- Choice of delivery date vs Choice of delivery time slot
- Choice of delivery date vs Choice of products consolidation
- Choice of delivery date vs Choice of point of delivery
- Choice of delivery date vs Choice of vehicle type
- Choice of delivery time slot vs Choice of products consolidation
- Choice of delivery time slot vs Choice of point of delivery
- Choice of delivery time slot vs Choice of vehicle type
- Choice of products consolidation vs Choice of point of delivery
- Choice of products consolidation vs Choice of vehicle type
- Choice of point of delivery vs Choice of vehicle type

The full list of pairwise comparisons is reported in the Annex to this report (see Chapter 8).

As part of the definition of the CodeZERO assessment framework, the pairwise comparisons have been administered to a sample of stakeholders. Details on the methodology of the survey and on its results are provided in section 5.

## 4.2 Calculation of weights for the KPIs

The weights for the KPIs are derived from the results of the pairwise comparisons. Initially, weights related to the **Attribute types** are quantified with the procedure explained below.

Each of the seven options is associated to a relative weight for A and for B as shown in Table 4-1. The definition of these initial weight is arbitrary.

Table 4-1: Initial weights associated to comparisons results

	Weight of A	Weight of B
<b>A is much more relevant than B</b>	0.90	0.10
<b>A is more relevant than B</b>	0.75	0.25
<b>A is slightly more relevant than B</b>	0.60	0.40
<b>A and B are equally relevant</b>	0.50	0.50
<b>B is slightly more relevant than A</b>	0.40	0.60
<b>B is more relevant than A</b>	0.25	0.75
<b>B is much more relevant that A</b>	0.10	0.90

Since several stakeholders belonging to a given group (customers, operators, etc.) provide answers to the same set of pairwise comparisons, the relative weights are computed as average of the responses.

In general terms, being:

$PairWeight_s^{A-B}$ : Relative weight of attribute type  $a$  resulting from the choice expressed by stakeholder  $s$  in the pairwise comparison between attribute type  $A$  and attribute type  $B$ .

$PairWeight_s^{B-A} = 1 - PairWeight_s^{A-B}$ : Relative weight of attribute type  $B$  resulting from the choice expressed by stakeholder  $s$  in the pairwise comparison between attribute type  $A$  and attribute type  $B$ .

The average relative weight, considering the responses of all stakeholders of the same group, is:

$$AvWeight^{A-B} = \frac{\sum_s^S PairWeight_s^{A-B}}{S}$$

Then the average weight of the attribute type  $A$  for a certain stakeholder group, considering all pairwise comparisons, is computed as follows:

$$AvWeight^A = \frac{\sum_B AvWeight^{a-b}}{\sum_A \sum_B AvWeight^{a-b}}$$

The same process is applied to the responses on the pairwise comparisons related to the **Attributes**:

$PairWeight_s^{kA-jA}$ : relative weight of attribute  $k$  – element of attribute type  $A$  – resulting from the choice expressed by stakeholder  $s$  in the pairwise comparison between attribute  $k$  and attribute  $j$ .

$PairWeight_s^{jA-kA} = 1 - PairWeight_s^{kA-jA}$ : relative weight of attribute  $j$  – element of attribute type  $A$  – resulting from the choice expressed by stakeholder  $s$  in the pairwise comparison between attribute  $k$  and attribute  $j$ .

The average relative weight, considering all stakeholders, is:

$$AvWeight^{kA-jA} = \frac{\sum_s^S PairWeight_s^{kA-jA}}{S}$$

And the average weight of the attribute  $k$  – element of attribute type  $A$  – considering all pairwise comparisons, is:

$$AvWeight^{kA} = \frac{\sum_{jA} AvWeight^{kA-jA}}{\sum_{kA} \sum_{jA} AvWeight^{kA-jA}}$$

A **preliminary** overall weight of each attribute  $k$  is obtained as the product of the weight of the same attribute within the attribute type it belongs to and the weight of the attribute type:

$$PrWeight^k = AvWeight^A * AvWeight^{kA}$$

For example, if for the attribute type “flexibility” it is computed an average weight of 0.283 ( $AvWeight^A = 0.283$ ), and for the attribute “choice of delivery date” – element of the attribute type “flexibility” – it is computed an average weight of 0.272 ( $AvWeight^{kA} = 0.272$ ) the preliminary overall weight of the attribute “choice of delivery date” is  $0.272 * 0.283 = 0.077$ .

These values are only preliminary because they are affected by the different number of attributes belonging to each attribute type. Attributes belonging to attribute types including only 2 or 3 elements, can easily receive an overall weight higher than the overall weight of attributes belonging to attribute types including 5 or 6 attributes. To compensate for this bias, preliminary values are scaled by the ratio between the number of attributes belonging to the attribute type and the average value of this number. Furthermore, these scaled values are divided by their sum to obtain the final set of weights, whose overall sum is 1. In short, the final overall weight is computed as:

$$Weight^k = \frac{PrWeight^k * \frac{AttNum^{kA}}{AvAttNum}}{\sum_k \left( PrWeight^k * \frac{AttNum^{kA}}{AvAttNum} \right)}$$

Where:

$AttNum^{kA}$  = Number of attributes within the attribute type  $A$  the attribute  $k$  belongs to

$AvAttNum$  = Average value of  $AttNum^{kA}$  across all attribute types  $A$ .

### 4.3 Calculation of the normalised scores of each KPI

To apply the weights obtained with the procedure above for comparing alternative delivery options, the scores of KPIs (i.e. the value quantifying the state of level of the attribute) should be normalised. This step is required because some KPIs are just indices (0, 1, 2, ...), others are percentages, others are absolute values expressed in very different units: euro, days, grams and so on.

The normalisation is obtained by scaling the original value of the indicator using a factor based on the expected magnitude of the indicator itself. The magnitude is a sort of average, but it is not computed on a set of data (since there will never be available a set of measures of the indicators covering the whole range of values that they can assume). The magnitude is rather an educated estimate of the size of the values that could be found for a delivery option. For instance, the magnitude of the delivery price can be reasonably assessed (even if it will be different by product type: delivering book is not like delivering refrigerators). Also, an expected “level” of emissions or of the length of the delivery time slot can be anticipated and so on. The following rules apply:

- The magnitude of KPIs defined as percentages is always 50.
- The magnitude of KPIs defined as discrete indexes from 0 to N (i.e. 0, 1, 2, ..., N) is always N/2

Given the expected magnitude, the scaling factor is the ratio between 50 (the average of a 0 – 100 scale) and magnitude. For instance, if the expected magnitude of the delivery price is 5 € (which means that for some delivery options it might be lower – even zero – and for other options it might be higher), the scaling factor is  $50/5 = 10$ . Similarly, if the average length of the delivery time slot is 3 hours, the scaling factor is  $50/3 = 16.67$ .

Note that the variability around the expected magnitude can be different indicator by indicator. In some cases, the variability could be relatively large (e.g., for domestic appliances the magnitude of the delivery price could be set to 25 € as one expects prices ranging from 0 to 50 € per delivery) and in other cases the range is limited (e.g. the magnitude of the length of the delivery time slot could be set to 3 hours as one expects that it will be between 2 and 4 hours). However, this different level of variability has nothing to do with the normalisation. It is just that delivery options can be quite different to each other according to some indicators and more similar to each other according to some other indicators.

Another aspect of the normalisation is ensuring that, for each KPI, a higher value is preferred to a lower value. Of course, this is certainly untrue for some KPIs – e.g., delivery price. For other KPIs it is a matter of perspective. For instance, higher values of workers’ wage are preferred by labour’s representative while logistics operators prefer lower wage values.

Therefore, building on the original value of the KPI, the normalised score is computed as follows:

When higher values of the KPI are preferable:  $NScore^k = Value^k * ScFact^k$

When lower values of the KPI are preferable:  $NScore^k = (2 * Size^k - Value^k) * ScFact^k$

Where:

$Value^k$  = Original value of the KPI

$ScFact^k$  = Scaling factor defined for the KPI

$Size^k$  = Expected magnitude of the KPI

**Since there are different preferences, the rules above should be applied separately for each stakeholder group.**

#### 4.4 Calculation of the aggregated scores

Once the normalised scores are defined, overall evaluation scores of one delivery option are obtained as the weighted sum of these scores, where weights are those obtained at the end of the Analytic Hierarchy Process described in paragraph 4.2.

A set of overall scores is initially computed separately by attribute category and by stakeholder group. Therefore, there will be an overall score for the demand-side attributes for customers, an overall score for supply-side attributes for operators, an overall score for social impacts for customers, an overall score for social impacts for public authorities and so on. This initial set of overall scores allow to see how the alternative delivery options compare under different perspectives. Looking at these overall scores it could be observed that some options can be considered superior from all perspectives or that some options are preferable from one perspective but not from others. This is a useful outcome of the evaluation process. These initial overall scores are computed according to the following equation.

$${}^A_S Score_D = \sum_{k \in A} ({}^A NScore_D^k * {}^A_S Weight^k)$$

Where:

${}^A NScore_D^k$  is normalised score  $NScore^k$  of the KPI  $k$  belonging to the attribute category  $A$  for the delivery option  $D$

${}^A_S Weight^k$  is the weight of the KPI  $k$  belonging to the attribute category  $A$  for the stakeholder group  $S$ .

These aggregated scores are the main outcomes of the CodeZERO assessment framework. Nevertheless, further aggregations can be made.

The set of overall scores can be integrated into overall scores by attribute category (irrespective of the stakeholder group) and by stakeholder group (irrespective of the attribute category). This aggregation can be used to assess the “best” alternative option considering a certain category (customer satisfaction, efficiency, sustainability) or a certain stakeholder group. However, it should be noted that this aggregation cannot build on objective weights nor on stakeholders’ evaluations. The relative importance of each attribute category or each stakeholder group is left to the analyst and is, therefore, completely arbitrary. Formally, this further aggregation is made according to the equation:

$${}^A Score_D = \sum_S ({}^A_S Score_D * {}^A CatWeight)$$

$${}_S Score_D = \sum_A ({}^A_S Score_D * {}_S SthWeight)$$

Where:

${}^A CatWeight$  is a vector of weights associated with each attribute category  $A$

${}_S SthWeight$  is a vector of weights associated with each stakeholder group  $S$

Finally, it is conceivable to produce a single aggregated final score which would allow to compare the delivery options in absolute. Again, this aggregation could not be based on objective weights or stakeholders' evaluations and would be completely arbitrary. The final single score could be obtained building on the aggregate score by category or on the aggregate score by stakeholder:

$$Score_D = \sum_A ({}^A Score_D * {}^A CatWeight)$$

$$Score_D = \sum_S ({}_S Score_D * {}_S SthWeight)$$

### 4.5 An example of application

In this section an example of the application of the assessment methodology is presented. The example considers two fictitious different delivery options. For both these options, KPIs values are defined, the rules for normalisation of the KPIs values are applied and the weights derived from the online "Pairwise Comparison" survey (see section 5) are associated to the KPIs values to derive aggregated scores.

#### 4.5.1 Definition of the fictitious delivery options

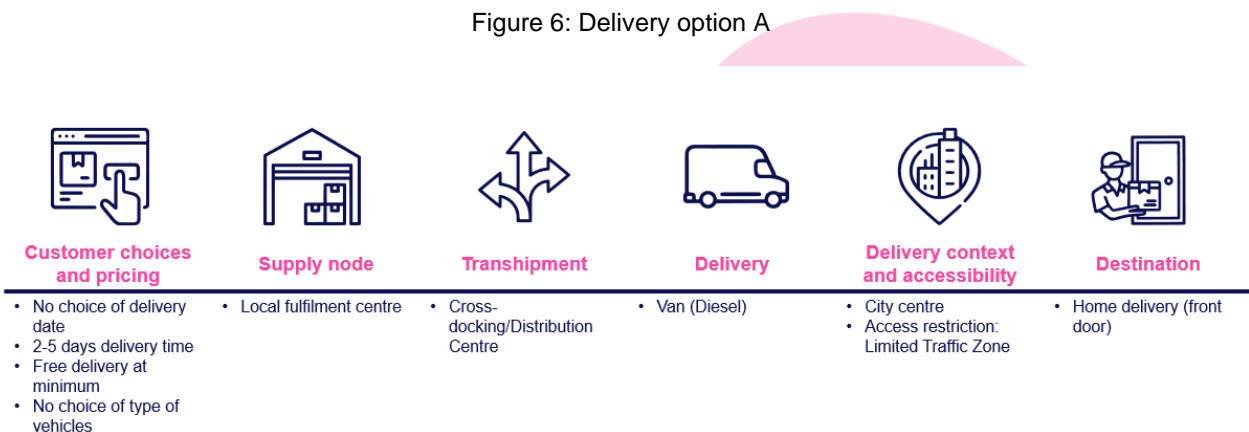
Two delivery options are considered for delivering small size products (e.g. a book, a jumper, shoes, etc.) to customers living in a city centre location. The first option, referred to as "Delivery Option A," represents a more "traditional" approach, whereas the second option, "Delivery Option B," is more innovative, offering consumers greater flexibility.

Delivery Option A (Figure 6) represents a traditional and straightforward logistics model. Consumers have no flexibility in selecting the delivery date, method, or type of vehicle used, leaving them with limited influence over the process. Once the product has been purchased, the process begins at a local fulfilment centre, where the order is prepared for shipment. From there, the parcel is routed through a cross-docking or distribution centre, where it is sorted and dispatched for final delivery.

The last stage of the journey is carried out by a diesel-powered van, which delivers the parcel directly to the recipient's front door. While this option ensures reliable and direct delivery, it offers no flexibility to the consumer.

This option reflects a conventional approach to urban logistics, prioritising operational efficiency over personalisation. However, it must operate within the constraints of city centres, such as Limited Traffic Zones, which impose restrictions on vehicle access.

Figure 6: Delivery option A



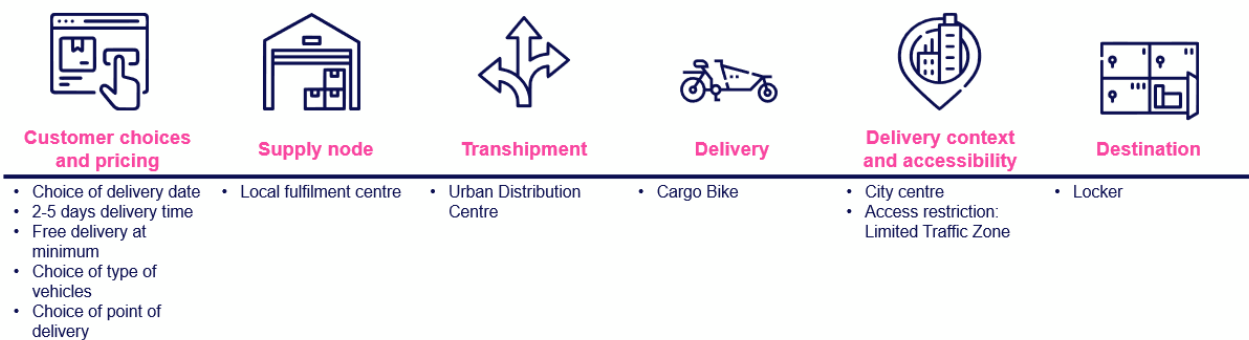
Delivery Option B (Figure 7) adopts a more innovative and flexible approach, designed to cater to modern consumer needs. The process begins at a local fulfilment centre, similar to Option A, but

introduces key differences in the subsequent steps. After preparation, the parcel is transported to an urban distribution centre, optimised for efficient last-mile delivery.

Furthermore, it is assumed that customers have the possibility of choosing the type of vehicle used for the delivery and decide to receive products by means of cargo-bikes. Therefore, it is assumed that the final delivery is completed using a cargo bike, an environmentally friendly alternative to traditional vehicles. Instead of being delivered to the customer’s home, the parcel is placed in a locker chosen by the consumer and located in the city centre. This offers the recipient the convenience of retrieving the parcel at a time of their choosing.

This delivery model provides customers with several choices, such as selecting the delivery date, method, and location. By offering greater personalisation, Option B reflects a more consumer-centric and sustainable approach to urban logistics. It also aligns with the constraints of Limited Traffic Zones, ensuring compliance while reducing environmental impact.

Figure 7: Delivery option B



#### 4.5.2 Quantification of the KPIs

For both the delivery options illustrated above the value associated to each indicator has been defined. Since the two options are fictitious, the KPIs scores are all assumptions based on available data and professional experience of the authors.

For instance, regarding the KPI Delivery Price, the scores are based on research carried out on various ecommerce offering traditional deliveries without subscription services and e-commerce offering cargo bike deliveries.

For the KPI "Warehouse location" the score was based on a real example of warehouses used by e-commerce companies that deliver with vans and those that deliver by cargo bike in the city of Milan.

For the KPI "Noise" the scores of the two options were assigned considering the EU legal framework on motor vehicles noise polluting<sup>4</sup>, while for cargo bikes, literature data and newspaper articles<sup>5</sup> have been used.

<sup>4</sup> Regulation (EU) No 540/2014 of the European Parliament and of the Council of 16 April 2014 on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC [2014] OJ L 158, p. 13

<sup>5</sup> K. Valdez, "Do Electric Bikes Generate Noise: A Guide to E-Bike Noise", 18 August 2023; "H.T. Harvey & Associates, "Update on the Electric Bicycle (e-bike) Noise Study," Midpeninsula Regional Open Space District, 10 November 2021.

For the KPIs related to the labour conditions, the scores were based on the Italian “Contratto Collettivo Nazionale – Trasporti e Logistica”<sup>6</sup> supported by assumptions based on the professional experience of the research team.

Some KPIs can be considered not directly relevant for one or another delivery option, but the example shows that one value can be defined anyway. For example, some indicators measure how much the delivery option respect the preferences expressed by consumers regarding e.g. delivery date, time slot, product consolidation, point of delivery, vehicle type, etc.). Option A is assumed to allow only limited choices, so these indicators are reflecting this assumption. Assuming that the lack of right of choice corresponds to the condition where the option is in line with the preference of part of the consumers, and not in line with the other part, it is possible to associate a “neutral” value (50%) to the indicators.

The following table provides the KPIs scores for each category of attributes for both delivery options.

Table 4-2: Quantification of the KPIs

Attribute category	Attribute type	Indicator	Measurement Unit	Delivery Option A	Delivery Option B
Demand attributes	Cost	Delivery price	€/delivery	4.99	7.00
Demand attributes	Flexibility	Choice of delivery date	Dimensionless	0	2
Demand attributes	Flexibility	Choice of delivery time slot	Dimensionless	0	0
Demand attributes	Flexibility	Choice of products consolidation	Dimensionless (Yes/No)	1	0
Demand attributes	Flexibility	Choice of point of delivery	Dimensionless	0	1
Demand attributes	Flexibility	Choice of vehicle type	Dimensionless (Yes/No)	0	1
Demand attributes	Delivery time	Delivery date	Number of days	3.5	3.5
Demand attributes	Delivery time	Delivery date punctuality	%	95%	90%
Demand attributes	Delivery time	Delivery time slot	hours	10	5
Demand attributes	Delivery time	Delivery time slot punctuality	%	97%	75%

<sup>6</sup> Contratto Collettivo Nazionale di Lavoro (CCNL) is the Italian national collective labour agreement that regulates employment conditions for specific sectors. It is negotiated between labour unions and employer associations, setting minimum wages, working hours, benefits, and rights for workers. While companies can offer better conditions, they cannot go below the standards set by the CCNL. It ensures fair labour practices and protects workers’ rights across industries.

Attribute category	Attribute type	Indicator	Measurement Unit	Delivery Option A	Delivery Option B
<b>Demand attributes</b>	Delivery time	Products consolidation	%	100%	100%
<b>Demand attributes</b>	Delivery method	Point of delivery	Dimensionless	1	3
<b>Demand attributes</b>	Delivery method	Point of delivery - Share of deliveries	%	100%	100%
<b>Demand attributes</b>	Delivery method	Vehicle type	Dimensionless	1	3
<b>Demand attributes</b>	Delivery method	Vehicle type - Share of deliveries	%	50%	100%
<b>Demand attributes</b>	Information	Tracking of shipment	Dimensionless	2	2
<b>Demand attributes</b>	Information	Delivery reminder	Dimensionless	3	3
<b>Demand attributes</b>	Information	Impact of purchase	Dimensionless	0	0
<b>Demand attributes</b>	Reliability	Products safety	%	99%	95%
<b>Demand attributes</b>	Reliability	Actual delivery	%	5%	5%
<b>Supply attributes</b>	Service organisation	Stock level	%	5%	5%
<b>Supply attributes</b>	Service organisation	Shops coordination system	Dimensionless	1	1
<b>Supply attributes</b>	Service organisation	Delivery optimisation system	Dimensionless	1	1
<b>Supply attributes</b>	Service organisation	Products handling protocols	Dimensionless	2	3
<b>Supply attributes</b>	Impact monitoring system	Impact measurement process	Dimensionless	3	3
<b>Supply attributes</b>	Size and composition of the vehicle fleet	Delivery vehicles - Total vehicles	N° of vehicles	1	10

Attribute category	Attribute type	Indicator	Measurement Unit	Delivery Option A	Delivery Option B
Supply attributes	Size and composition of the vehicle fleet	Delivery vehicles by type and technology	Dimensionless	0.52	0.85
Supply attributes	Workforce arrangement	Number of drivers - Total	N° of drivers	1	10
Supply attributes	Workforce arrangement	Number of warehouses workers	Number of workers	200	200
Supply attributes	Distribution network	Number of warehouses	N° of warehouses	2	2
Supply attributes	Distribution network	Size of warehouses	Squared meters (sqm)	30000	30000
Supply attributes	Distribution network	Warehouses organization and equipment	Pallets (or parcels) per hour	2	0,5
Supply attributes	Distribution network	Warehouses location	%	20%	100%
Context attributes	Spatial arrangement	Streets accessibility - pedestrians	%	1%	1%
Context attributes	Spatial arrangement	Streets accessibility – zero emissions	%	4.5%	4.5%
Context attributes	Spatial arrangement	Parking lots	Parking lots/km	2,25	6
Context attributes	Spatial arrangement	Micro-hubs	Sites/km <sup>2</sup>	0	2
Private Impacts	Service efficiency	Vehicles load factor	%	70%	95%
Private Impacts	Service efficiency	Travelled distance	km	100	45
Private Impacts	Service efficiency	Travelled distance by vehicle type	km	100	45
Private Impacts	Service efficiency	Shipments consolidation	Number/tour	200	25
Private Impacts	Service efficiency	Shipments consolidation by type of vehicle	Number/tour	200	50
Private Impacts	Service efficiency	Total delivery time	Hours	9	22

Attribute category	Attribute type	Indicator	Measurement Unit	Delivery Option A	Delivery Option B
Private Impacts	Service efficiency	Total delivery time by vehicle type	Hours	8	20
Private Impacts	Service efficiency	Delivery production cost	€/delivery	4.69	6.58
Private Impacts	Service efficiency	Distribution and warehouse cost share	%	75%	80%
Public Impacts	Environmental impacts	GHG emissions	g/delivery	24.91	0
Public Impacts	Environmental impacts	Pollutant emissions - PM	g/delivery	1	0
Public Impacts	Environmental impacts	Pollutant emissions - NOx	g/delivery	16	0
Public Impacts	Environmental impacts	Noise	dB(A)	70	20
Public Impacts	Transport impacts	Congestion	hours*sqm	20	120
Public Impacts	Labour impacts	Drivers labour conditions - Wage	€/h	10.80	9.62
Public Impacts	Labour impacts	Drivers labour conditions - Working time	Dimensionless	1.12	1.00
Public Impacts	Labour impacts	Drivers labour conditions - Workload	deliveries/hour*worker	25	6
Public Impacts	Labour impacts	Logistic chains labour conditions - Wage	%	8.3%	7.4%
Public Impacts	Labour impacts	Logistic chains labour conditions - Working time	Dimensionless	1.125	1
Public Impacts	Labour impacts	Logistic chains labour conditions - Workload	parcels/hour*worker	70	20

### 4.5.3 Normalisation of KPIs scores

Once the KPIs have been quantified, the scores have been normalised according to the procedure described above.

For each KPI, the magnitude considers the values assigned to the options as well as the realistic range of values that the KPI could potentially assume. These magnitudes are used to calculate the scaling factors according to the formulas outlined in paragraph 4.3 to ensure that the contribution of KPIs to the overall score is not affected by their different scale.

Note that the magnitude of the KPIs is one pre-defined element of the framework rather than a computational step that should be repeated any time the comparison of some options is made. The values exemplified in Table 4-3 are not necessarily the final ones; they might be revised in the light of the KPIs values for the delivery options that will be developed in the next steps of the project. However, the definition of these magnitudes is not part of the tasks required to the users of the assessment framework, who should just compute the normalised KPIs using the given magnitudes.

Table 4-3: Example: KPIs normalised

Indicator	Delivery option A score	Delivery option B score	Magnitude	Scaling factor	Normalised Score Deliv. Option A	Normalised Score Deliv. Option B
Delivery price	4.99	7	6	8.3	58.42	41.67
Choice of delivery date	0	2	1.5	33.3	0.00	66.67
Choice of delivery time slot	0	0	2	25.0	0.00	0.00
Choice of products consolidation	1	0	0.5	100.0	100.00	0.00
Choice of point of delivery	0	1	1	50.0	0.00	50.00
Choice of vehicle type	0	1	0.5	100.0	0.00	100.00
Delivery date	3.5	3.5	3	16.7	41.67	41.67
Delivery date punctuality	95%	90%	90%	55.6	52.78	50.00
Delivery time slot	10	5	6	8.3	16.67	58.33
Delivery time slot punctuality	97%	75%	70%	71.4	69.29	53.57
Products consolidation	100%	100%	50%	100.0	100.00	100.00
Point of delivery	1	3	1.5	33.3	33.33	100.00
Point of delivery - Share of deliveries	100%	100%	100%	50.0	50.00	50.00

Indicator	Delivery option A score	Delivery option B score	Magnitude	Scaling factor	Normalised Score Deliv. Option A	Normalised Score Deliv. Option B
Vehicle type	1	3	2	25.0	--	--
Vehicle type - Share of deliveries	50%	100%	100%	50.0	25.00	50.00
Tracking of shipment	2	2	1	50.0	100.00	100.00
Delivery reminder	3	3	1.5	33.3	100.00	100.00
Impact of purchase	0	0	1.5	33.3	0.00	0.00
Products safety	99%	95%	90%	55.6	55.00	52.78
Actual delivery	5%	5%	10%	500.0	75.00	75.00
Stock level	5%	5%	7.50%	666.66	66.67	66.67
Shops coordination system	1	1	2	25	75.00	75.00
Delivery optimisation system	1	1	0.5	100	100.00	100.00
Products handling protocols	2	3	1.5	33.33	66.67	100.00
Impact measurement process	3	3	1.5	33.33	100.00	100.00
Delivery vehicles - Total vehicles	1	10	5	10	90.00	0.00
Delivery vehicles by type and technology	0.52	0.85	1.62	30.76	16.15	26.15
Number of drivers - Total	1	10	5	10	90.00	0.00
Number of warehouses workers	200	200	200	0.25	50.00	50.00
Number or warehouses	2	2	2	25	50.00	50.00
Size of warehouses	30000	30000	25000	0.002	40.00	40.00
Warehouses organization and equipment	2	0.5	1	50	100.00	25.00
Warehouses location	20%	100%	50%	100	20.00	100.00
Streets accessibility - pedestrians	1%	1%	1.50%	3333.33	33.33	33.33

Indicator	Delivery option A score	Delivery option B score	Magnitude	Scaling factor	Normalised Score Deliv. Option A	Normalised Score Deliv. Option B
Streets accessibility – zero emissions	4.50%	4.50%	2.50%	2000	90.00	90.00
Parking lots	2.25	6	3	16.66	37.50	100.00
Micro-hubs	0	2	1	50	0.00	100.00
Vehicles load factor	70%	95%	50%	100.00	70.00	95.00
Travelled distance	100	45	50	1.00	0.00	55.00
Travelled distance by vehicle type	100	45	50	1.00	0.00	55.00
Shipments consolidation	200	25	150	0.33	66.67	8.33
Shipments consolidation by type of vehicle	200	50	100	0.50	100.00	25.00
Total delivery time	9	22	15	3.33	70.00	26.67
Total delivery time by vehicle type	8	20	15	3.33	73.33	33.33
Delivery production cost	4.69	6.58	5.5	9.09	57.36	40.18
Delivery production cost - Distribution and warehouse cost	75%	80%	50	1.00	99.25	99.20
GHG emissions	24.91	0	25	2.00	50.18	100.00
Pollutant emissions - PM	1	0	0.5	100.00	0.00	100.00
Pollutant emissions - NOx	16	0	8	6.25	0.00	100.00
Noise	70	20	35	1.43	0.00	71.43
Congestion	20	120	50	1.00	80.00	-20.00
Drivers labour conditions - Wage	10.80	9.62	10	5.00		
Drivers labour conditions - Working time	1.12	1.00	1.1	45.45	46.00	51.90
Drivers labour conditions - Workload	25	6	15	3.33	51.14	45.45

Indicator	Delivery option A score	Delivery option B score	Magnitude	Scaling factor	Normalised Score Deliv. Option A	Normalised Score Deliv. Option B
Logistic chains labour conditions - Wage	8.3%	7.4%	7.8	6.41	83.33	20.00
Logistic chains labour conditions - Working time	1.125	1	1.1	45.45	46.69	52.52
Logistic chains labour conditions - Workload	70	20	35	1.43	51.14	45.45

#### 4.5.4 Calculation of the aggregated score and comparison

Using the normalised scores, the final step of the evaluation process is the calculation of the aggregated scores, which allow the comparison of the alternative options. The aggregated scores have been obtained by applying to the normalised KPI values the weights generated by the Pairwise Comparisons performed across the four categories of stakeholders (see tables in section 5). As explained in the section 4.4, this procedure has generated one aggregated score for each attribute category relevant for each stakeholder group.

For the stakeholder group of consumers, two aggregated scores have been computed: one for the demand impacts and another for the social impacts (Table 4-4). According to both the impact categories, Option B results preferable to Option A.

For logistics operators and retailers separately, four aggregated scores have been generated: for the supply impacts, the context impacts, the private impacts, and the social impacts (Table 4-5 and Table 4-6). Unlike the case of consumers, these aggregated scores do not depict a unique ranking of the two options. Namely, for both logistics operators and retailers, Option A is preferable to Option B in terms of supply impacts and in terms of private impacts while Option B prevails regarding the context and the social impacts.

These differences illustrate one important feature of the assessment framework, i.e., the provision of results that explicitly highlight that different perspectives lead to different preferences either between different stakeholder groups or even within the same stakeholder group. This type of outcomes can help to consider potential variants of the option aimed at addressing the conflicts of interest or just to acknowledge that conflicts exist.

Finally, for local authorities, one aggregated score was produced related to social impacts (Table 4-7). As for consumers, Option B results as the preferable one.

Table 4-4: Options aggregated scores from the consumers' perspective

Demand side attributes	
Delivery option A	Delivery option B
46.88	59.49
Social impacts	
Delivery option A	Delivery option B
38.10	54.28

Table 4-5: Options aggregated scores from the logistics operators' perspective

Supply side attributes	
Delivery option A	Delivery option B
64.08	57.88
Context	
Delivery option A	Delivery option B
36.03	82.59
Private impacts	
Delivery option A	Delivery option B
59.47	52.69
Social impacts	
Delivery option A	Delivery option B
42.00	53.14

Table 4-6: Options aggregated scores from the retailers' perspective

Supply attributes	
Delivery option A	Delivery option B
66.82	56.32
Context	
Delivery option A	Delivery option B
38.77	84.35
Private impacts	
Delivery option A	Delivery option B
60.43	50.72
Social impacts	
Delivery option A	Delivery option B
38.87	48.93

Table 4-7: Options aggregated scores from the Public Authorities perspective

Social impacts	
Delivery option A	Delivery option B
37.12	53.07

The aggregated scores by impact category and stakeholder group are the main outcomes of the assessment framework as they depend on the preferences of the stakeholders as measured by the weights. As mentioned in section 4.4, these scores can be used to calculate a single aggregated score for each stakeholder group, This aggregation is not really informative when one option results preferable to the alternative ones according to all the impacts categories relevant for a given stakeholder group. It can be considered more useful when, as it happens in this example for logistics operators and retailers, the assessment of the options according to different categories of impacts diverges. The summary of the aggregated scores by category requires to assign a weight to each of the categories considered for one stakeholder. In the three following tables, the result of the computation of an overall score for the four is presented for the three stakeholder groups where an aggregated score is computed for more than one category of impact under the assumption that each category has equal weight. This assumption is purely demonstrative; one might think that e.g. for the logistics operators supply side is more relevant than context and reflect this assumption in the definition of weights.

Building on the aggregated scores computed above and under the assumption of equal importance of each category of impact, Table 4-9 and Table 4-10 show that also for logistics operators and retailers, Option B can be considered preferable to Option A.

Table 4-8: Consumer overall score

Consumer	
Delivery option A	Delivery option B
42.49	56.89

Table 4-9: Logistics operator overall score

Logistic operator	
Delivery option A	Delivery option B
50.40	60.82

Table 4-10: Retailer overall score

Retailer	
Delivery option A	Delivery option B
51.22	60.08

The last potential summary is the one where stakeholder groups' overall scores are further aggregated in one single value for each option. This synthesis could be considered in case the overall scores by stakeholder groups are diverging (e.g. for some groups one option is preferable, while for other groups the alternative is better). This step is particularly delicate as it imposes to assume a weight for each stakeholder group, which is obviously quite a strong assumption. In this example, option B is ranked higher for all groups; therefore, the aggregation is useless but, purely informative, Table 4-11 reports an overall score computed assuming that all the stakeholders have the same weight in the calculation.

Table 4-11: Overall score

Overall score	
Delivery option A	Delivery option B
45.31	57.72

## 5 CodeZERO pairwise comparison survey results

The relative importance of indicators and criteria within the assessment framework has been based on a Multi Criteria Analysis (MCA) involving consumers, retailers, transport operators, local authorities in jointly establishing the relative importance of evaluation criteria and indicators through an Analytic Hierarchy Process (AHP).

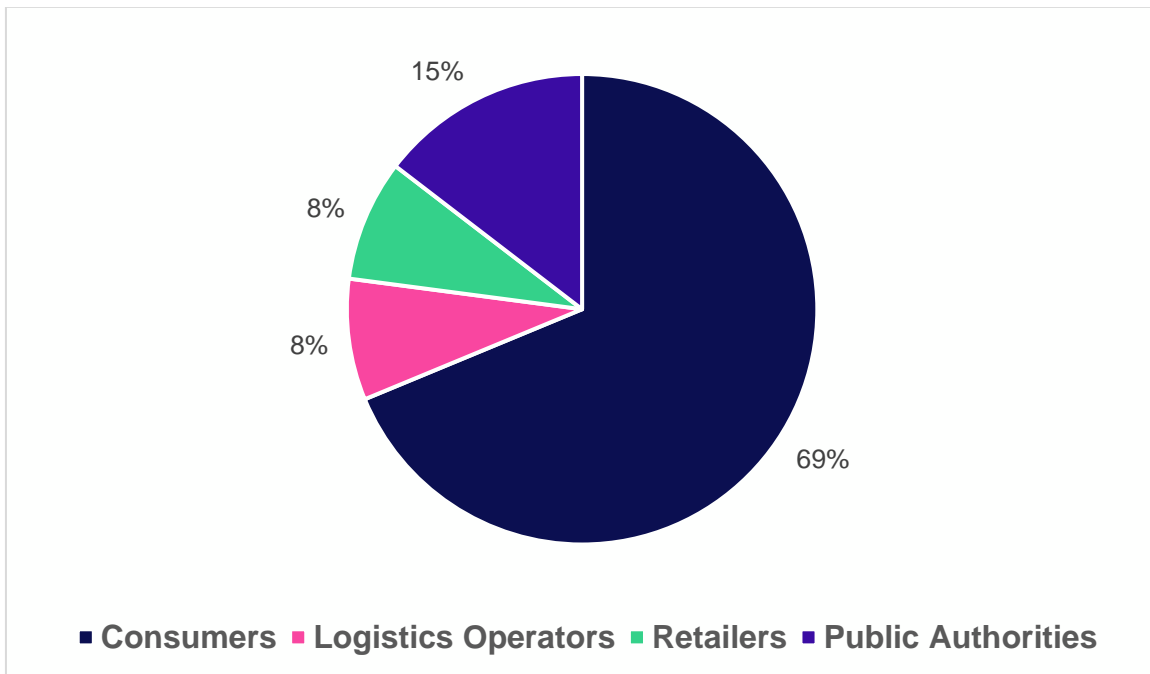
To this aim an on-line pairwise comparison survey was carried from 15 January to 15 February 2025 asking respondents to compare delivery attributes and evaluation criteria against each other in pairs (i.e. two alternatives at a time) to judge which of each entity is preferred by them.

The online survey was structured so that each stakeholder was asked to compare only the attributes relevant to their experience. Consumers compared “Demand-side Attributes” and “Social Impacts.” Logistics operators and retailers compared “Supply-side Attributes,” “Context Attributes,” “Private Impacts,” and “Social Impacts.” Finally, local authorities compared “Social Impacts”. The full list of the pairwise comparisons, distinguishing first level and second level (see section 4.2) is reported in the Annex.

The survey was conducted online using the Microsoft Forms platform. It was disseminated through various channels, including the CodeZERO newsletter, the project’s LinkedIn profile, and the LinkedIn profiles of consortium partners.

A total of 48 individuals completed the survey. The following figure shows the distribution of respondents among the various stakeholder groups.

Figure 8: Composition of respondents



In the following tables, weights obtained from the pairwise comparison survey performed in CodeZERO are reported for demand-side (Table 5-1) supply-side and context attributes (Table 5-2), private impact attributes (Table 5-3) and social impact attributes (Table 5-4).

Table 5-1: Demand-side attributes weights

SUB-CATEGORY	TYPE	ATTRIBUTE	Consumers
Purchase experience	Delivery price	Delivery price	0.063
	Flexibility	Choice of delivery date	0.062
		Choice of delivery time slot	0.062
		Choice of products consolidation	0.060
		Choice of point of delivery	0.078
		Choice of vehicle type	0.044
	Delivery time	Delivery date	0.053
		Delivery time slot	0.053
Delivery experience	Delivery time	Delivery date punctuality	0.035
		Delivery time slot punctuality	0.058
		Products consolidation	0.025
	Delivery method	Point of delivery	0.081
		Vehicle type	0.035
	Information	Delivery reminder	0.023
		Tracking of shipment	0.041
		Impact of purchase	0.044
	Reliability	Products safety	0.102
		Actual delivery	0.079

Table 5-2: Supply-side and context attributes weights

TYPE	ATTRIBUTE	Logistics operators	Retailers
<b>Service organisation</b>	Stock level	0.085	0.113
	Shops coordination system	0.077	0.087
	Delivery optimisation system	0.102	0.116
	Products handling protocols	0.071	0.071
<b>Impact measuring process</b>	Impact monitoring system	0.009	0.009
<b>Size and composition of the vehicle fleet</b>	Number of vehicles	0.057	0.083
	Composition of the fleet	0.090	0.052
<b>Workforce arrangement</b>	Number of drivers	0.097	0.073
	Number of warehouses workers	0.064	0.073
<b>Distribution network</b>	Number of warehouses	0.094	0.061
	Size of warehouses	0.060	0.083
	Warehouses equipment	0.092	0.088
	Warehouses' location	0.103	0.090
<b>Spatial context</b>	Streets accessibility	0.454	0.408
	Parking lots	0.214	0.363
	Micro-hubs	0.332	0.229

Table 5-3: Private impacts attributes weights

TYPE	ATTRIBUTE	Logistics operators	Retailers
<b>Service efficiency</b>	Vehicle load factor	0.217	0.204
	Distance travelled	0.169	0.153
	Shipments consolidation	0.187	0.222
	Total delivery time	0.199	0.191
	Delivery cost	0.229	0.229

Table 5-4: Social impacts attributes weights

TYPE	ATTRIBUTE	Consumers	Logistics operators	Retailers	Local authorities
<b>Environmental impacts</b>	CO2 emissions per delivery	0.168	0.217	0.140	0.177
	Polluting emissions per delivery	0.180	0.146	0.164	0.186
	Noise	0.101	0.111	0.115	0.116
<b>Transport impacts</b>	Congestion	0.094	0.159	0.153	0.137
	Irregular parking	0.107	0.072	0.107	0.109
<b>Labour impacts</b>	Fair salary	0.121	0.100	0.113	0.094
	Fair working time	0.107	0.101	0.116	0.090
	Sustainable workload for delivery personnel	0.120	0.093	0.092	0.091

## 6 Conclusions

Building on concepts presented and discussed in the CodeZERO deliverable D1.1, this deliverable presents the methodological framework for assessing the impacts of zero-emission delivery options. More specifically, the CodeZERO assessment framework is based on a Multi Criteria Analysis (MCA) and is designed to identify preferable options among alternative ones from the perspective of all stakeholders involved in last-mile e-commerce: consumers, e-tailers, logistics operator and local authorities.

Even if the assessment framework will be applied for comparing the delivery options of the pilot cases against comparable references, its scope is not limited to those options, nor it is limited to existing options. The framework is a general methodology that can be applied to potential options that can be described in terms of the attributes defined.

One major part of the work done to build the assessment framework has consisted of the definition of the Key Performance Indicators (KPIs) interpreting the attributes used for defining the delivery options. The KPIs are structured according to the analytical categories: demand, supply, spatial contexts and impacts.

The other major component of the assessment framework is the specification of the process for producing summary scores associated to each delivery option building on the values of the KPIs. As part of this process, the definition of the relative contribution of each KPI to the summary score is based on an Analytic Hierarchy Process (AHP). The results of the application of this process building on the responses obtained by means of a direct survey involving all categories of stakeholders are shown in this deliverable.

These two elements of the framework define the general method that can be applied case by case upon the quantification of the values of the KPIs for the options to be assessed. When the method is applied to existing options, several inputs can be derived from the observation/measurement of the delivery process. Inputs that cannot be directly measured can be defined by means of assumptions guided by expertise and experience. The same applies to all KPIs when the assessment framework is applied to theoretical options of this kind.

The deliverable provides an example of application of the assessment framework to two fictitious delivery options. The example shows that the assessment framework can highlight different preferences between stakeholder groups as well as within the same stakeholder group considering different categories of impacts.

In conclusion, the assessment framework represents a tool for comparing alternative delivery options considering the different types of impacts and the different perspectives of various stakeholders. The outcomes of the comparisons help summarising multiple judgements and identifying conflicting targets.

## 7 References

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## 8 Annex: Pairwise comparisons

### 8.1 Demand-side attributes pairwise comparisons

#### 8.1.1 First level (Comparison between attribute types)

##### 8.1.1.1 Purchase experience

Attribute type A	Attribute type B
Delivery price	Flexibility
Delivery price	Delivery time
Delivery price	Information
Flexibility	Delivery time
Flexibility	Information
Delivery time	Information

##### 8.1.1.2 Delivery experience

Attribute type A	Attribute type B
Delivery time	Delivery method
Delivery time	Reliability
Delivery time	Information
Delivery method	Reliability
Delivery method	Information
Reliability	Information

8.1.2 Second level (Comparison between attributes)<sup>7</sup>

8.1.2.1 Purchase experience - Flexibility

Attribute $k_A$	Attribute $j_A$
Choice of delivery date	Choice of delivery time slot
Choice of delivery date	Choice of products consolidation
Choice of delivery date	Choice of point of delivery
Choice of delivery date	Choice of vehicle type
Choice of delivery time slot	Choice of products consolidation
Choice of delivery time slot	Choice of point of delivery
Choice of delivery time slot	Choice of vehicle type
Choice of products consolidation	Choice of point of delivery
Choice of products consolidation	Choice of vehicle type
Choice of point of delivery	Choice of vehicle type

8.1.2.2 Purchase experience - Delivery time

Attribute $k_A$	Attribute $j_A$
Delivery date	Delivery time slot

8.1.2.3 Delivery experience - Delivery time

Attribute $k_A$	Attribute $j_A$
Delivery date punctuality	Delivery time slot punctuality
Delivery time slot punctuality	Products consolidation

<sup>7</sup> The attribute type “delivery price” and the attribute type “information” (under the purchase experience) correspond to one indicator; therefore, for both there are not pairwise comparisons at the second level of the sequence

#### 8.1.2.4 Delivery experience - Delivery method

Attribute $k_A$	Attribute $j_A$
Point of delivery	Vehicle type

#### 8.1.2.5 Delivery experience - Reliability

Attribute $k_A$	Attribute $j_A$
Products safety	Actual delivery

#### 8.1.2.6 Delivery experience - Information

Attribute $k_A$	Attribute $j_A$
Tracking of shipment	Delivery reminder

## 8.2 Supply-side and context attributes pairwise comparisons

### 8.2.1 First level (Comparison between attribute types)

Attribute type A	Attribute type B
Service organisation	Size and composition of the vehicle fleet
Service organisation	Distribution network
Service organisation	Workforce arrangement
Service organisation	Impact monitoring system
Service organisation	Delivery context
Size and composition of the vehicle fleet	Distribution network
Size and composition of the vehicle fleet	Workforce arrangement
Size and composition of the vehicle fleet	Impact monitoring system
Size and composition of the vehicle fleet	Delivery context
Distribution network	Workforce arrangement
Distribution network	Impact monitoring system
Distribution network	Delivery context
Workforce arrangement	Impact monitoring system
Workforce arrangement	Delivery context
Impact monitoring system	Delivery context

8.2.2 Second level (Comparison between attributes)<sup>8</sup>

8.2.2.1 Service organisation

Attribute $k_A$	Attribute $j_A$
Stock level	Shops coordination system
Stock level	Deliveries optimisation system
Stock level	Product handling protocol
Shops coordination system	Deliveries optimisation system
Shops coordination system	Product handling protocol
Deliveries optimisation system	Product handling protocol

8.2.2.2 Size and composition of the vehicle fleet

Attribute $k_A$	Attribute $j_A$
Number of vehicles	Composition of the fleet

8.2.2.3 Distribution network

Attribute $k_A$	Attribute $j_A$
Number of warehouses	Size of warehouses
Number of warehouses	Warehouses' location
Number of warehouses	Warehouses equipment
Size of warehouses	Warehouses' location
Size of warehouses	Warehouses equipment
Warehouses' location	Warehouses equipment

<sup>8</sup> The attribute type "Impact monitoring system" corresponds to one indicator; therefore, there are not pairwise comparisons at the second level of the sequence.

8.2.2.4 Workforce arrangement

Attribute $k_A$	Attribute $j_A$
Number of drivers	Number of warehouses workers

8.2.2.5 Delivery context

Attribute $k_A$	Attribute $j_A$
Streets accessibility	Dedicated parking lots
Streets accessibility	Micro-hubs
Dedicated parking lots	Micro-hubs
Dedicated parking lots	CCAM available paths
Dedicated parking lots	Drones flight permits
Micro-hubs	CCAM available paths

### 8.3 Impact attributes pairwise comparisons

#### 8.3.1 First level (Comparison between attribute types)

Attribute type A	Attribute type B
Service efficiency	Transport impacts
Service efficiency	Environmental impacts
Service efficiency	Labour impacts
Transport impacts	Environmental impacts
Transport impacts	Labour impacts
Environmental impacts	Labour impacts

#### 8.3.2 Second level (Comparison between attributes)

##### 8.3.2.1 Service efficiency

Attribute $k_A$	Attribute $j_A$
Vehicle load factor	Distance travelled
Vehicle load factor	Shipments consolidation
Vehicle load factor	Delivery cost
Distance travelled	Shipments consolidation
Distance travelled	Delivery cost
Shipments consolidation	Delivery cost

##### 8.3.2.2 Transport impacts

Attribute $k_A$	Attribute $j_A$
Congestion	Irregular parking

8.3.2.3 Environmental impact

Attribute k <sub>A</sub>	Attribute j <sub>A</sub>
Average quantity of CO2 emissions per delivery	Average quantity of polluting emissions <sup>9</sup> per delivery
Average quantity of CO2 emissions per delivery	Noise
Average quantity of polluting emissions per delivery	Noise

8.3.2.4 Labour impacts<sup>10</sup>

Attribute k <sub>A</sub>	Attribute j <sub>A</sub>
Fair salary	Fair working time
Fair salary	Sustainable workload
Fair working time	Sustainable workload

---

<sup>9</sup> There are two KPIs associated to polluting emissions (NOx and PM), but since they are very correlated to each other, the pairwise comparisons refer to the attribute “polluting emissions as a whole”.

<sup>10</sup> There are different KPIs associated to the same attribute. Since they are not necessarily correlated to each other, the pairwise comparisons refer to the KPIs rather than to the attributes. At the same time, in the pairwise comparisons it is not necessary to distinguish KPIs related to drivers and the same KPI related to logistic workers (e.g. wage).