# IMPACTS OF EXISTING DELIVERY MODELS AND OPTIONS

## Project deliverable 1.2

***Version number: V1***

***Date for release: 31/01/2025***

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This project has received funding from the European union's Horizon Europe research and innovation programme under grant agreement Nr. 101146909.

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# Deliverable administrative information

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<tr><td>Deliverable no.</td><td>1.2</td><td>Name</td><td colspan="5">Co-Design Of E-Commerce Last-Mile Delivery and Return Options With Zero-Emissions</td></tr>
<tr><td>Status</td><td>Final</td><td>Due</td><td>31/01/2025</td><td>Date</td><td colspan="3">29/01/2025</td></tr>
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<tr><td>Dissemination level</td><td colspan="7">PU</td></tr>
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# List of abbreviations and acronyms

| Acronym | Meaning |
|---|---|
| 3PL | Third party logistics provider |
| AMAT | Agenzia Mobilità Ambiente e Territorio Srl (Milan) |
| ANTWERP | Stad Antwerpen |
| BPOST | bpost |
| CDC | Customer Distribution Centre |
| DC | Distribution centre |
| EUC | Eurocities Asbl |
| GA | Grant Agreement |
| IKEA IT | IKEA Italia Retail Srl |
| IKEA NO | IKEA As |
| IPR | Intellectual Property Rights |
| JUMBO | Jumbo Supermarkten Bv |
| KER | Key Exploitable Result |
| LCV | Light Commercial Vehicle (van) |
| LEFV | Light Electric Freight Vehicle |
| OSLO | Oslo Kommune |
| RIAB | Research and Innovation Advisory Board |
| SODE | Magma Srl Impresa Sociale |
| TNO | Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek |
| TOI | Transportøkonomisk Institutt |
| TORFS | Torfs |
| TRT | TRT Trasporti e Territorio Srl |
| UTRECHT | Gemeente Utrecht |
| vkt | Vehicle kilometers travelled |
| VUB | Vrije Universiteit Brussel |

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## Copyright Statement

# Abstract

**Delivery options** are the possibilities that consumers have at their disposal when ordering goods (online), whereas **delivery models** are different configurations of transport and logistics activities needed to physically transport a product from a retailer to the customer (or to a pick-up point).

E-commerce delivery models and returns are highly diverse, as well as delivery options presented to customers when ordering goods. Behind different delivery options, there are different delivery models to fulfil the order and transport it to the customer. Delivery models get shape in a distribution network in which (transshipment and/or cross-dock) facilities and transportation modes are the primary aspects.

Different delivery models have varying impacts upon the various impact areas. As already elaborated in D1.1, e-commerce delivery models – and the organization of last-mile transport – are shaped by four key aspects: the type of product, the available delivery options and related customer preferences (demand side), the physical context and its regulations, and the transportation capabilities (supply side). Decisions on those four aspects shape a delivery model of a specific context in a geographical area. By changing some of these aspects, delivery models and hence their impact can be altered.

Released within WP1 'Impacts of existing delivery models and options' of the CodeZERO Horizon Europe research project, this deliverable presents a taxonomy that illustrates the baseline to shape delivery models and provide an analysis of the impact of the current delivery models in the four CodeZERO pilot cities (Milan, Antwerp, Utrecht and Oslo). Furthermore, this work starts setting the basis for the co-design workshops in WP4 and the impact assessment of the pilots.

**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.

Central to CodeZERO are four pilots in four different European cities in Italy, Netherlands, Belgium, and Norway to test a set of sustainable solutions, identified within the project, with the aim of determining their feasibility, fine-tune their design and assess their impacts from the perspective of all relevant stakeholders.

This CodeZERO report 'Impacts of existing delivery options and models' consists of:

- A **taxonomy** of different delivery options and models for e-commerce deliveries and returns that can be used as framework to configure the delivery model depending on attributes related to different (e-commerce) **products**, **check-out options**, **distribution structure** and **transport services**.
- A definition of the current delivery options and models of the CodeZERO retailer partners in the four pilot-cities. The taxonomy was used to collaboratively define the current delivery models during interviews with the parties from the four cities.
- An **impact assessment** of the delivery options and models of the four retailers.

There are significant differences in the delivery models that can primarily be traced back to the differences in type of products, customer requirements, transportation capabilities, and the physical and policy context (i.e. dense areas, emission requirements). There is also a distinction between transport on own account that consolidates the deliveries within the organisation, and outsourced deliveries where deliveries of different shippers are consolidated. Vehicle types also vary from small trucks for two-person deliveries to cargo bikes for parcel deliveries. In most cases, light commercial vehicles, sometimes electric, are deployed. Delivery addresses are mostly customers' homes, but certain models further provide options for pick-up points. Depending on the type of products (i.e. size) and delivery options offered, some retailers have multiple delivery models.

The impact assessment shows the impact of deliveries with regard to distance driven (in total, per trip and between stops), drop density (number of items per delivery), $CO_2$ emissions, duration and dwell time per stop. The latter is longest in case of e-groceries and furniture, especially compared to parcels. Two retailers outsource deliveries to a 3PL (third party logistics provider), which makes it difficult to isolate the impact of specific deliveries by the retailers. In this case, a description of the potential impact has been added. The taxonomy in this deliverable serves as input for the co-design workshops in WP4 and the impact assessment of the pilots.

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

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# 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 how they are shaped by the needs and constraints of all involved stakeholders; (2) an in-depth intersectional analysis of various groups of online 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

This deliverable provides an analysis of current **e-commerce delivery models and options**. Delivery models are different configurations of transport and logistics activities needed to physically transport a product from a retailer to the customer (or to a pick-up point). There are many different possibilities, or configurations possible here. Different choices can be made regarding the vehicle type, transshipment locations, delivery locations, facilities, drop-off points, and so on. These choices depend upon different so-called 'delivery attributes' (see CodeZERO Deliverable 1.1). Based upon these attributes, different configurations of delivery models result in different impact on costs, physical environment, climate, delivery personnel wellbeing, etc. Eventually a configuration can be organized in such a way that the negative effects on different impact areas can be minimized.

This deliverable focuses on the e-commerce delivery models (and associated options) and their impact upon the environment. To that end a taxonomy (a visual representation) of different delivery options and models for various use cases is formulated. This taxonomy is used, in combination with data from each of the partners, to describe and analyse the impact of the current delivery models. The analysis aims to provide an initial assessment of the impact of the delivery model on costs, the physical environment and social contexts.

Released within 'WP1 Analysis of current delivery models', this deliverable illustrates:

- The work performed in task 1.2 on the development of a taxonomy of different delivery options and models for e-commerce deliveries and returns.
- A determination of the delivery models currently applied by CodeZERO online retailers in the four pilot cities.
- A preliminary impact assessment of these delivery models.

The document is structured as follows:

- Chapter 2 provides a brief description of the methodology to develop the taxonomy and assess the impact of current delivery models in the four cities,
- Chapter 3 illustrates the conceptual approach underpinning the taxonomy,
- Chapter 4 presents the taxonomy of delivery models,
- Chapter 5 shows the current delivery models of the online retailers in the four cities,
- Chapter 6 presents the impact of the delivery models of the online retailers currently.

Annexes are provided to complement the report by illustrating the key findings from desk and field research.

# 2 Methodology

The development of a taxonomy to analyse delivery models and options is based on a two-steps approach. First, the taxonomy is developed and validated. In a second step, delivery models of CodeZERO retailer partners are analysed using this taxonomy and an initial impact assessment is conducted.

## 2.1 Taxonomy development and validation

To develop a taxonomy of delivery models, desk research is conducted in combination with expert judgement. The taxonomy is used to outline the different choices that can be made within delivery models. By illustrating different choices at each step of the taxonomy, this approach outlines the delivery model for a given configuration. The different components of this taxonomy are elaborated in Chapter 3 and the taxonomy itself is presented in Chapter 4.

Subsequently, this taxonomy was presented to CodeZERO online retailers and transport operators during separate interviews. Based on these interviews the delivery models of the respective online retailers in the four pilot areas are defined.

This definition of the delivery models functions as the baseline showing how the online retailers currently organise the transportation of their respective goods to customers. Additionally, this definition acts as a point of reference from which the pilots in 2025 will be developed in WP4.

## 2.2 Impact assessment

After the definition of the delivery models, key transport data for an average week or month for the four pilot areas were collected and analysed. These data include:

- Location of the regional DC where products are picked
- Vehicle types in terms of size and technology
- Number of trips (per delivery round)
- Number of deliveries per trip
- Length of trips (distance driven)
- Delivery locations (or addresses)
- Number of items per delivery (drop size)
- Duration of the trip
- Stop time per delivery
- Access regulations or constraints of the delivery area

The descriptive analysis of the data provides an overview of the delivery characteristics in each of the four pilot areas. It uses available information on trips and stops to illustrate the delivery pattern for each pilot partner. By linking vehicle kilometres and vehicle type to emission factors, the analysis calculates assumed emissions for the different delivery flows in the delivery area. The emission calculations are based on the following assumptions: each average distance per trip includes one cold start; all vans are from 2022 or newer; and the driven kilometres are 70% in cities, 10% on country roads and 20% on highways.

# 3 Overview elements taxonomy

This chapter discusses the essential elements that make up the taxonomy of delivery models and options. It elaborates on how these elements relate to one another and describes the potential future use case of the taxonomy.

## 3.1 Different e-commerce flows

One's image of e-commerce mostly equates to parcel deliveries to individual households (see for instance the topic of most research articles such as Morganti et al., 2014).

Even though parcels can contain different types of goods, these are mostly considered to be non-perishable (retail) goods such as fashion and electronics. That being said, the diversity of e-tailers and types of goods ordered online extends beyond this, further exacerbated since the COVID19-pandemic. Based on products characteristics, different transportation possibilities potentially apply. First, there are **digital products** such as eBooks and videogames for which no transport is required. Secondly, when focusing on physical products, there are roughly two product groups with different sub-groups having different transport requirements:

- **Perishable and time-critical goods**:
    - **Instant meals and groceries** that often have a short lead time ('**quick commerce'**), are transported locally and light (electric) freight vehicles (LEFVs[1]) such as e-(cargo)bikes and scooters are mostly used (e.g. Deliveroo) (Allen et al., 2021; Buldeo Rai et al., 2023; Peppel et al., 2022)
    - **Meals** with longer lead times that often come in boxes with recipes and pre-portioned ingredients and are transported in light commercial vehicles (e.g. Hellofresh) (Dablanc et al., 2017)
    - **E-groceries** that generally have longer lead times than instant meals, are larger in volume, and mostly are delivered in crates by light commercial vehicles (e.g. Jumbo) (Bjørgen et al., 2021; Kumar & Chidambara, 2024; Peppel et al., 2022)
    - **Medicines** that are potentially (highly) time-critical and expensive, whose transport is either local (from a pharmacy) or from a wholesaler (Zubin et al., 2020).
- **Non-perishable and not (always) time-critical goods**
    - **Retail goods** that are sent as **letter-box packages**, which can be delivered unattended through the mailbox. Whether it is sent as a letter-box package depends mostly upon the size and weight of the product(s), the transport company that is responsible (e.g., bpost) and the value of the good. Deliveries are mostly done by bike or LEFVs.
    - **Retail goods** that are sent as **parcels**, which often contain similar products as letter-box packages but are larger in size, weight and/or require a signature because of their value (attended delivery). These goods are increasingly delivered to pick-up points. Deliveries are often done by LEFVs or LCVs (Allen et al., 2018; Halldórsson & Wehner, 2020)
    - **Retail goods** that must be transported in **large packages with non-regular sizes** (e.g. a bike). Those distinguish themselves from parcels by their weight and/or size, which

[1] LEFVs can be roughly defined as freight vehicles smaller than a van with a maximum capacity of 750kg, and can be again divided into cargo cycles, electric mopeds, and other L-category vehicles such as microvans and quadricycles (van Amstel et al. 2018)

has its limitations as deliveries can often not go to a pick-up points and require at least a LCV (Perboli & Rosano, 2019), (Mangiaracina et al., 2019).

- **Two-person deliveries of retail goods** (e.g. furniture) with goods exceeding the weight and/or size that can be handled by one person (the driver). At least a LCV and sometimes trucks are used. In most cases goods are delivered behind the front door (Lauenstein & Schank, 2022).

The majority of products sold online can be grouped into these eight different e-commerce flows: **books and media** (digital or as parcels), **clothes and shoes** (mostly parcels), **cosmetics and beauty** (mostly as parcels, sometimes as or together with medicines), **health and wellness** (mostly as parcels, sometimes as or together with medicines), **electronics** (digital or as parcels), **household items** (parcels, large packages or two-person deliveries), **pet care** (parcels or large packages), **and food and beverage** (all perishable and time-critical types). Shipments are usually sent by a retailer before they get sent by the retailer itself or by a 3PL. In some cases, goods are sent by individuals (e.g. Ebay). The focus in this deliverable is on goods sent by a **retailer** after an online order.

## 3.2 Delivery options

Delivery options are the possibilities that consumers have at their disposal when ordering goods (online). These options vary per retailer, per e-commerce flow (or product type), per location of the consumer (or spatial context) and even per consumer in the same postal code area. With regard to the latter, there might be different options offered to consumers that order similar products from the same retailer based on their ordering behaviour or loyalty programs (Buldeo Rai, 2019). CodeZERO D1.1 elaborates on the attributes that shape delivery options from both the **demand-side** (including product type and customer type) and the **supply-side** (including product type and retailer).

## 3.3 Delivery models

Delivery models are different configurations of transport and logistics activities needed to fulfil a delivery option to physically transport a product from a retailer to a customer (or a pick-up point). This mostly comes down to the **design of the distribution network** or **last mile fulfilment strategies** along two main aspects (Halldórsson & Wehner, 2020; Janjevic & Winkenbach, 2020; Kin et al., 2018; Onstein et al., 2021; Rodrigue, 2020):

- **Logistics facilities**: different types of facilities with different functions and varying sizes (e.g., inventory, picking, transshipment, etc.) that together can form a multi-echelon network. This includes attended and unattended pick-up points (e.g. parcel lockers) where customers can pick-up or return their products (see Figure 1 for examples of logistic facilities).
- **Transportation modes:** different transportation modes or vehicle types are deployed for the last mile. In case there is a multi-echelon network, facilities often also function as a cross-dock locations where goods are mostly transhipped to smaller vehicles.

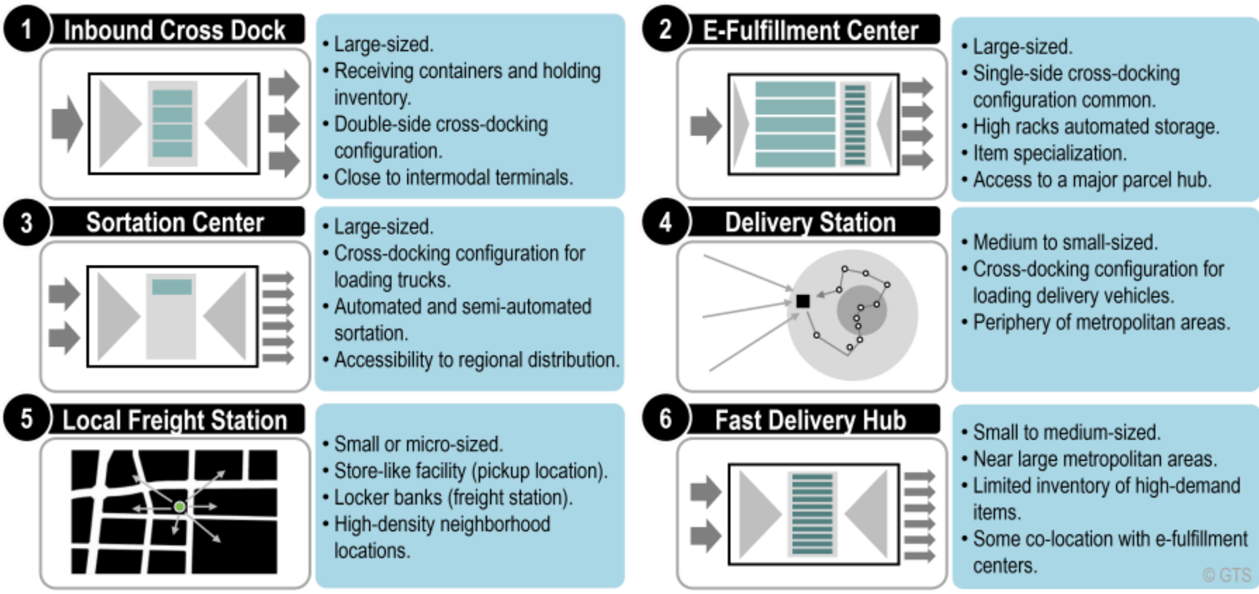


*Figure 1. Logistics facilities supporting e-commerce (Rodrigue, 2020)*

Delivery models, or design of the last mile distribution network including the type and number of facilities and choice of transportation modes, are shaped by three main constraints (based on Halldórsson & Wehner, 2020; Kin et al., 2018):

- The **delivery options**, which can be translated as constraints to the customer and reflecting his/her preference for specific delivery attributes. One exemplary attribute is the width of the delivery time window.
- The **physical environment** in which the transport to the customer takes place. This includes (access) regulations that (local) authorities implement. The zero-emission zone is an example.
- The **transportation capabilities** including the network of distribution centres and available vehicles. This refers to either the retailer transporting on own account or a 3PL.

A retailer or 3PL can have multiple delivery models, even in the same region. A possibility is, for instance, the use of a mixed fleet, in which larger conventional diesel vehicles are deployed in suburban and more rural areas, whereas smaller electric freight vehicles deliver in dense areas and low/zero emission zones. In terms of logistics facilities, a transition from single- to multi-echelon networks appears. Furthermore, a diversification in the size and type of facilities emerges. In addition to the more traditional facilities with storage and cross-dock as main functions, stores increasingly come to function as facilities from where goods are shipped (Arslan et al., 2021; Hübner et al., 2016). E-commerce deliveries (and returns) are not necessarily all the way to (and from) the customers' doorstep as different types of collection points are also introduced in urban areas. Figure 2 illustrates the manyfold options for the distribution network in e-commerce, including varying facilities and transportation modes.

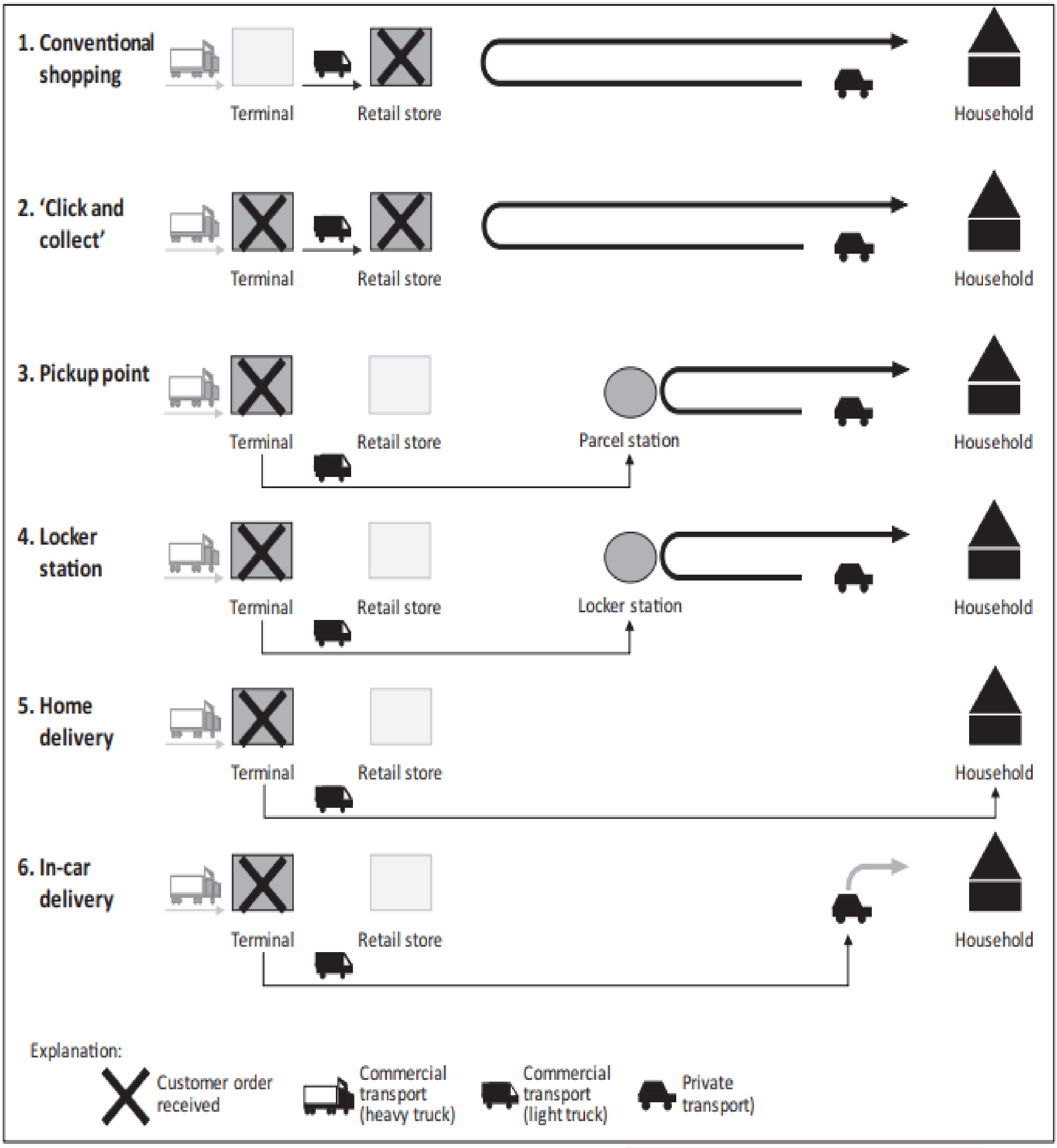


*Figure 2. Overview of last mile fulfilment options in e-commerce (Halldórsson & Wehner, 2020)*

# 4 Taxonomy

As discussed in Chapter 2, a taxonomy (see Annex I) was developed as a framework to sketch the different delivery models of the CodeZERO industry partners. This taxonomy can be used to configure the delivery model according to the different attributes, including the impact it has on the environment it operates in (see D1.1). Due to the complexity and variety of all possible delivery models that can be defined, it was chosen to divide the taxonomy into different sections (largely based on literature mentioned in section 3). These sections were defined in the sequence of actions that are taken to order and deliver a product. The taxonomy was therefore divided into the following sections:

**Products**

This section of the taxonomy refers to the type of items delivered by the delivery chain under examination. Products are categorized into non-perishable and perishable items (see section 3.1). In the context of this research, the focus is mainly on e-groceries, letter-box packages, retail (parcels), large packages and two-person deliveries.

**Check-out options**

The check-out options describe all possible choices that a customer can make when ordering a product from a retailer. One example is the choice of delivery time, which can encompass both the choice of day and time of day. Both of these options can either be given for the customer to choose, through the use of delivery windows, or left up to the 3PL to decide (Buldeo Rai et al., 2019; Klein & Popp, 2022). Additionally, there are numerous options for delivery locations, both attended and unattended, such as at home (Halldórsson & Wehner, 2020), in a parcel locker (Janjevic & Winkenbach, 2020) or at a service point (Allen et al., 2018). Various pilot programs have also explored alternative unattended delivery methods like in-fridge[2] (Buldeo Rai et al., 2021) or deliveries in the trunk of your car (Mangiaracina et al., 2019). The third option, often influenced by supply-side attributes, is the pricing of the delivery, which can be free, based on a minimum purchase price, part of a loyalty programme or determined by other customer characteristics (Allen et al., 2018; Buldeo Rai et al., 2019).

**Distribution structure**

The distribution structure in the taxonomy refers to the choices that are primarily made by the supplier to distribute their products. Firstly, this involves the sourcing of the product, which can be done either at an e-fulfilment centre, local fulfilment centre or at a store (Janjevic & Winkenbach, 2020). To consolidate deliveries for last-mile transportation, the sourced goods can then be transhipped at either a regional or urban levels, or even at mobile warehouses and depots (Janjevic & Winkenbach, 2020; Olsson et al., 2019). Transshipment further offers several consolidation options: products can be combined within the same delivery structure or company, or consolidated at the delivery flow level, meaning deliveries from multiple suppliers are combined. Additionally, vehicle access restrictions in cities, such as zero/low-emission zones, time-based vehicle restrictions, or weight regulations, further shape the distribution structure (Janjevic & Winkenbach, 2020).

**Transport service**

Choices in transport service are the last aspect to consider. These include decisions about the transport operator, which can be managed by the supplier themselves or outsourced to third parties including parcel couriers, postal companies, or 3PL (Ignat & Chankov, 2020; Janjevic & Winkenbach, 2020).

[2] This method involves the delivery company delivering goods in a fridge that is located outside the house of the customer.

Additionally, there are choices regarding the type of vehicles used for last-mile delivery. Common options here include LCVs (or vans), trucks and cargo bikes, but innovative methods like delivery by public transportation, drones and other LEFVs are also being piloted and are increasingly present in delivery structures (Buldeo Rai et al., 2019; Janjevic & Winkenbach, 2020; Kaplan & Heaslip, 2024; Peppel et al., 2022). These vehicles vary in fuel type, further impacting their sustainability. Lastly, there are different types of tracking options for the last-mile delivery and if a pickup option is provided to customers, there are choices within the vehicle they may choose to pick up these orders, significantly affecting the sustainability of the delivery (Halldórsson & Wehner, 2020).

# 5 Current delivery models

In this section, the delivery models of CodeZERO partners are visualized and described including comments that were mentioned during the interview.

## 5.1 Jumbo (Utrecht)

Jumbo is one of the biggest grocery shop chains in the Netherlands with 725 stores throughout the Netherlands in 2023. Since previous years, Jumbo is increasingly moving towards providing home-delivery services for their customers.

Grocery deliveries are done by Jumbo to both individual households and businesses. The home delivery network of Jumbo in the Netherlands consists of 700 LCVs (< 3.5 - 4.25 tonnes) and 19 delivery hubs out of which three are integrated in larger fulfilment centres. The company has the goal to electrify 80% of the fleet in the coming five years (until 2029). A gravity model is used to determine the delivery model for the region of each hub, which comes down to planning the routes in different parts of that region. This is done by estimating the potential sales per zip code (based on the composition of the population) and the (logistics) costs.

Based upon different variables, including the density of customers in an area and the order frequency per customer, customers can choose different time slots and delivery dates. If available, next day deliveries are also possible. Deliveries are conducted until the front door, also for apartment buildings. Pricing also depends on different variables (see Figure 3).

The area of Utrecht is served from the Jumbo hub in Nieuwegein Ravenswade, an industrial area close to Utrecht (see Figure 4). In certain parts of the region, access restrictions apply. This is primarily the case in the inner-city of Utrecht. Next to home or work deliveries, customers are provided the option to order their groceries online and pick them up at one of 300 designated pick-up points at Jumbo stores (nationally).

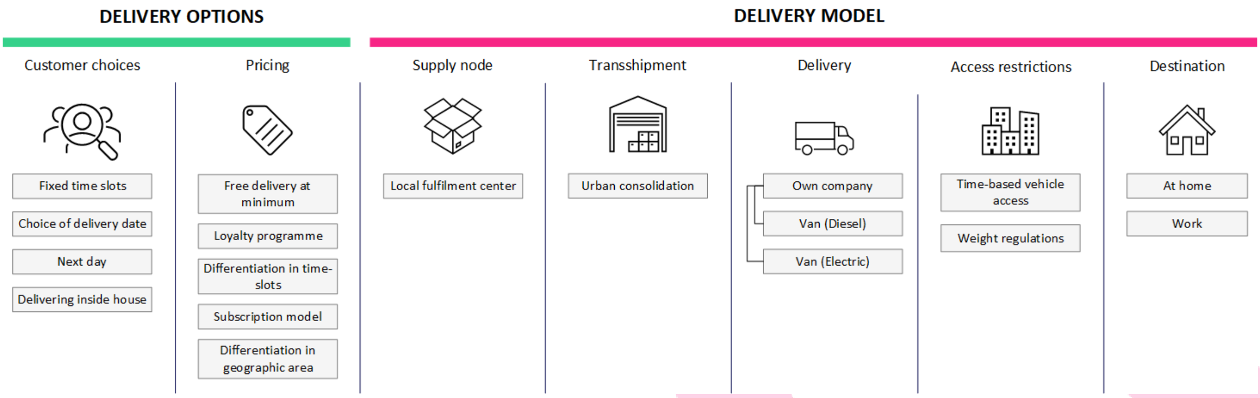


*Figure 3. Illustration of the Jumbo delivery model*

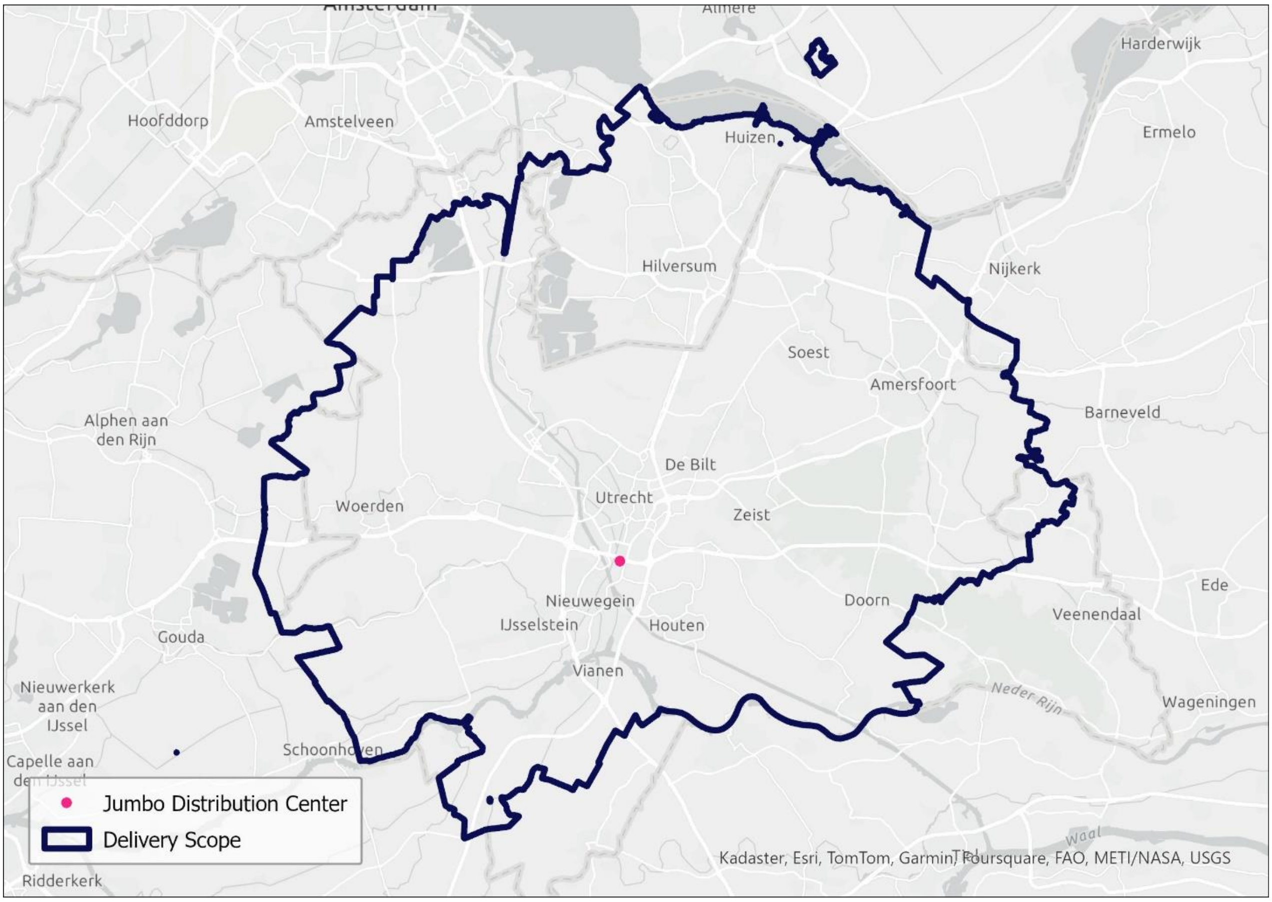


*Figure 4. Size of the delivery area for Jumbo in the Utrecht region*

## 5.2 IKEA (Oslo)

As a big retail for furniture and household articles, IKEA has seven stores in Norway, each of them also used as shipping point. The main distribution centre is in Sweden. Furthermore, there are seven plan-and-order points (with only sales of customer orders and no stock keeping) in Norway. In the Oslo region there are two full IKEA stores and one additional city centre store with limited stock of smaller items.

IKEA has three distinctive delivery models to deliver products (offline in store and ordered) to their customers. Firstly, a distinction is made between '**light' orders** (up to 35 kilograms) and more bulky and **heavier orders**.

**Lighter orders** are being picked and shipped by a 3PL and distributed in an open network in combination with products from other shippers. In this network, direct home deliveries (both attended and unattended) as well as deliveries to pick-up points (either manned pick-up points or parcel lockers) are possible (see Figure 5).

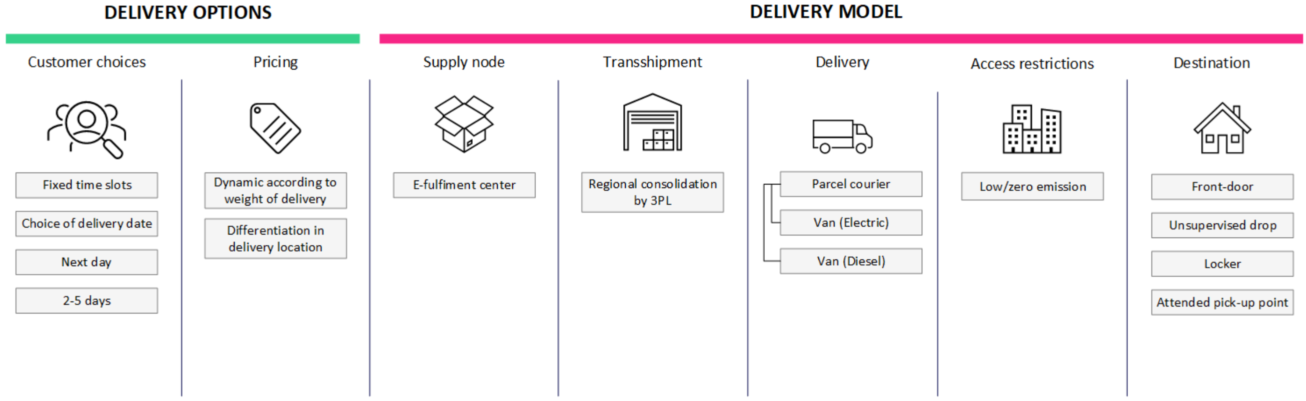


*Figure 5. Illustration of the IKEA Norway (light parcel) delivery system*

For **heavier goods**, two delivery models are applied based on the assortment and the location where the products are stored – either in store or in the central DC in Sweden.

A part of the assortment is picked and packed in stores. IKEA plans the routes and buys transportation capacity from a 3PL. During planning, a distinction – to the possible extent – is made between smaller orders than can be delivered by one person and bigger orders for which two persons are required. The difference is based on two aspects: the number of items (possible to carry) and the size of the total order (number of items and volume). Delivery rounds are dedicated to IKEA products only. Customers can select two options for the delivery: delivery on the curb side or inside the building. Drivers do not install any furniture, but a handyman can be requested for assembly or installation the next day. This process is detached from the delivery options (Figure 6). This delivery model is the focus in CodeZERO.

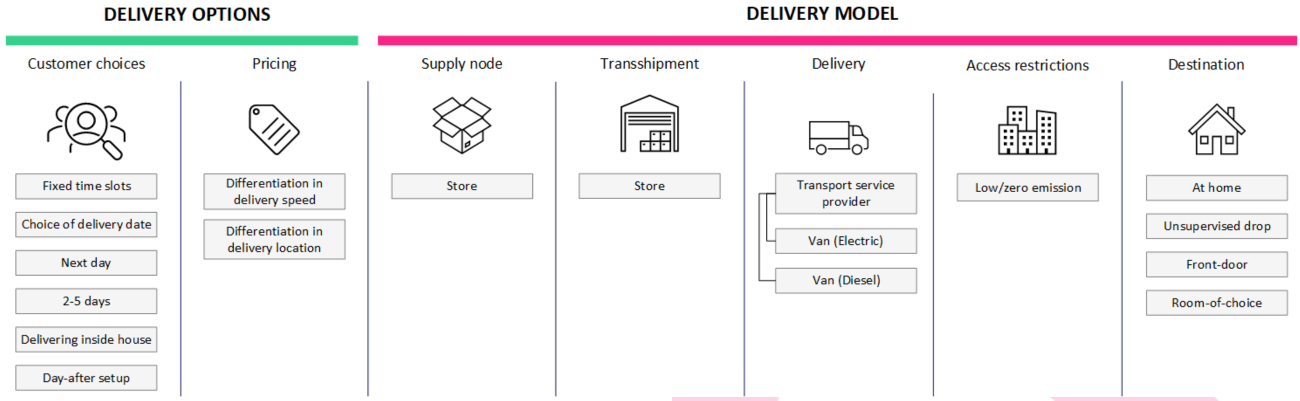


*Figure 6. Illustration of the IKEA Norway (large packages) delivery system*

The lead time for these deliveries is generally shorter than for other ‘heavier’ products in the assortment in the central DC in Sweden, to which another delivery model applies. In case of the latter, products are shipped by train from the distribution centre in Sweden to one of the 35 fulfilment centres of a 3PL in Norway. This 3PL subsequently transports the products to the customers, mixing the IKEA shipments with deliveries from other shippers (see Figure 7).

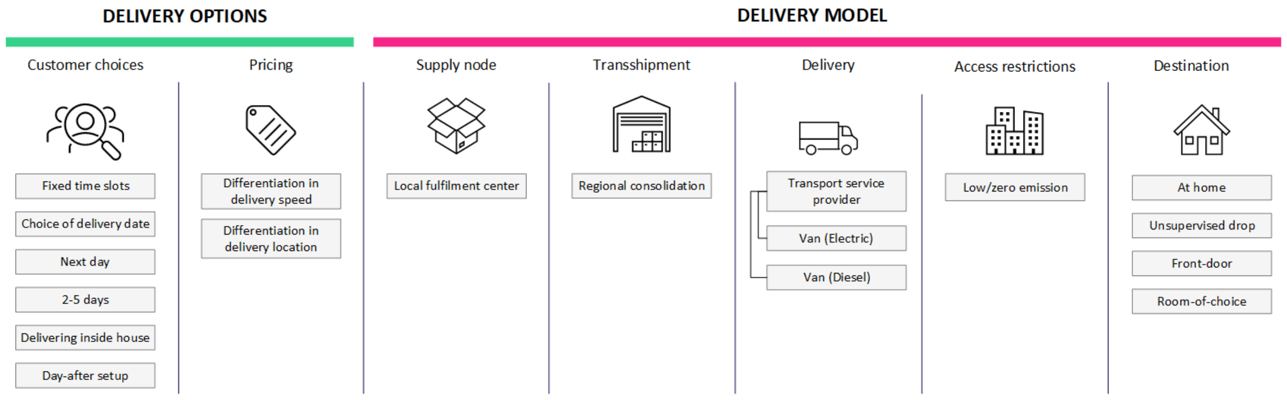


*Figure 7. Illustration of the IKEA Norway (large packages) delivery system with shipments from Sweden*

As part of their zero-emission agenda, a collaboration with 3PL's for deploying electric vehicles on the last-mile is in place. In the model with the lighter goods or shipments from Sweden there is less influence on the modal choice, as the 3PL will determine which vehicle is used for delivery. The main vehicles used are LCVs with a gross weight of 3.5 tonnes, which is being increased to 4.25 tonnes for electric vehicles requiring a B driver license in line with EU regulations.

Customers generally have two pricing options. Prices are distinguished between curb side or in-room deliveries and an additional fee can be paid for express delivery. For deliveries after 36 hours, the customer is further provided an option with timeslots. At some stores, customers can use cargobikes to transport the goods home, which have to be returned back to the store after use. Figure 8 shows the size of the Oslo delivery area.

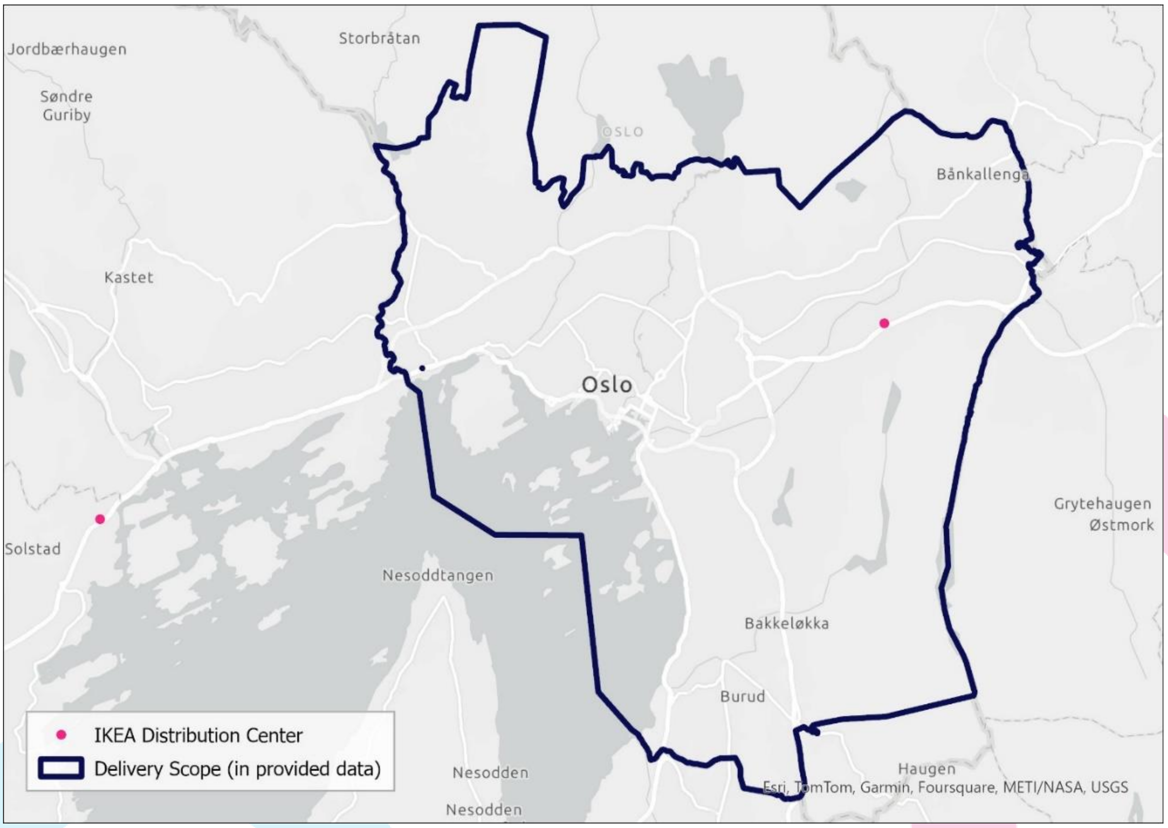


*Figure 8. Oslo delivery area for Ikea*

## 5.3 Torfs/Bpost (Antwerp)

Torfs is a retailer that sells shoes in Belgium both from physical stores and online. 25% of the online sales are made from a screen within a physical store. For the distribution of goods, Torfs utilizes the logistical network of Bpost, the national postal service provider in Belgium. For e-commerce, roughly one delivery model is used with differences in point of departure, delivery location and vehicle type.

When a customer places an order, it is picked up from the central DC in preparation for a pick-up by Bpost. Torfs optimises its storage, which means that items that are not in stock in the DC might be present in a store. In that case these are shipped from the store. As there are no labelling possibilities in store, goods are first shipped back to the DC where these are picked up by Bpost in the same evening. In this way, stores come to function as small storage facilities themselves. Bpost transports the goods to their sorting centre after which these are spread over the different regions, including Antwerp. In the regional fulfilment centre located in the north of Antwerp, orders either go into the mail delivery network to be delivered as letterbox packages by the postman, or they go into the parcel delivery network. To this end, 12 different smaller transhipment centres in the region are being used. Deliveries from Torfs are consolidated with other parcels and are distributed in a milkrun-model. Parcels are delivered by a van or cargobike, partly during evenings. Letterbox packages are only delivered during the day on weekdays. Alternatively to home deliveries, customers can also select a (manned or unmanned) pick-up point from Bpost. The delivery model is visualised in Figure 9.

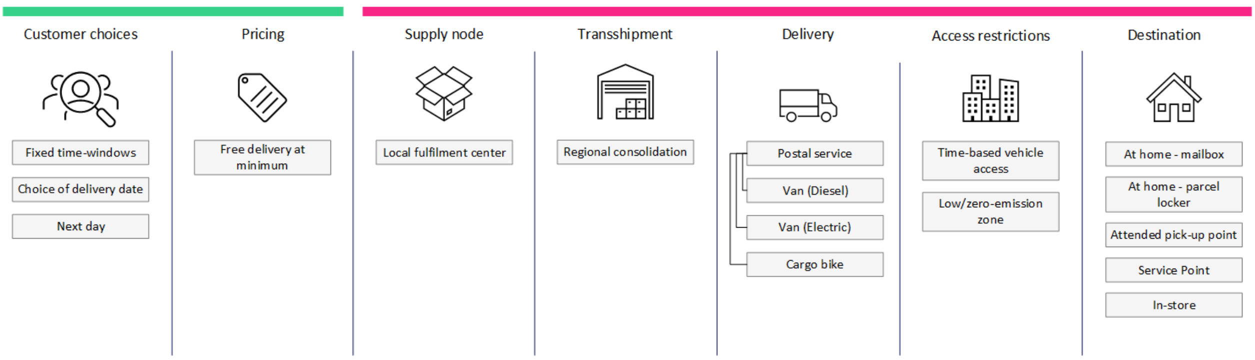


*Figure 9. Illustration of the Torfs/bpost delivery model*

Furthermore, Torfs also has the possibility of a pick-up-in-store model after ordering online. This is not a classic click-and-collect-model since Torfs stores do not have the ability to prepare entire orders by themselves. Instead, these orders are added in the existing supply flows, allowing the customers to pick up their order and pay at the store.

Vehicles used by Bpost are mostly (diesel and electric) vans. Bpost has plans to increase their share of electric vans, however this expansion is currently limited by constraints in grid capacity. For certain orders Bpost chooses to deliver their orders by (cargo)bike, which usually originate from smaller hubs.

Figure 10 shows the wider Antwerp delivery region. The focus in this project is on the city centre.

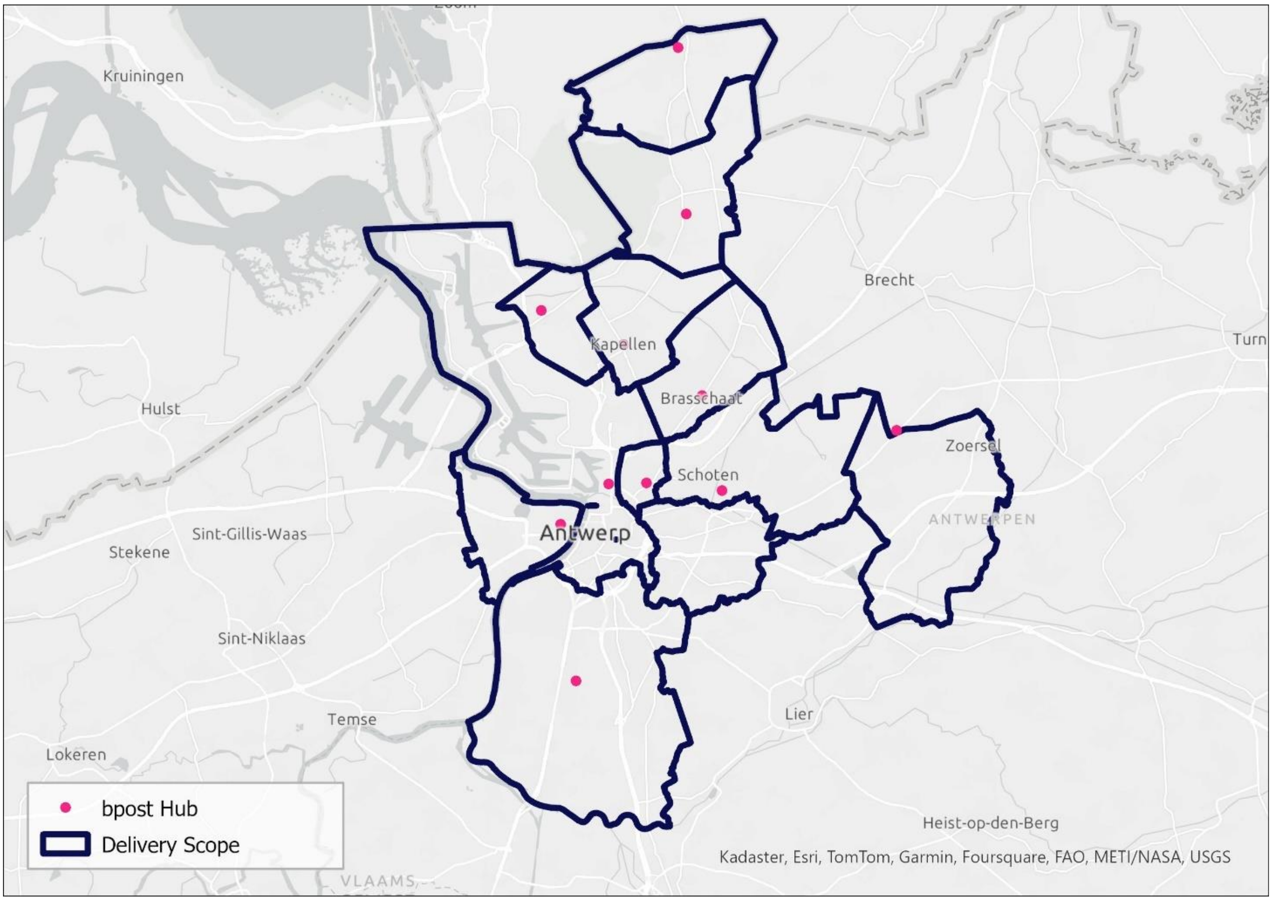


Figure 10. Antwerp delivery area for Torfs/Bpost

## 5.4 IKEA and So.De (Milan)

IKEA Italy has one central DC for store distribution and two for customer distribution centres (CDC) for the whole country in Piacenza and Riano. In the region of Milan, the selected use case of this project, IKEA has three stores. So.De is a social delivery company operating with cargobikes. They hire couriers with fragile backgrounds (e.g. migrants) and support the redistribution of leftover groceries for lower socio-economic groups.

To explain the delivery models of IKEA Italy, a distinction is made between two different flows: parcel flows and truck flows. This distinction is based on both weight and size of orders. Parcel flows are made of orders whose weight is lower than 30 kilograms, with a maximum of 60 x 60 x 60 cm in size. Truck flows consist of orders that exceed these dimensions.

**Parcel flows** are prepared in the central customer distribution center (CDCs). IKEA has chosen against using their own stores for these flows since it is currently not economically viable to prepare orders at their stores. In the Milan region goods are delivered by Poste Italiane from the CDC in Piacenza to partner hubs of either Poste Italiane or So.De. Goods are subsequently delivered by Poste Italiane with a light commercial vehicle or by So.De with a cargobike. At the time of placing the order, the customer can independently choose whether the delivery will be made by cargo bikes, that is with So.De, with an additional charge. If customers choose to have their package delivered by So.De, they can select a time window either in the morning or in the afternoon for their order to be delivered. So.De consolidates the incoming flows together with other goods, and distributes these using their cargo bike fleet. In case of a failed delivery, So.De returns the goods to their hub, and contacts the customer to make another delivery appointment. The focus in CodeZERO will be on this delivery model (see Figure 11).

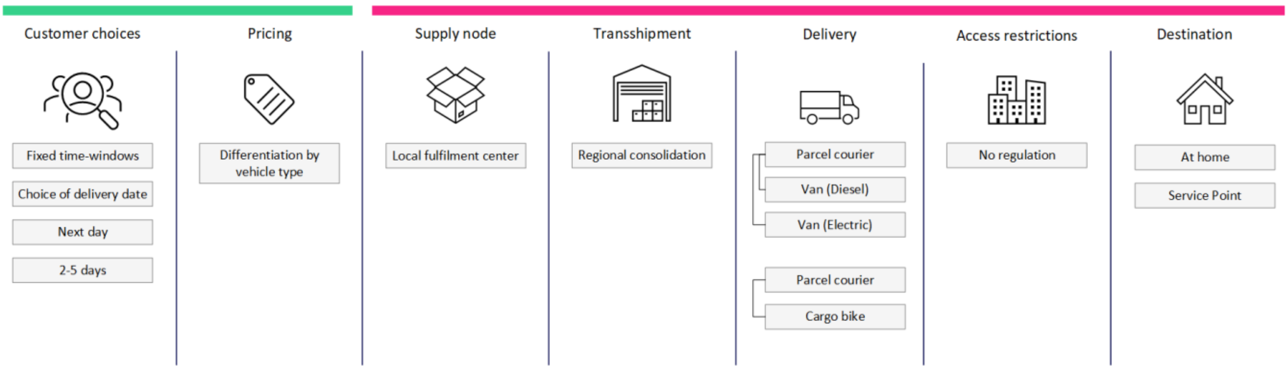


*Figure 11. Illustration of the IKEA Italy (parcel) delivery model*

The **truck flows** for goods exceeding the dimensions of the parcel flow can be split into two parts: 1) goods delivered from one of the stores **directly to customers (Express Delivery)**; or 2) goods prepared in the central CDC in Piacenza (or Riano, depending on the delivery matrix), or in an IKEA store, delivered to a partner hub, merged and subsequently delivered at the customers home.

IKEA has its own electric fleet to achieve the goal of 100% zero emissions deliveries. Electric trucks might be located both at IKEA stores and at partner hubs, because they are granted for use by IKEA to its transport and service partners for both IKEA deliveries as well as deliveries from other suppliers. This is done as long as the majority of the orders in the truck are still IKEA orders. The delivery of the goods is planned for a specific day with a specific time window selected by the customer during the ordering process (morning or afternoon), and the customers are contacted by phone half an hour before arrival to ensure they are present to receive the ordered goods (Figure 12). For assembly, it is possible for customers to order an assembly-service for their ordered goods.

In the Milan metropolitan area there are no restrictions in weight. The lack of adequate cycling infrastructure and high amount of traffic make deliveries through cargo bikes challenging. There are restrictions on other parameters such as emission and length of a vehicle.

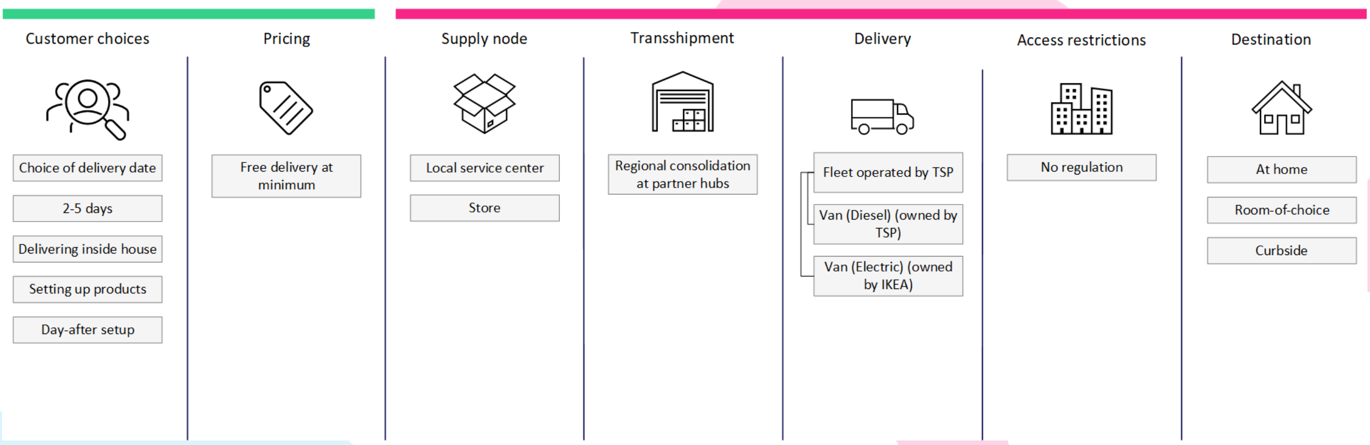


*Figure 12. Illustration of the IKEA Italy (larger product) delivery system*

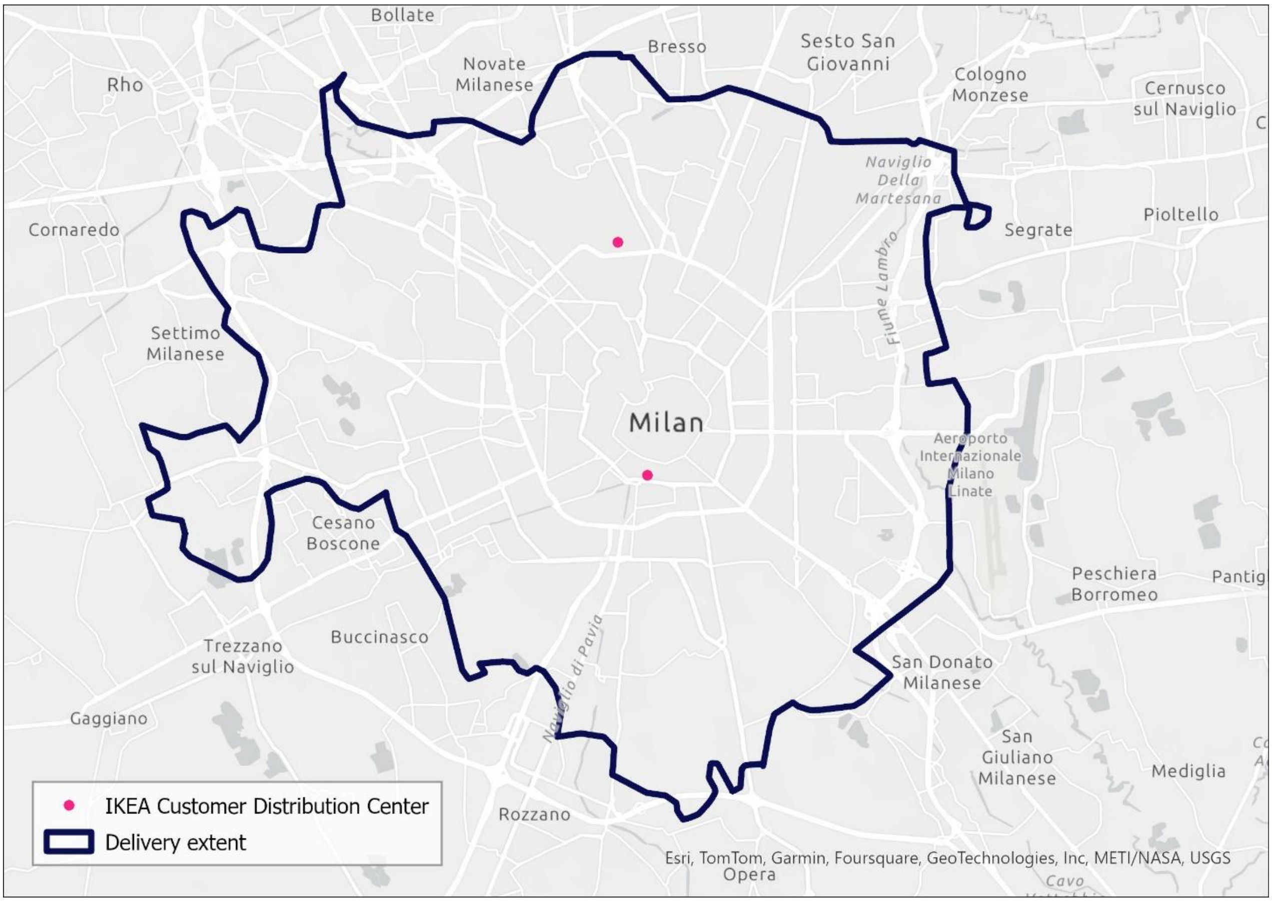


*Figure 13. Milan delivery area for Ikea/So.De*

# 6 Impact of current delivery models

This section makes and initial impact assessment of the delivery models discussed in Section 5. The assessment is based upon data provided by the respective partner and illustrates aspects of cost and environmental and social impact. As defined in CodeZERO D1.1, the costs are mainly associated with the delivery costs of each delivery model, while the environmental impact assesses emissions and air quality. The information used to analyse both the costs and environmental impact is from public sources and interviews with the respective companies related to the use case. Further, the social impacts determine influence on working conditions and involvement in local communities. As the operations of each partner extend further than just home-delivery, the assessment on social impacts is based upon their broader business operations.

## 6.1 Jumbo (Utrecht)

This section explores a first estimate of impacts for the delivery model used by Jumbo based on delivery data of one month in the Utrecht area. Jumbo currently uses Renault Master (EURO 6) vehicles for all their grocery deliveries to customers. The descriptive analysis in Figure 14 and Table 1 indicates that most stops involve delivering between 4 and 5 "footprints".

As defined by Jumbo, 1 crate is 1 footprint and 1 insulated box is 1.24 footprints. Each delivery takes approximately 7 to 8 minutes to complete. A median trip operated by Jumbo consists of 82 footprints. A vehicle can carry about 103 footprints. Due to various circumstances an LCV can be overloaded in footprints (volume) but not in weight. Even though the average number of crates per trip (74.94) represents a load factor of over 50%, it is important to consider that there is also a maximum admissible weight limit (3.5t) on the vans. This weight restriction becomes even more relevant for EV vans as these have a higher unladen vehicle weight compared to their diesel counterparts.

From the delivery data, it is estimated that the grocery deliveries in the Utrecht area emit approximately 25.6 tonnes of $CO_2$ per month. This is based on 1,922 trips with 25,294 stops and a total distance driven of 129,291 km.

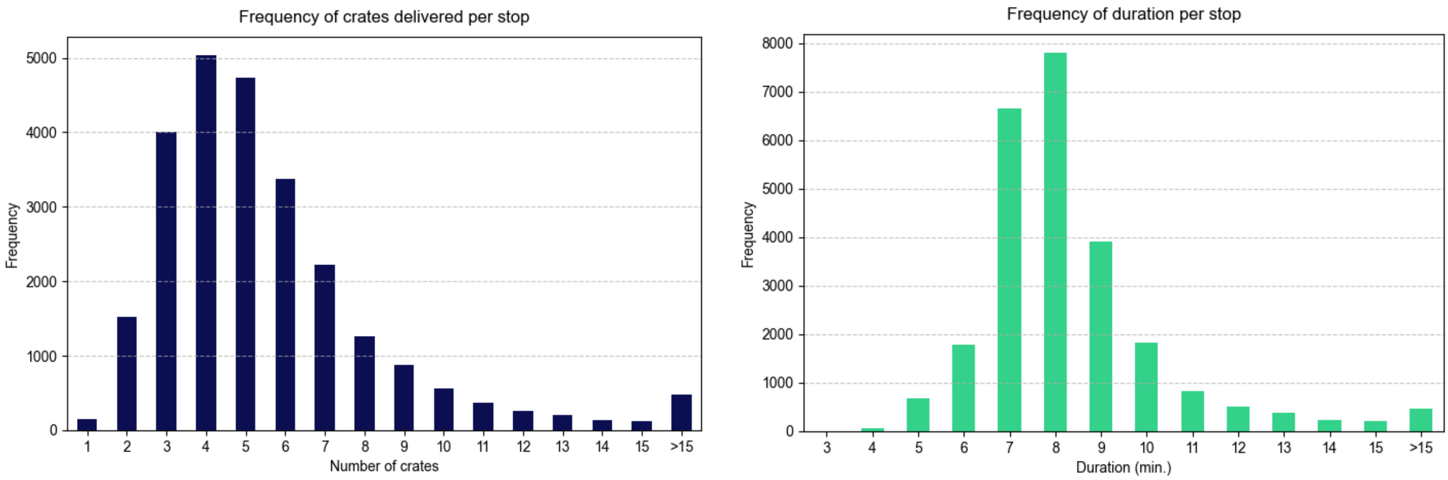


*Figure 14. Frequency tables showing the number of crates delivered per stop by Jumbo (left) and the duration per stop (right)*

*Table 1. Descriptive statistics for Jumbo deliveries (one month)*

| Variable | Total | Mean | Median | Std. dev. | Max. |
|---|---|---|---|---|---|
| **Total distance (km)** | **129,291** | | | | |
| **CO2 (tonne)** | **25.59** | | | | |
| **NOx (kg)** | **3.69** | | | | |
| **PM (kg)** | **0.07** | | | | |
| **Number of trips** | **1,922** | | | | |
| Distance per trip (km) | | 67.66 | 66.20 | 30.60 | 152 |
| Duration per trip (min.) | | 267.10 | 269 | 98.9 | 477 |
| Crates per trip | | 74.94 | 82 | 23.38 | 133 |
| **Number of stops** | **25,294** | | | | |
| Number of stops per trip | | 13.24 | 13 | 5.70 | 26 |
| Distance between stops (km) | | 3.95 | 2.02 | 5.30 | 46 |
| Dwell time per stop (min.) | | 8.35 | 8 | 2.22 | 34 |
| Crates per stop | | 5.63 | 5 | 3.49 | 63 |

Calculations above are based on emission factors calculated every year for the Dutch fleet (TNO, 2024) and the following assumptions:

- The vehicles of Jumbo are assumed under the Euro-class 6d Heavy. This means that all vans are assumed to be from 2022 or younger, and all have a net weight of 2,400 kg.
- The average distance per trip is used to determine the number of cold starts[3] in the total kilometres driven (one cold start per average trip).
- The distribution of the kilometres driven over different road types (determined by Emission Registration[4]) is 70% on urban roads, 10% on rural roads, and 20% on highways.
- Only exhaust emissions[5] are calculated.

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[3] In the Emission Registration (Verkeer en vervoer | Emissieregistratie), so called ‘Cold Starts’ are added as a separate emission factor. This refers to the spike in emissions when a cold motor is started. For more information, see Emissiefactoren wegverkeer 2024.

[4] The Emission Registration is a central database of the Dutch government that stores all data on emission measurements and analyses.

[5] Exhaust emissions solely encompass emissions produced by the tailpipe of a vehicle. It therefore does not include additional emissions caused by vehicles (e.g. tire wear, break wear, cooling systems)

**Costs**

The delivery costs of Jumbo are based upon an algorithm which aims to achieve higher logistics efficiency by providing dynamic pricing according to the timing and location of the individual customer. Additionally, Jumbo provides the option of having free delivery at a minimum price, a loyalty programme and a subscription model, which provide extensive variation in pricing for customers.

**Social impact**

Jumbo is committed to making a positive impact beyond its environmental initiatives. The company actively works to minimize its impact in the local community by addressing neighbourhood disturbances, such as noise pollution. Further, Jumbo is involved in local initiatives through charities, social projects and food banks (Jumbo, 2023).

Employee satisfaction and well-being are a core priority at Jumbo, with the company conducting annual assessments of the current situation. The company also provides professional training to their employees through their Jumbo Academy. Furthermore, there are a number of initiatives to promote diversity and inclusion within the company, providing equal treatment across all spectrums of individuals (Jumbo, 2023).

Overall, the impact of Jumbo delivery model is largely linked to their use of LCVs. Currently, the fleet is made up entirely of diesel vans, which indicates higher impact on air and noise pollution, as compared to their EV counterparts. Due to the unknown stopping position of the vehicle (e.g. on-road, on-curb, unloading zone, etc.) it is difficult to determine the exact spatial impact of the vehicle on the urban environment. Furthermore, Jumbo aims at having a positive social impact by providing healthy working conditions for their employees.

## 6.2 IKEA (Oslo)

This section discusses the delivery patterns for IKEA Norway in the greater Oslo region and is based on a dataset of a representative week of deliveries. The trips originate at two distribution centres that deliver the goods for the region (see Figure 8 in Chapter 5.2) and have at least one stop in the Oslo postal code region. It is assumed that each trip consists of picking up the goods at the DC, delivering the goods and returning to the DC, meaning that an LCV can complete multiple trips in one day. Overall, 209 trips are made from the two distribution centres, delivering to 1,162 locations. The deliveries are all done by 74% electric and 26% diesel LCV. The average trip duration is 191 minutes with an estimated average distance of 48.4 km. Each trip serves around 5.72 locations, with an average dwell time of around 6 minutes and an average delivery weight of 99.72kg. One aspect to note is the high standard deviation of the dwell time per stop, indicating high variability in stop times.

The assumptions made to calculate emissions are the same as for the analysis for Jumbo in Chapter 6.1, albeit in this case refer to weekly emissions. For this calculation, an additional assumption is made on the distribution of kilometres driven per vehicle assumed distributed evenly. In other words: the share of electric kilometres is assumed to be 74%.

*Table 2. Descriptive statistics for Ikea deliveries (one week)*

| Variable | Total | Mean | Median | Std. dev. | Max. |
|---|---|---|---|---|---|
| **Total distance (km)** | **10,115** | | | | |
| **Share of electric trips (%)** | **74%** | | | | |
| **CO2 (tonne)** | **0.57** | | | | |
| **NOx (kg)** | **0.07** | | | | |
| **PM (kg)** | **<0.01** | | | | |
| **Number of trips** | **209** | | | | |
| Estimated distance per trip (km) | | 48.4 | 39.76 | 38.34 | 219.04 |
| Duration per trip (min.) | | 191.14 | 146.1 | 239.19 | 619.00 |
| **Number of stops** | **1,162** | | | | |
| Number of stops per trip | | 5.72 | 5.00 | 3.82 | 19 |
| Dwell time per stop (min.) | | 6.28 | 3.39 | 42.65 | 187.8 |
| Weight delivered per stop (kg) | | 99.27 | 66.38 | 108.73 | 1,002.41 |

### Costs

In the case of IKEA (Oslo), the cost of the delivery model is differentiated between the two models discussed in Section 5.2, namely light parcels and large packages. Firstly, weight of the delivery will determine which of the two delivery models will be used. Within each of these delivery models the cost is then determined according to the speed and location (e.g. curb-side or room-of-choice) of the delivery.

### Social impact

Central to IKEA's strategy is the "People and Planet Positive" initiative, which guides the company's decision-making process. IKEA is dedicated to providing and supporting the wages of its employees through the use of a comprehensive wage scheme. Between 2019 and 2023, IKEA created jobs for 3,000 asylum seekers, demonstrating its commitment to positive social impact. Furthermore, IKEA leverages its diverse product range to promote a more sustainable lifestyle, aiming to enable 1 billion people to improve their life within the planet's ecological limits by 2030. Additionally, IKEA has running initiatives to improve the working conditions of its employees and ensure that drivers involved in logistics processes find meaningful and healthy work within the company (IKEA, 2023).

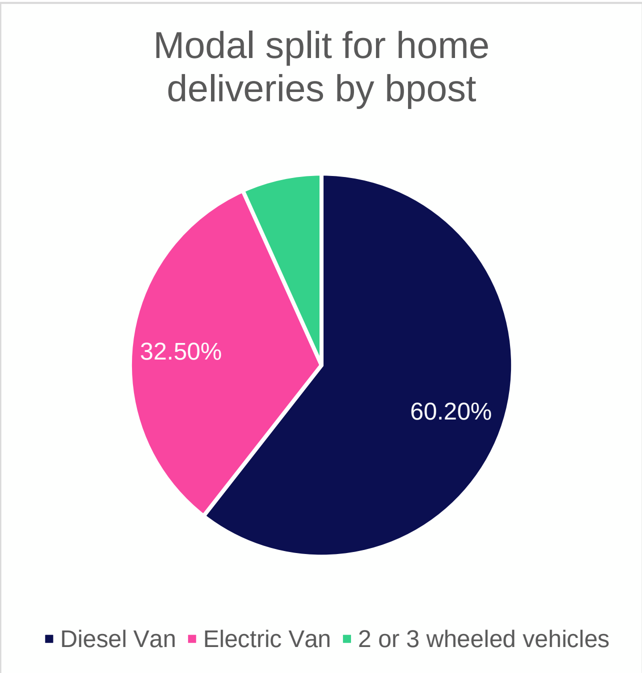
Overall, the environmental impact of the delivery model of IKEA Norway is largely minimized due to their fleet consisting largely of EV LCVs. Additionally, the use of LCVs ensures a lower spatial footprint than the use of larger delivery trucks. However, it is difficult to determine the exact spatial impact, given the unknown stopping locations of the vehicle (e.g. on-road, on-curb, unloading zone, etc.). Further, IKEA aim at having a positive social impact by providing a healthy work environment for their employees through multiple approaches.

## 6.3 Torfs/Bpost (Antwerp)

Bpost delivers on behalf of Torfs by consolidating shipments of different retailers. It is therefore difficult to isolate the impact of deliveries of Torfs's products from the total. Based on available data, however, some descriptives are possible. 21.7% of all Torfs deliveries are ordered directly to one of their stores. These deliveries are combined with the existing internal delivery system and therefore have a low marginal carbon footprint. Furthermore, 21.5% of deliveries are to parcel lockers and 56.8% are delivered directly to customers houses. In the latter two cases, the delivery is carried out by Bpost. Out of all parcel deliveries by Bpost in Belgium, 88% are delivered to households and 12% to pick-up (or service) points. The modal split in different postal code areas in the Antwerp region can be found in Table 3 and Figure 15. Currently, diesel vans are mostly used, and the share of electric vans is higher for deliveries to service points. Furthermore, almost 9% of home deliveries are made with different types of small (electric) vehicles.

*Table 3. Modal split for deliveries by Bpost*

| | Home delivery | | | | | | Service point | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Postal code** | **2000** | **2030** | **2050** | **2060** | **2170** | **Total** | **2000** | **2030** | **2050** | **2060** | **2170** | **Total** |
| **Diesel van** | 56.1% | 73.2% | 0.0% | 71.2% | 95.4% | 60.17% | 81.1% | 99.8% | 0.0% | 88.5% | 100% | 80.2% |
| **Electric van** | 24.2% | 26.8% | 98.8% | 27.7% | 0.0% | 32.5% | 18.5% | 0.3% | 100% | 11.5% | 0.0% | 19.8% |
| **(electric) 2- or 3-wheeled vehicles** | 17.8% | 0.1% | 1.2% | 1.1% | 4.6% | 6.72% | 0.3% | 0.0% | 0.0% | 0.0% | 0.0% | 0.01% |
| **On foot** | 1.9% | 0.0% | 0.0% | 0.0% | 0.0% | 0.63% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.63% |



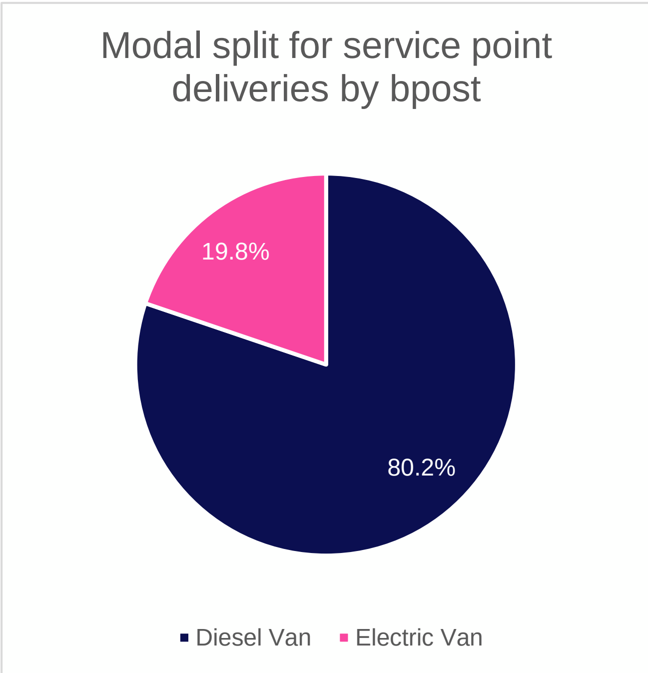




*Figure 15. Modal split for home deliveries (left) and to service points (right)*

**Costs**

The delivery costs at Torfs are based upon a free delivery at minimum price strategy.

**Social impact**

Bpost has multiple ambitions regarding social impacts. The company is dedicated in creating a work environment that ensures both physical and mental well-being for its employees. This is achieved through various initiatives for mental health and programs promoting diversity, equality and inclusion. With a workforce of over 33,000 employees from 112 nations, Bpost emphasizes inclusivity. Since 2019, they have increased employee training hours by 29% and reduced occupational accidents by 15.5% (Bpost, 2023).

Torfs is dedicated to making a positive social impact both within and outside the company. They have been recognized as the first-place winner of the Great Place to Work in Belgium award ten times. Diversity and inclusion are key priorities, as they strive to ensure a non-discriminatory working environment. On broader societal scale, Torfs donates around 1.5% of their profits to charities annually and actively contributes to the sustainability transition of ecommerce by aiming to reduce the environmental impact of their transportation, heating, packaging and overall CO2 footprint (Torfs, 2025).

Overall, it is difficult to determine the exact impact of Torfs delivery model, given the limitation in the data. Similarly to Jumbo and IKEA Norway, most of the deliveries are done using LCVs. When considering home delivery, 32.5% of these are EVs, lowering the emissions and noise impact. Moreover, around 6.72% of the deliveries are completed using 2 or 3 wheeled vehicles, which further have low environmental impact and on an individual vehicle basis, have lower spatial impact than LCVs. Further, both Torfs and Bpost focus on having a positive social impact through providing various programs for employees and ensuring a healthy work environment.

## 6.4 IKEA / So.De (Milan)

The delivery model of IKEA related to parcel flow in the Milan region is, as mentioned earlier, split up in deliveries by So.De and deliveries by Poste Italiane. Both delivery parties further consolidate the goods of IKEA with those of other suppliers. It is therefore difficult to sketch the exact impact of purely IKEA deliveries at So.De. However, from the current available information, approximately 15 tours per day are (partly) made for the delivery of IKEA goods in the Milan region. Each of these tours is on average 8 km, includes from 2 up to 12 deliveries and serves an average of 8.4kg of goods per order. For a general run, this equates to around 5 deliveries per hour and accounts for around 10% of parcel deliveries for IKEA in the Milan region.

**Costs**

In the context of IKEA (Milan) and So.De, the delivery costs are determined according to the vehicle type that is chosen to complete the delivery. If the customer chooses for their goods to be delivered by cargo bike, and therefore by So.De, an additional charge is applied.

**Social impact**

Overall, So.De aims at having a positive impact both inside and outside its delivery operations. With a total of over 21,000 deliveries and 40,000 km travelled, they have contributed to the saving of around 12,000kg of CO2. Furthermore, they place social equity and fair conditions at the heart of their business operations by providing opportunities for workers from marginalized and fragile backgrounds, such as refugees. Their impactful efforts have been recognized through various honors and awards, including the Social Impact Prize in 2023, which they received for their contributions to improving society and actively supporting the UN Sustainability Development Goals (So.De, 2025).

Overall, considering their choice of using cargo-bikes for their deliveries, the impact of the So.De delivery model is quite minimal. In comparison to using diesel LCVs, both the spatial and environmental impacts are reduced, as on an individual vehicle basis, cargo-bikes have a much smaller footprint and don’t require fossil fuel. Further, So.De focuses on having a positive social impact not only through providing a healthy working environment for their employees, but actively involve themselves in charities and initiatives aimed at having a positive impact on the world.

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# Annex I – Taxonomy

This figure illustrates the taxonomy used to collaboratively discuss the last-mile delivery models of each company involved in the project. (For visibility, it has been cut into 3 pieces)