

*Unlocking the benefits of pick-up  
points for sustainable E-commerce  
distribution in urban areas*

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*Do not go where the path may lead,  
go instead where there is no path  
and leave a trail.*

Ralph Waldo Emerson

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# *Unlocking the benefits of pick-up points for sustainable E-commerce distribution in urban areas*

## ABSTRACT

E-commerce has been increasing dramatically during the last decade. This disruption in shopping behaviour has brought about changes to the way freight moves in cities. For example, in the US, in 2009, one out of three freight trips had a household as a final destination. Within only 10 years, by 2019, the number of household deliveries had tripled and now three out of five freight trips are destined to households. For the future, this trend is expected to continue.

Despite the obvious convenience of home deliveries, the last mile of e-commerce is the most expensive leg of the supply chain. Additionally, home deliveries cause a number of negative impacts to residential areas such as street blocking because of double parking, an increased risk of accidents, as well as other negative externalities linked to freight vehicles (e.g. pollution, congestion, noise).

Pick-up points are therefore widely regarded as a solution for increasing the efficiency and reducing the traffic of freight vehicles in residential areas. If doorstep deliveries get consolidated in pick-up points, household freight trips become less frequent. Municipalities and companies are recognising this potential and start focusing their attention on densifying pick-up point networks. From their perspective, those pick-up point networks constitute an instrument to mitigate the negative impacts of e-commerce in urban areas. Estimations suggest that in Europe so far there are about 200,000 pick-up points, while in Belgium this number is getting close to 7,000.

Simply densifying the pick-up points may however lead to unintended consequences: the positive side is that a high density of pick-up points provides more convenience to the customer while at the same time discouraging the use of individual motorized trips to collect packages. However, if there are too many pick-up points, the consolidation effect gets lost commercial vehicles will still need to drive in residential areas causing high operational and external costs.

In this dissertation, the conditions under which pick-up points can be beneficial for society were disentangled. A cost model was developed to understand the effects on operational and external costs resulting from location and density patterns of pick-up points. Our results show that the total costs (external and operational) are almost insensitive to the density of the pick-up point network. However, it appears that the same costs decrease proportionately to an increase in the flow of parcels through the pick-up point network. This suggests that a wider acceptance for off-home deliveries will further unlock the benefits of pick-up points. To reach a larger audience, not only geographical proximity between home and pick-up points should be considered, but also other service level attributes.

# *Een analyse van de baten van afhaalpunten als alternatief voor duurzame distributie van e-commerce in stedelijke gebieden*

## *NEDERLANDSTALIGE SAMENVATTING*

Het aandeel van de E-commerce in de aankopen is het afgelopen decennium heel sterk toegenomen. Dit nieuwe winkelgedrag heeft geleid tot veranderingen in de manier waarop vracht zich verplaatst in steden. In de VS bijvoorbeeld, had in 2009 één op de drie vrachtrips een huishouden als eindbestemming. Anno 2019 is het aantal leveringen aan huishoudens verdriedubbeld, en is het grootste deel van de vrachtrips bestemd voor huishoudens. De verwachting is dat deze trend zich in de toekomst zal voortzetten.

Ondanks het overduidelijke gebruiksgemak voor de consument van een levering aan huis, is de ‘last mile’ van e-commerce het duurste onderdeel van de supply chain. Bovendien hebben leveringen aan huis een aantal negatieve gevolgen voor woonwijken, zoals verkeersopstoppingen vanwege dubbel parkeren, verhoogd risico’s op ongevallen, en andere negatieve externe effecten gerelateerd aan vrachtvoertuigen (bijv. vervuiling, congestie, lawaai).

Ophaalpunten worden daarom aanzien als een goede oplossing voor het verhogen van de efficiëntie en het verminderen van het verkeer van vrachtvoertuigen in woonwijken. Als leveringen aan huis worden geconsolideerd in afhaalpunten, wordt het aantal vrachtrips minder frequent. Gemeenten en bedrijven erkennen dit potentieel en richten hun aandacht steeds meer op het opzetten en verdichten van de afhaalpuntnetwerken. Vanuit hun perspectief vormen deze pick-up point-netwerken een ideaal

instrument om de negatieve effecten van e-commerce in stedelijke gebieden te verzachten. Volgens schattingen zijn er in Europa tot nu toe ongeveer 200.000 afhaalpunten, waarvan bijna 7.000 in België.

Het verdichten van het aantal ophaalpunten kan leiden tot onbedoelde consequenties. Een positief gevolg is dat een grotere dichtheid van het aantal ophaalpunten de klant meer gebruiksgemak biedt. Bovendien is de kans dan groter dat de consument zijn bestelling te voet of met de fiets ophaalt. Als er echter te veel ophaalpunten zijn, gaat een deel van het consolidatie-effect verloren. Commerciële voertuigen zullen nog steeds in woonwijken moeten rijden, waardoor hogere operationele en externe kosten ontstaan.

In dit proefschrift werden de voorwaarden waaraan afhaalpunten de samenleving ten goede kunnen komen verder in detail geanalyseerd. Er werd een kostenmodel ontwikkeld om inzicht te krijgen in de effecten op de operationele en externe kosten als gevolg van locatie- en dichtheidspatronen van deze ophaalpunten. De resultaten van dit onderzoek laten zien dat de totale kosten (zowel operationele als externe kosten) bijna ongevoelig zijn voor de dichtheid van het afhaalpuntennetwerk. Het blijkt echter dat deze kosten evenredig dalen met een toename van het aantal pakketten in de afhaalpunten. Dit suggereert dat een bredere publieke acceptatie van leveringen buitenhuis de voordelen van afhaalpunten verder zal vergroten. Om een groter publiek te bereiken, moet niet alleen rekening worden gehouden met de geografische nabijheid tussen thuis- en afhaalpunten, maar ook met andere kenmerken van het door de klant gewenste serviceniveau.

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# Chapter 1

## Research Frame

## 1.1 Background

For the first time in human history, in 2007, the majority of the world population is living in cities (Sclar, Garau, & Carolini, 2007). However, the phenomenon of “urbanization”, the move of people from the country side to urban areas, is all but new. Already for the past 250 years, people have left rural areas, because of the attractiveness of urban settlements: cities play a crucial role in economic and social welfare by offering advantages of agglomeration (Fujita & Thisse, 2002). Urbanization does however not only have implications for productivity via input sharing and labour pooling, but also creates a higher demand for goods in the cities. Citizens acquire commodities for their professional tasks and leisure activities. Consequently, a manifold of commercial vendors settles in cities to provide inhabitants with goods and services. By collecting, storing and distributing goods when and where they are demanded, logistics systems enable the supply of goods for all the different needs in the city.

To create and exploit urbanization economies and enhance economic welfare for their citizens, cities need a good infrastructure for transport, knowledge creation and exchange, and communication. A crucial determinant for the success of economic activities in the city is an efficient urban logistics system. To be efficient, a logistics system must focus on reliability, quality of infrastructure, accessibility, low congestion levels, and having access to a skilled labour force.

However, cities not only aim at having a thriving economy, they also need to keep in mind other dimensions of the welfare of their inhabitants. A clean environment, social equality, education, and access to recreational zones and activities accompany economic prosperity and constitute the cornerstones of the concept of “liveability” in urban areas. Urban logistics systems are also part of this liveability sphere, however, for several reasons, they are mostly

regarded negative. That happens for several reasons. (1) Urban freight vehicles deployed for the last-mile represent only 10% to 18% of the total number of vehicles in cities, but contribute to about 40% of pollution and noise (Lindholm, 2010). (2) The traffic of urban freight vehicles is perceived to have caused an increase in the number of serious accidents. (3) Logistics companies compete for the use of infrastructure and public space, which arouses a negative perception from ordinary citizens. This negative conception of urban freight transport, but also its undeniable importance for economic growth, have made the design and management of urban freight transport a major concern for public and private stakeholders and the citizens themselves (Dablanc & Rodrigue, 2017). Early responses in the form of restrictions to urban freight include, so far, time windows, low-emission zones and extra tolls for freight. However, still, the traditional focus of urban planning does not totally consider goods (Lindholm, 2010).

The surge of E-commerce during the last years aggravates the situation. For example, in the city of New York in 2009, the share of freight trips attracted by households was half of the trips to commercial establishments. By 2017, the household trips have increased by three times, catching up with and exceeding the commercial trips. Moreover, all indications lead to believe that these freight trips will only rise in the future (Browne et al., 2019). E-commerce has affected the distribution channels of several goods by replacing the traditional model where goods were distributed to retailer's stores and where individuals perform "shopping trips" to buy and collect their goods. In contrast, E-commerce skips the intermediate steps and goods arrive in individual shipments directly at the final customer. Simplistically, one would assume that a tour of a fully loaded vans requires less energy for transportation than if customers are individually performing trips to buy and move goods from retail stores (J. B. Edwards, McKinnon, & Cullinane, 2010). While the former assumption is not wrong in theory, to calculate the

“real” cost of E-commerce, additional factors, besides the mere cost of direct supplier-customer transportation, need to be considered.

Firstly, it has to be clarified that E-commerce activity is part a substitutive and part a complementary demand in comparison to traditional shopping (Shi, Vos, Yang, & Witlox, 2019; Weltevreden, 2007; Zhou & Wang, 2014a). The new demand for E-commerce goods represents and increase on freight trips as evidenced in different studies . Secondly, delivery is a process that demands a higher degree of coordination between the receiver and the shipper. In a traditional distribution scheme, schedules for receiving goods in stores are pre-arranged between shipper and receiver remaining fixed for long periods. In contrast, in the home delivery model, each receiver is unique, which makes prearrangements concerning the exact delivery time challenging. A consequence of a failed delivery is that receivers must individually organize trips to retrieve parcels that could not be delivered. Even when companies invested in technologies to improve the communication with the receiver, failed deliveries remain a key (and yet unresolved) issue of last mile operations.

Finally, coupled with the growth of E-commerce, the handling of the number of returned items is increasing. A logistics system has to be organized to collect the goods that must be shipped back to the sender because of malfunction, satisfaction or other reasons. As it is logistically expensive for the carriers to organize collection trips, receivers have to go to collection points to return parcels. Thus, the additional trips from customers complementing shopping activities, failed deliveries and those related to reshipments simply add to the net demand for transport derived from E-commerce. In consequence, the number of freight trips generated by households has become an important share of the freight movements in the city (Wang & Zhou, 2015).

As a response to the continuing rise in the number of home deliveries, last-mile companies and municipalities, during the last years, have increasingly engaged in finding alternatives to the present process of E-commerce activities. For municipalities, the main objective is intervening the last-mile before home deliveries become a problem due to their negative externalities. For companies, the objectives are more varied. Generally, they look for solutions that either reduce the costs of the distribution of goods or improve the service level. However, in most cases, companies are willing to put forward sustainable innovation as long as it does not result in additional costs.

During the last decade, the “last mile” has experienced a “hype” in innovation initiatives: drones, scooters, e-bikes, cargo bikes, segways, crowd deliveries, mobile points, lockers and pick-up points, among others, have received widespread media attention. Despite a number of trials, the large-scale implementation of these innovation initiatives is still questionable. Often not economically attractive for companies, also their sustainability is in most cases disputable. Consequently, despite E-commerce in itself being one of the most innovative sectors of the last years, everyday home deliveries continue to be carried out with little innovation. The only innovation of delivery modes that has seen the light of the day remains the “pick-up point”.

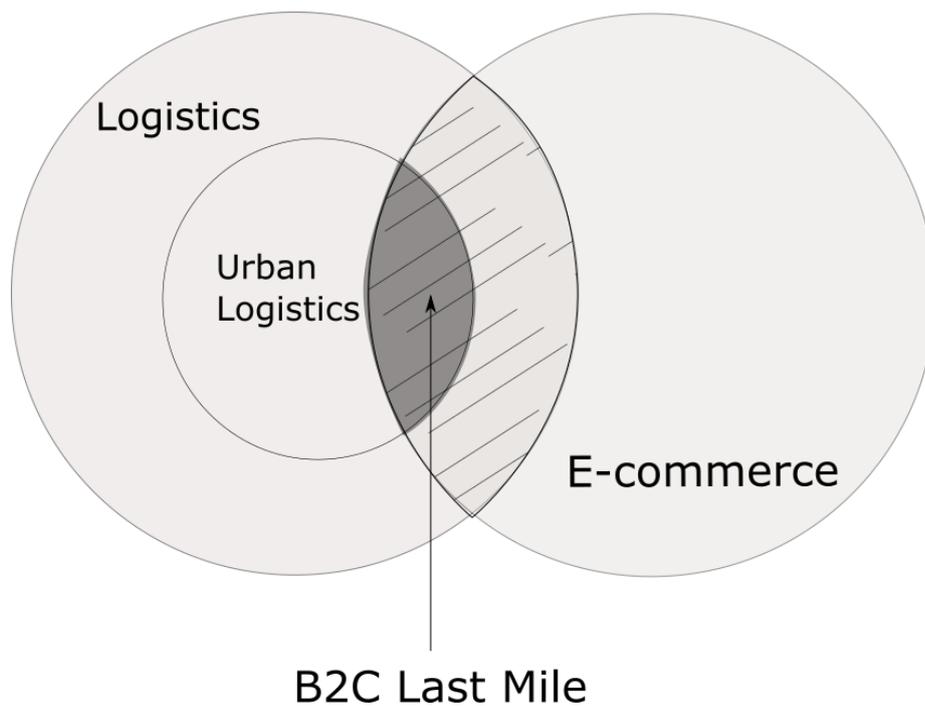
The pick-up point model aims at reducing failed deliveries by providing an alternative location for “off-home” deliveries. Pick-up points can be “attended”, when a person is there to deliver the parcels to (e.g. a shopkeeper), or it can be “unattended”, when the reception desk is unmanned, such as in the form of an automated locker. The main difference between the two models is that in the former, receivers can only collect the parcels in working hours, while in the latter the availability in time to collect packages is more flexible. Even though the concept has been already used by catalogue sales for a long time, more recently, and especially in Europe, pick-up points have experienced a rapid expansion (Morganti, Dablanc, & Fortin, 2014a;

Weltevreden, 2008). Also from a sustainability perspective, pick-up points are considered an interesting option as they replace home deliveries and reduce the use of light goods vehicles (LGV) in residential areas. For example, the new freight and service plan from London, launched in March 2019, foresees the identification and safeguarding of space in the city for pick-up points and envisages tendering procedures for the development of networks of automated collection points (Transport for London, 2019).

Despite the optimism of companies and authorities about the implementation of pick-up points, some considerations need to be addressed. An estimation made in The Netherlands claims that using pick-up points is more polluting than home deliveries since many of the receivers use car trips to collect the goods (EY, 2015). Therefore, the additional gains or costs arising from the pick-up points depend on the chaining of trips (i.e. combining activities with the collection of parcels) and the choice of using motorized means to collect the parcels (Brown & Guiffrida, 2014). These two variables are mainly influenced by the location of pick-up points (J. Edwards, McKinnon, Cherrett, McLeod, & Song, 2010). However, studies indicate that the allocation of pick-up points is not optimal: often, distances between the delivery location and the receiver's home are not in the walking/biking range (Weltevreden, 2008). Moreover, there is overlapping among the service areas of pick-up points from different companies (I. D. Cardenas & Beckers, 2018).

This dissertation aims to shed light onto the rationale behind the use of pick-up points, and how the potential benefits for companies and cities can be unlocked. Understanding this rationale is key for both authorities and practitioners to develop planning processes around the management of E-commerce urban logistics and the design of pick-up points networks in urban areas. To address this subject, this dissertation positions itself at the intersection of three different perspectives (see Figure 1). These cover: (i) logistics and transport - an area where the efficient organization and

coordination of economic activities and, in particular the flow of goods is at the centre of attention(ii) ; and (iii) E-commerce – which is a new distribution channel where goods are demanded under particular characteristics and with certain expectations. At the intersection between logistics and E-commerce, what is known as E-commerce logistics is found. The warehousing, fulfilment, packaging and distribution processes fall under this category. This research is positioned in the B2C last mile of E-commerce, where E-commerce distribution, logistics and urban logistics come together aiming to deliver the goods in the most efficient way but considering the sustainability of these processes.



*Figure 1. Research frame of the dissertation*

*Source: Own Composition*

Following, the dissertation defines and elaborates in more detail the three central perspectives of this dissertation and how they are interrelated around the central subject: sustainability in the last-mile of E-commerce.

## 1.2 Logistics

Defining logistics is not a simple task. Logistics has been present throughout human history supporting many accomplishments. Whether transporting stone from the quarry to the monument, assigning human resources to certain tasks such as agriculture or hunting, or storing goods for later consumption, e.g. cheese for maturation, logistics is present in almost every complex human activity. Since many “actions” fall under the concept of logistics, finding an adequate and all-encompassing definition is far from simple. Often the term itself is linked with other industry jargons such as “operations” or, more recently “supply chain management”.

From a historical point of view, references to “logistics” appeared at first in French war books. Back then, logistics was defined for the first time as *“the art of well ordering the functionings of an army, of well combining the order of troops in columns, the times of their departure, their itinerary, the means of communication necessary to assure their arrival at a named point [...]”* (Jomini, 1830). Nowadays, in various dictionaries, the definition of logistics shares common adjectives such as “detailed”, “complex operation”, and verbs such as “plan”, “coordinate”, “organize”, “manage” and/or “implement”. Another more recent definition coming from the commercial sphere, is provided by the Council of Supply Chain Management Professionals. The Council defines logistics as *“that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order*

*to meet customers' requirements*". (Council of Supply Chain Management Professionals, 2019).

To avoid confusion, in this dissertation, logistics is defined as the chain of **processes to manage the material and information flow** in order to have the right materials, at the right time, in the right place. Since materials are normally sourced from different places and/or at different points in time than the place and the moment they are consumed, the role of logistics is bridging the time and space gaps between the location of production and the location of consumption. For this purpose, logistics relies on two major mechanisms: **inventories** and **transport**.

Following, Hesse and Rodrigue (2004) identify two major functions in logistics: one is a "dynamic function" in charge of moving goods from origin and destination, which is defined by the authors as *physical distribution*. The other logistics function is called *materials management* and represents the "static" processes that take part within the facilities. Production, marketing, production planning, demand forecasting, purchasing and inventory management are some of the operations that fall under materials management. While it is impossible to neglect the importance of materials management in logistics, given its close link with transport and urban logistics, in this dissertation, the focus will remain on the physical distribution of goods.

For physical distribution, the design of a network of facilities plays an important role. Network design decisions target economies of scale and consolidation during the journey of goods from their production location to the consumption place. How are these networks configured? And how can a

more efficient configuration be achieved? Are two of the main questions to be addressed when studying physical distribution.

A detailed summary of the different design options for distribution networks is provided by Chopra and Meindl (2016). The authors identify different types of network configurations that vary according to the requirements from different sorts of goods and the characteristics of demand and supply. Figure 2 schematically illustrates the three most relevant network configurations.

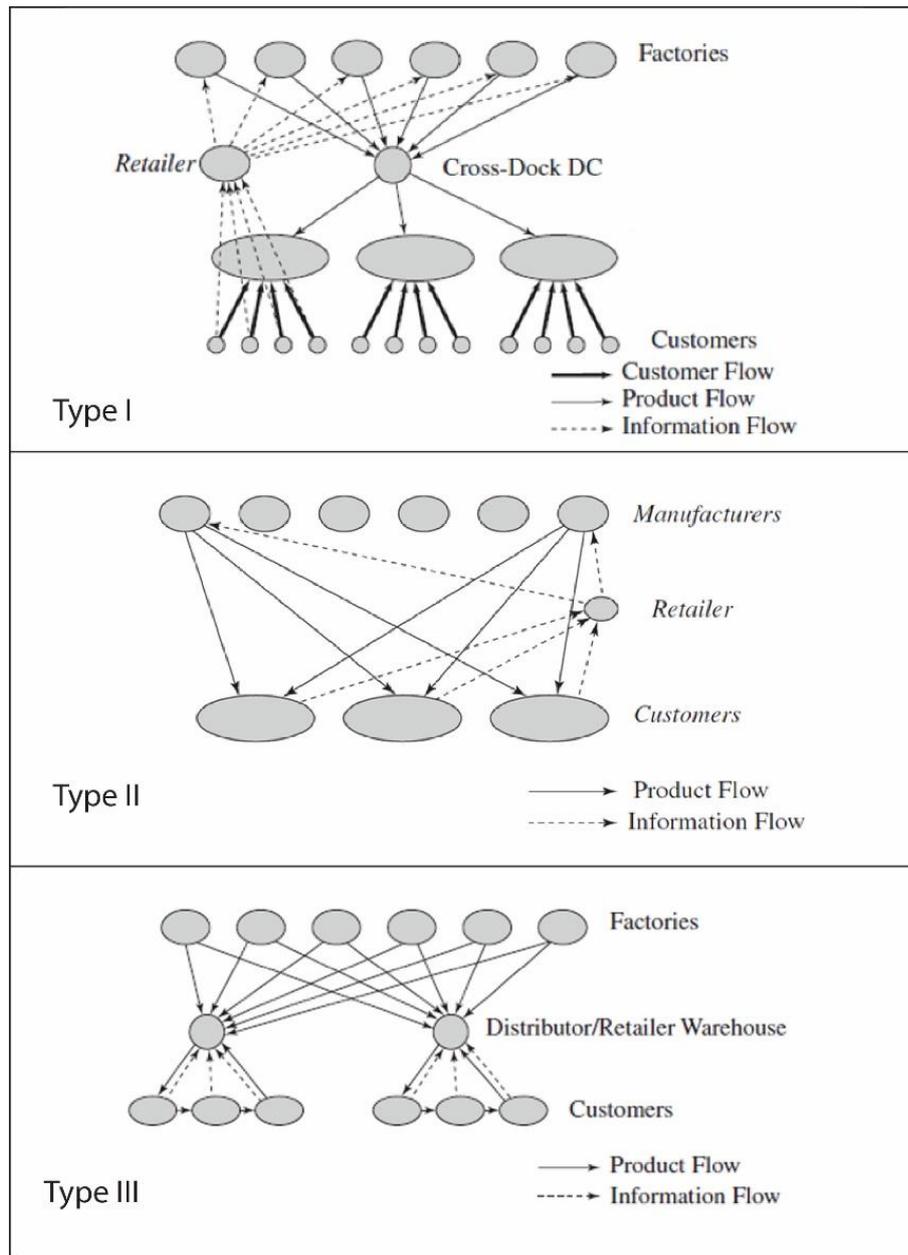


Figure 2. Design options for a distribution network

Own composition based on (Chopra & Meindl, 2016)

The first type exemplifies a traditional distribution network. In this configuration, inventories get stored at retail stores where customers walk in and shop for their goods. The major cost drivers of this configuration are the inventories and facilities that are needed to pre-position the goods close to the

customers without knowing the exact demand in advance. Transportation costs are low since the shipments are consolidated and full truckload (FTL) can be used to re-supply the goods at the retailer. Customers enjoy having the goods immediately and returns can be easily handled, but the variety is limited and the convenience depends on whether the customers like to spend time with shopping activities. This type of network is suitable for fast moving items or when customers value fast response.

A second type of configuration is known as *drop shipping*. In this type of network, inventories are located “high” in the supply chain (i.e. the manufacturer) and goods get directly shipped to the customer. This type of configuration works for products with high value / low demand. The customer’s choice is not limited by the physical inventories, but the time to get the goods delivered is longer. The costs of facilities and inventories are low in comparison with the first type, however this comes at the expenses of increasing transport costs from longer distances and disaggregated shipments. For the customer, the variety of items is larger and the configuration offers the convenience of receiving the items at home. However, the time to receive the goods may be long and the handling of returning items is complicated.

Finally, the advent of the Internet and E-commerce paved the road for a new distribution model. This model, known as *last-mile delivery*, improves the first type of configuration by reducing costs on inventories using a more aggregated system. In E-commerce, inventories are kept at the manufacturer tier and at intermediate locations. Those are not as close to the final customers as in traditional retail distribution systems. At the same time, transportation costs are lower than in the second type of distribution configurations, because the shipments for multiple customers get aggregated. The level of aggregation is an important, though not sole, factor determining the costs of transport. Last-mile distribution in low-density areas remains expensive as the distance between the customers is long and the average cost per stop is high. In highly

dense areas, the stops are also denser, however competition with other *urban logistics* modes causes congestion, increasing again the costs of distribution.

From a service perspective, E-commerce-based distribution offers the convenience of receiving goods at home. In contrast to the drop shipping model, which offers similar convenience, the E-commerce delivery service is not customized and receivers often miss the delivery window. Consequently, last-mile deliveries require an additional effort for coordinating the carrier and the customer to, in effect, receive the ordered goods at home. Although the time to receive goods is shorter for E-commerce delivery systems compared to drop shipping, it is not fast enough to satisfy urgent demand. Finally, returns systems are organized to collect unsatisfactory items; however, collection networks generally work in parallel with delivery networks and the lack of integration increases the difficulty for customers to return items.

Physical distribution systems have changed during recent years given new distribution modes. The impact from E-commerce on logistics can be summarized along three key features: (i) fragmentation of shipments, (ii) failed deliveries, and (iii) the return of items. In comparison to other configurations, E-commerce networks encourage the reduction of decentralized inventories at the expense of increasing transportation, especially in residential areas. The following section will look in detail how logistics for E-commerce work.

### **1.3 E-commerce**

Generally speaking, E-commerce is the trading of goods and services on a digital platform. However, with growing digitalization, companies nowadays conduct many transactions by digital means that are not considered E-commerce. E-commerce only refers to transactions made on the Internet, rather than on any digital platform. More and more companies also source

their products and supplies from internet-based companies. Some companies sporadically order products from e-shops, while others have long-term buyer-supplier relations. For example, assume a clothing shop re-supplies the stock of a stock-out item by using “E-commerce” and buying that single item from another clothing e-shop. Traditionally, this transaction is considered a B2B channel, however all the logistics processes in such delivery are executed jointly with the B2C deliveries and are essentially sharing the same characteristics.

In this dissertation, since the focus is on the logistics perspective, and to avoid confusion of terms, distance is taken from the B2B/B2C spectrum. The dissertation rather refers to E-commerce as the trading of goods by private customers or businesses via buying on websites and where the purchased goods all have the characteristic that they count as small shipments which eventually can be transported by companies in the courier, express and parcel (CEP) sector. This type of logistics flow is the focus of this dissertation, since those are specifically the ones changing the landscape of goods distribution in urban areas. To contextualize this type of flows, the dissertation reviews the evolution of E-commerce in the next paragraphs.

The history of E-commerce, while short, has been very dynamic. In the early 1990s, the ownership of personal computers increased dramatically, and at the end of the decade, also access to the Internet started to widely spread, catapulting us in what is known as the information age. An overconfident environment made it possible for technology-based companies to raise financing easily. This led to a highly speculative market at the beginning of the millennium that imploded shortly after in the so-called “dot-com bust”. The burst of the tech “bubble” took a toll on small and promising Internet-based companies. Nevertheless, after the overheated market cooled down, a more mature market with more defined services and products could

emerge for the new millennium. In 2018, the five most valuable brands globally are companies related to Internet and E-commerce (Apple, Google, Microsoft, Facebook and Amazon respectively) (Forbes, 2018). This clearly exemplifies the importance of E-commerce nowadays.

After its initial struggle during the dotcom bear market, E-commerce has only grown during the last years (see Figure 3). Double-digit growth has been reported almost everywhere in the world every year (Ecommerce Foundation, 2018) and currently, E-commerce has claimed about 35% of the total retail sales in China and, respectively, 10% in the US and Europe (International Post Corporation, 2017). Striking is also the geographic heterogeneity in the supply of E-commerce when compared to traditional retail. Since businesses from all over the globe can easily participate on E-commerce platforms, the products available on the Internet cover a wider portfolio and variety for consumers compared to the choice offered by traditional “brick and mortar” shops. However the larger product portfolio opportunities come at the challenge of greater complexities in the supply chains.

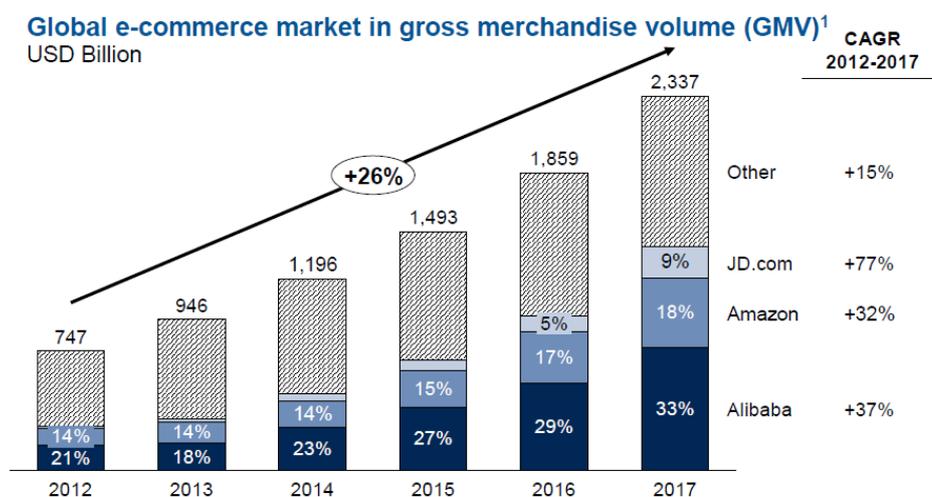


Figure 3. Global E-commerce market in gross merchandise volume (GMV)

Source: (Analysis, 2019)

The supply of E-commerce goods is spread worldwide. Thus, the dissertation denotes not only local flows, but also “cross-border flows” E-commerce. Cross-border E-commerce flows simply imply that goods are produced or distributed from one country to customers in another country. By 2014, the ratio of cross-border E-commerce compared to domestic E-commerce transactions was 13%, forecasts suggest that it will increase to up to 23% by 2020 (Analysis Seabury Consulting, 2019).

In such a complex environment, only an integrated global network can handle the distribution of parcels to the final destination. Consequently, the delivery process occurs in a quite concentrated pool of shippers. The delivery of parcels is performed by (i) the national postal offices (NPO) ~40% of the deliveries; (ii) the integrators, who deliver a similar quantity of parcels and (iii) other parcel delivery companies, who deliver the remaining 20% (Copenhagen Economics, 2013).

Besides the complexities of global goods distribution, once the goods arrive at their destination, a more challenging process starts: last-mile

delivery (see Figure 4). The last leg of the distribution chain is regarded one of the most expensive and polluting parts of the whole journey (Gevaers, 2013). Companies struggle to increase economies of density to reduce the costs and to create a valuable experience with the e-shoppers to gain competitive advantages. At the same time, city authorities face the need to intervene in the most tangible impact of the growing e-economy. Overall, there exists little knowledge about how big is even the problem of the E-commerce last-mile, or even more which mechanisms can be implemented.

Given the challenges on the last mile, a new ecosystem of innovative firms emerged, producing sustainable solutions that contest the traditional composition of the delivery market. These innovative solutions can be categorized into three different types: (i) “off-home” deliveries (e.g. pick-up points, lockers, other proximity facilities); (ii) clean vehicles (e.g. cargo bikes, electric vehicles, drones) and (iii) customer delivery management (e.g. apps to coordinate delivery windows, track & trace). Because of their direct link with transport, the two former solutions are slowly changing the way operations in last mile occur.

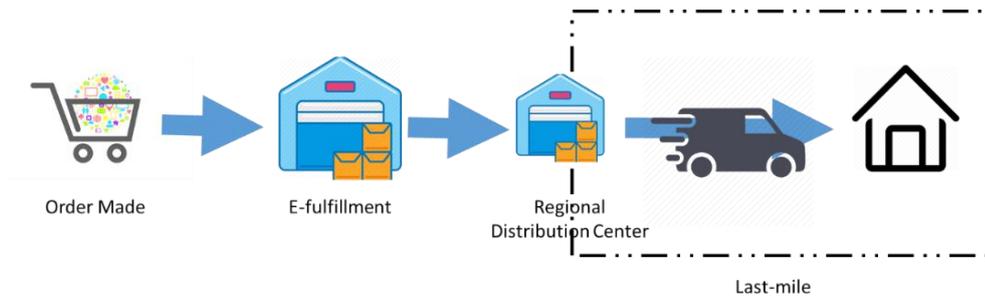


Figure 4. Simplification of a traditional E-commerce distribution

Source: Own composition

The “off-home” deliveries created a new arrange of micro-facilities where e-shoppers who were absent during day can retrieve their parcels. At the same time, clean vehicles are closely related to drop-off locations.

Because of capacity (in the case of bikes) or autonomy restrictions (in the case of electric vehicles), smaller tours are desirable. These two solutions created a new layer of facilities in residential areas (Beckers, 2019), and a completely new set of flows in the E-commerce last mile (see Figure 5 & Figure 6) with different impacts for carriers, receivers and citizens in general.

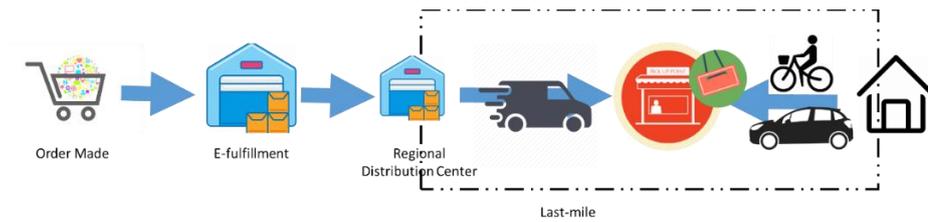


Figure 5. E-commerce distribution with pick-up points

Source: Source: Own composition

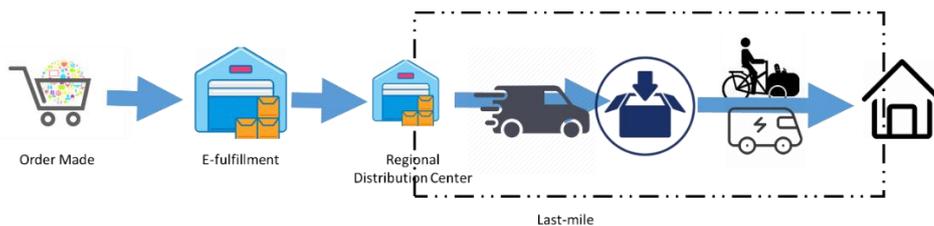


Figure 6. E-commerce distribution with drop-off points

Source: Own composition

In this dissertation, pick-up points is referred to locations where “not-at-home deliveries” take place. Different alternatives fall under this categorization such as: parcel lockers, small shops, supermarkets, or others. While we acknowledge that for certain operational issues, differentiating between these alternatives makes sense, as this dissertation copes with the changes that these facilities have in transport, they are presented in aggregated manner.

From the business perspective, the use of pick-up points is becoming more and more acceptable. Pick-up point networks are in expansion

especially in Europe (Morganti, Dablanc, et al., 2014a) and it becomes part of the portfolio of options to receivers. However, from a sustainability perspective, the advantages of the pick-up points are disputable: a study in The Netherlands estimated that using pick-up points causes the same CO<sub>2</sub> footprint as traditional retail shopping, and in that scenario, home deliveries are better (EY, 2015). In a theoretical analysis, Brown & Guiffrida (2014) also come with similar results and determine that the mode choice (motorized vs non-motorized) and the trip chaining (chaining the collection of parcels with other activities) are the determinants for pick-up points to be a more sustainable alternative.

In contrast, drop-off points can perform in a clean way the last mile, but unfortunately, the extra costs from the additional drop-off location, and a less efficient distribution because of significantly lower capacities from the clean vehicles render out this model from high scale implementations. During the elaboration of this dissertation, the number of pilots with drop-off points has been growing, but because of the lack of data and high volume applications, this dissertation will leave drop-off points out of the scope and focus on the implications from pick-up points.

## **1.4 Urban Logistics**

During history, authorities have always struggled with the management of freight in cities. Already in the Roman empire, laws restricting the movement of freight vehicles (at that time rather carts than trucks) were applicable (Quak, 2008). Besides the mode of transportation, little has changed though in these days with respect to the externalities. Managing freight in cities is complex because of the trade-offs already discussed before: the repercussions for the citizens and the need for goods order to carry out activities in the city. As of today, it is not fully clear how to optimally manage urban logistics. For example, the European Commission

(2011) set as a goal the introduction of CO<sub>2</sub>-free urban logistics in major urban centres by 2030.

How to achieve this goal is however far from being clear. The existence of this knowledge gap led to an interdisciplinary research field to shed light on how to achieve sustainable logistics in cities. Urban or city logistics is defined as “*the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy*” (E. Taniguchi, Thompson, Yamada, & van Duin, 2001).

More recently, a new proposed definition for urban logistics is the following: “*the pluridisciplinary field that aims to understand, study and analyze the different organizations, logistics schemes, stakeholders and planning actions related to the improvement of the different goods transport systems in an urban zone and link them in a synergic way to decrease the main nuisances related to it*” (Gonzalez-Feliu, Routhier, & Semet, 2014).

Both definitions gravitate around finding holistic solutions that coordinate the actors in the system to look for global optimum rather than local ones. An additional component that is closely linked to the concept of urban logistics is **sustainability**. In a broader sense, sustainability is the ability to maintain something for a long period. According to its definition, sustainability have three dimensions: economic, environmental and social. In conclusion, the purpose of urban logistics as a research field is to contribute with the long-term goals about urban mobility by finding out how to make urban goods distribution more sustainable. The following paragraphs guide the reader to devise what are the topics which urban logistics is currently researching and where this research is embedded.

In a recent study in urban logistics sponsored by the European Commission (van den Bossche, Maes, Vanelslander, Macário, & Reis, 2017), different stakeholders of urban logistics were consulted about which topics should be considered in the study. Table 1 shows the results from the topics were the general interests of the stakeholders converge.

*Table 1. Topics of focus*  
*Source: (van den Bossche et al., 2017)*

<b>Type of topics</b>	<b>Average score (1-5)</b>
Access restrictions for urban freight transport vehicles on emissions	<b>4.54</b>
Low emission vehicles	<b>4.50</b>
E-commerce	<b>4.36</b>
Innovations in off-peak logistics	<b>4.28</b>
Return flows in logistics	<b>4.15</b>
Courier and express logistics	<b>4.15</b>
Parking, loading/unloading	<b>4.10</b>
Electric or hybrid propulsion	<b>4.07</b>
Waste logistics	3.97
Access restrictions for urban freight transport by time of the day	3.97
Noise of freight vehicles	3.94
Building logistics	3.79
Bicycle freight transport	3.76
Access restrictions for urban freight transport vehicles on vehicle types	3.72
Stock keeping in stores	3.66
Rail transport for urban freight flows	3.45
Barge transport for urban freight flows	3.41
Access restrictions for urban freight transport vehicles on weight	3.17
Tram transport for urban freight flows	3.07
Drones for urban freight transport	2.23

In parallel, during the years when this research was made, a number of conferences on urban logistics took place, below in Table 2, a non-exhaustive summary of the different topics addressed in the conferences where the author of this dissertation had the possibility to attend is presented. Two of the most recurring themes deal with the planning sphere: one is about

which policies lead the intervention of urban logistics systems around the world while the other considers how urban planning should consider the logistics activities in cities. Another recurring theme deals with how researchers can improve the modelling of logistics systems. One of the main objectives from contributions in this field is to adapt methodologies from passenger transport with freight transport. The other two themes found recurrently in every conference are the logistic operation itself, on the one hand, the intermodal opportunities in the last-mile, and the integration of cargo-bikes, waterways or tram/train freight transport. Finally, the E-commerce deliveries is another theme present at every conference; the majority of works on this theme had an exploratory character aiming to describe how current deliveries are carried out in different contexts.

Table 2. Summary of topics last urban logistics conferences

Themes	TRB 2019 <sup>1</sup>	VREF 2018 <sup>2</sup>	METRANS 2017 <sup>3</sup>	City Logistics 2017 <sup>4</sup>
Urban freight modelling	X	X	X	X
Land Use	X	X	X	X
Last Mile Deliveries	X	X	X	X
Planning and Policy	X	X	X	X
Intermodal urban freight transportation	X	X	X	X
Shared Economy	X	X		X
Curbspace Access	X		X	X
Urban transport economics	X		X	X
Governance		X	X	X
Off-Hour Deliveries		X	X	X
Urban Food Deserts	X		X	
Freight and commodity flows surveys	X		X	
Autonomous vehicles	X		X	
Freight Data	X		X	
Cargo Bikes		X	X	
Logistics Sprawl		X		X
Consolidation strategies		X		X
Trade nodes and hubs	X		X	
Business Models		X		
Digitalization		X		
E-groceries		X		

Source: Own composition

<sup>1</sup> Transportation Research Board Annual Meeting, Washington, January 2019

<sup>2</sup> 3rd VREF Conference on Urban Freight, Gothenburg, October 2018

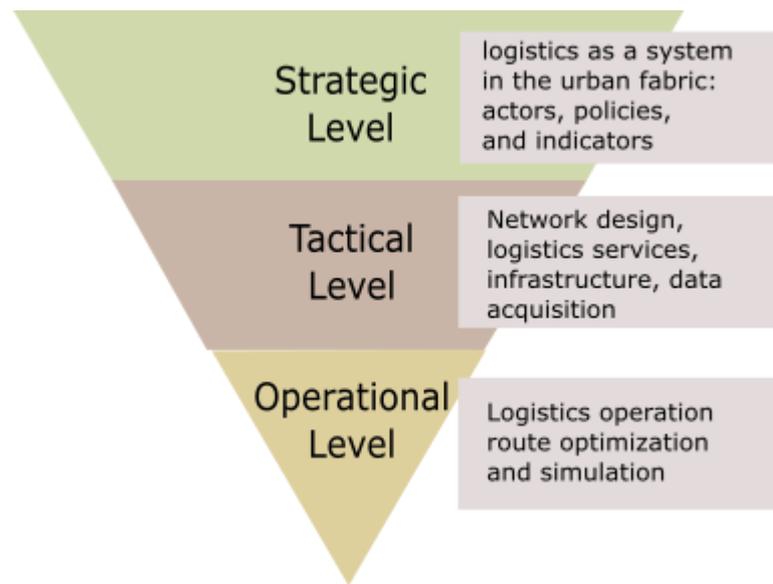
<sup>3</sup> 2017 METRANS International Urban Freight Conference , Long Beach, October 2017

<sup>4</sup> The 10th International Conference on City Logistics, Phuket, Thailand, June 2017

A typology for Urban Logistics is proposed by Cardenas et al. (2017). The authors argue that one can distinguish among three different levels in the urban logistics literature (Figure 7). First, a macro-level, dealing with policies and the urban area as a whole, investigating stakeholders' interactions and interrelationships. It uses qualitative methodologies such as multi-actor analysis, evaluating decision making processes, and citizens' perception analyses, among others. The insights of this domain are mainly for long term policies as land use, emissions reduction, liveability, etc

Secondly, a middle-level focusing on goods transport from the moment the freight enters the urban area. Investigation mainly on transport systems, logistics infrastructure, location decisions, consolidation schemes, storage, the interaction between freight vehicles and passenger vehicles and infrastructure.

Finally, a micro-level where the focus lies on the operations of goods distribution. At this level, attention is paid to the last mile where deliveries occur. This level has more quantitative studies with various applications from operations research and optimization. At the same time, the units of analysis are specific indicators such as time, costs, distance, vehicle kilometres travelled (VKT), etc.



*Figure 7. Levels in the urban logistics literature*

*Source: Based on (I. Cardenas, Borbon-Galvez, et al., 2017)*

To complement this discussion, another framework is proposed by the Transportation Research Board (2015). This typology focuses exclusively on the spheres of action from urban logistics. The authors propose a supply-demand spectrum to explain the aim from a given initiative, see Figure 8. The authors allocate in the top extreme the management of infrastructure and the street furniture for logistics such as loading/unloading bays. Then, at the intermediate level, initiatives that control the freight traffic as restrictions, pricing and other initiatives.

# Urban Freight Initiatives

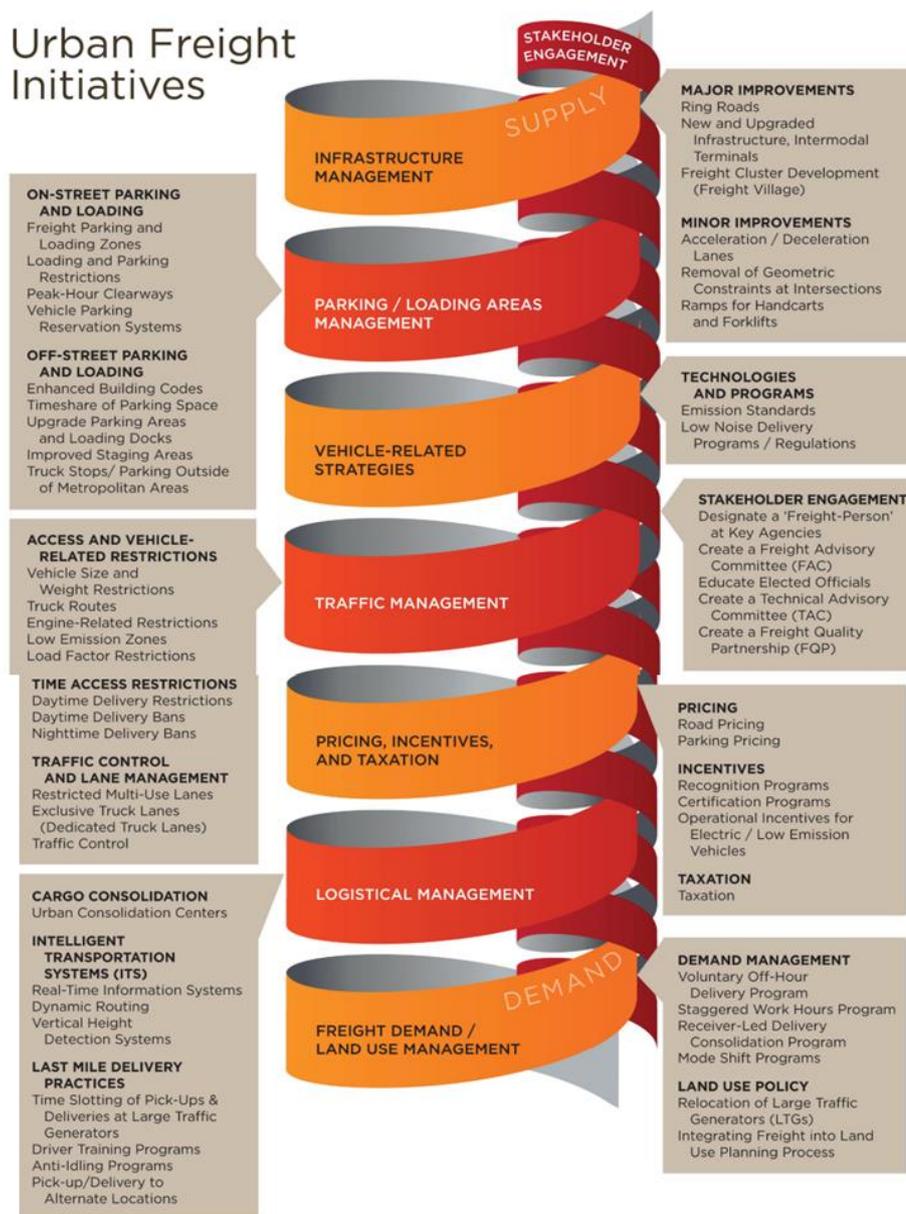


Figure 8. Urban freight initiatives

Source: (Transportation Research Board, 2015)

Finally, in the demand extreme, behaviour change related initiatives, consolidation in the last mile and the authors allocate policies that affect the land use.

Some similarities between this proposal and the proposal from Cardenas et al. can be noted; both typologies have a deductive approach from general or macro-issues to more micro- or detailed issues. The middle layer in both considers traffic management and focus on the transport as a link between the management of the city and the logistics operations.

To summarize, urban logistics is a very recent but rapidly growing field of research. The general purpose of urban logistics is to find innovative solutions to reduce the externalities produced by urban freight transport. This thesis subject has been recurrently appearing in last urban logistics conferences and studies, showing the relevance of this investigation. At the same time, according to the first typology, it is embedded at the micro-level sphere of action from urban logistics, while according to the second typology, in the initiatives that intervene directly in the demand side of the logistics.

# Chapter 2

## Research Antecedents

## 2.1 Literature Review

Interest in the specific effects of E-commerce in general transport research arose at the beginning of the new millennium. Since then, the overarching question of this new field of research has been: “Is E-commerce leading to an overall reduction of transport?” This chapter reviews the literature that emerged at the intersection of logistics, E-commerce and urban logistics. Especially, attention is paid on how the discussion turned to pick-up points as proximity delivery locations. The aim is to depict the evolution of this quickly evolving research domain and to provide a concise overview about the different branches that became evident during the past decade.

### **2.1.1 Substitution or complementarity?: the effect of E-commerce on urban transport.**

To answer this question from the literature, two major strands can be identified. First, there is a strand that argues that individual shopping trips decrease, because customers receive their goods at home. Since the commercial delivery trips can be aggregated in one freight vehicle, net transport demand decreases. In contrast, the “antagonist” strand argues that the frequencies of buying is being altered positively and therefore, despite the decrease in individual customer trips, the total amount of VKT will eventually increase. Additionally, E-commerce may not substitute for the needs of physical shopping and E-commerce freight trips have to be added to customers’ individual, “conventional” shopping trips.

In an early reflection, Mokhtarian (2004) discusses these issues and stresses the numerous challenges to providing a definitive answer to the fundamental question about the impact of E-commerce on transport. For the author, no significant support is apparent to assume that E-commerce reduces the overall transport volume. Related, Visser & Lanzendorf (2004) come to a similar conclusion: E-commerce will rather lead to an increase in freight and

customer-service transport in cities. The authors forecast that E-commerce distribution will shift to suburban areas in the future and consequently discuss the challenges that this trend implies for transport and urban planning.

Another strand of literature is dedicated to studying the impacts of E-commerce with a major focus on mobility. So far, however, little consensus has been reached on the matter (Rotem-Mindali & Weltevreden, 2013). According to Shi, Vos, Yang, & Witlox (2019), there exist four different potential effects from E-commerce on mobility: (1) A *substitution* effect between “traditional” shopping trips and E-commerce deliveries. (2) A *complementarity* effect, whereby freight transport increases due to E-commerce. (3) A *modification effect*, where shopping trips are altered and (4) a *neutrality effect*, implying that no effect on mobility is observed from E-commerce. Follow up studies only present conflicting results as effect sizes seem to be highly dependent on the demographic characteristics of the studied population (Zhou & Wang, 2014b).

In conclusion, it appears that there is no consensus to unequivocally give an answer whether E-commerce brought a positive or negative change in urban transport. What the authors agree on is that the behaviour of freight transport in the cities had a drastic change due to E-commerce. During the years, the discussion has moved towards accepting that E-commerce freight transport in the last mile is there and how to make it more sustainable.

### **2.1.2 Sustainability in the last-mile of E-commerce**

The above-mentioned research predominantly focuses on the effect on passenger transport specifically in shopping trips (Cullinane, 2009). Besides this angle, E-commerce last mile logistics need to be viewed from a freight-oriented perspective. Different studies have analysed the impacts of E-commerce on physical distribution networks, focusing on how, given the characteristics of E-commerce, a more sustainable system can be achieved.

In one of the first studies on the matter, Williams, Tagami, & Takashi Tagami (2002) analyse the Japanese book sector. The authors put forward that a reduction in failed deliveries by e.g. the simultaneous setting up of drop-off points can reduce energy consumption in E-commerce channels. Siikavirta, Punakivi, Kärkkäinen, & Linnanen (2003) study the effects of E-commerce in the grocery sector in Finland. Their observation is that customers tend to use cars more frequently when going for groceries because of the distinct goods characteristics. Consequently, the authors put forward that the environmental benefits from home deliveries depend on the efficiency of the logistics chain. To increase the efficiency, they suggest launching a reception box that gets installed at each customer's domicile and that would help avoiding failed deliveries.

Another study, this time for the UK grocery sector (van Loon, Deketele, Dewaele, McKinnon, & Rutherford, 2014), perform a similar analysis and link efficiency potentials for to delivery basket size (i.e. the quantity of the shipment). Straightforwardly, the authors argue that larger shipments achieve better environmental results because the demand gets fulfilled by means of a consolidated order. However, the authors acknowledge that the click-and-collect model, where customers pick up goods bought online at the supermarket, poses a threat to potential environmental benefits of a larger basket size. In addition, the results vary according to the bike-friendliness of the country under investigation, since no-emission bike trips increase the benefits on the environmental footprint of individual collection trips.

In the US, Laghaei, Faghri, & Li (2016) estimate the impact of E-commerce distribution regardless of the type of item ordered. The authors simulate the use of vehicles for E-commerce, comparing the years 2001, 2005 and 2008 in the city of Newark (Delaware, USA). Because of the growth of E-commerce, the demand for goods obviously increased during those years. However, the

authors evidence an increase on the greenhouse gases attributed to home deliveries, coupled with higher delays in traffic.

In Europe, Ducret (2014) categorizes the courier express and parcel (CEP) sector in three different types of players: the heirs - mainly national postal offices and integrators; other players - small parcel delivery companies, and new players - innovative small companies specialized in the last-mile. The author highlights that the “heirs” in the market follow a defensive strategy. In contrast to small players, sustainability is not an incentive for innovating efforts, only efficiency. Generally however, small players have low chances of succeeding in the sector, because of the high competitiveness of the market. That does not exclude that in some distribution models, the heirs are still in need of small players’ flexibility.

Another impact of E-commerce are the changes that logistics facilities experience due to the accelerated growth of E-commerce activities. In a study of the Paris region, Heitz & Beziat (2015) note, that the courier, express and parcel (CEP) sector exhibits lesser dispersion than other logistics activities. The authors claim that this pattern can partly be explained by some of the “heirs” having inherited the land long time ago with sufficient time to secure locations close to present urban agglomerations. However, a more functional explanation is that because of the complexity of the E-commerce last mile, the distribution stops in the outskirts of the city and the rest of the operation is outsourced to small innovative companies. The modality of this distribution is sometimes even encouraged by the municipality.

Even though innovation initiatives have a hard time to arrive and prosper in the CEP sector, this does not discourage last mile start-ups from booming. He and Haasis (2019) built a GE multifactorial analysis to review the urban freight innovation initiatives for the CEP sector appearing on papers in the period 2013-2018. They found and reviewed 11 new modes for E-commerce

logistics, concluding that electric vehicles and parcel lockers are already well researched in the academic literature as well as adopted by companies. In contrast, modular e-vehicles and autonomous vehicles have received little attention from scholars up until now.

Rai, Verlinde, & Macharis (2019) categorize the innovations existing in Brussels. They use a model proposed by Macharis & Kin (2017) to observe the effect size of a given solution on sustainability. Their findings suggest that CEP companies have solely implemented solutions focused on efficiency. These include pick-up points and locker and customer communication tools. According to their study, there is still room for innovations directly contributing to sustainability. Concerning the latter, however, the government plays a major role. Finally, the authors suggest micro-consolidation centres, cargo-bikes, electric vehicles and crowd logistics as solutions for a larger positive impact on sustainability.

In conclusion, the interest in pick-up points has been quickly emerging in academic literature as pick-up points are one of the few innovations that effectively have taken place as an economically viable solution for the last mile and are being used in large scale especially in Europe. At the same time, pick-up points have potential to reduce environmental costs associated with the E-commerce last mile (Thompson & Taniguchi, 2015).

### **2.1.3 Conditions where pick-up points can reduce economic and environmental costs**

Early references concerning pick-up points can be traced back to a series of papers about the Finnish grocery sector (Mikk Punakivi & Tanskanen, 2002; Mikko Punakivi, Yrjölä, & Holmström, 2001; Siikavirta, Punakivi, Ka, & Linnanen, 2003). In these articles, the authors propose the concept of individual or shared reception boxes as discussed above. Furthermore, the authors estimate the transport needed for distribution using such a reception

box system. They put forward that reception boxes would also help to decrease greenhouse gas normally emitted while transporting the goods to homes.

Despite the promising envisaged future for those “grocery post boxes”, only a few years after the study, pick-up points started to be noticeable especially in Europe. However, not as foreseen by the authors for the grocery sector, but rather for E-commerce. To our knowledge, one of the first studies considering E-commerce pick-up points is an article by McLeod, Cherrett, & Song (2006). Using the case of Winchester, a town in the UK, they estimate the distance and time to deliver parcels in the city when using pick-up points for failed deliveries. They model methods to deliver at home as redelivery attempts, or customers retrieving the parcel from the carrier’s depot. The results show that the most important effect of pick-up points is saving the customers the full trip to the carrier’s depot. The carrier, in contrast, only experiences “modest” savings from pick-up points. They also introduce two parameters that are key to understand the movements to collect parcels: the propensity of using a vehicle for such trip and the propensity of chaining the trip with other activities. Both parameters determine the extent to which pick-up points affect the customer’s transport. Their result was later confirmed using a similar study design, this time with a larger population (Song, Cherrett, McLeod, & Guan, 2009).

Although at the moment of his study, only 1,6% of E-commerce orders were directed to a pick-up point, Weltevreden (2008) was interested in the impact for retailers, shopping centres and mobility of an increase in the number of pick-up points in The Netherlands. Quantitatively, the authors analyse socio-economic characteristics that are associated with the usage of pick-up points. Their key finding is that the more time-constrained a customer is, the more likely (s)he is to use a pick-up point. To increase the usage of pick-up points, they should be located at maximum at five minutes’ driving distance.

According to the authors, it is only feasible for postal offices to provide such large scale coverage while other carriers only manage to implement systems at five minutes' driving distance stretching to half of the population.

Edwards, McKinnon, Cherrett, McLeod, & Song (2010) use a carbon audit model to calculate carbon emissions from different failed delivery rates. The authors claim that customers collecting the parcel in the carrier's depot produce around 85% to 95% of the net carbon emissions. In turn, they put forward that the estimations for pick-up points are similar to those related to traditional shopping. A limitation of the study is however that the authors only compare the picking-up of goods after a failed delivery, either at the carrier's depot or at a pick-up point. Not considered in their calculations remains the option that pick-up points may be chosen as the first delivery option.

Conducting a case study in Lyon (France), Durand & Gonzalez-Feliu (2012) analyse the concept of proximity deliveries. Focusing on e-groceries, the authors describe three main logistics strategies. Firstly, delivering from or in the supermarket by means of a kind of "drive-through" system. Secondly, home deliveries from a carrier's depot, similarly to other E-commerce goods. Thirdly, delivering to pick-up points in proximity of the consumption point. The authors perform a simulation to compare these three strategies versus a baseline scenario including only traditional shopping. The results show that the pick-up point strategy leads to a reduction of net freight flows. A limitation of the study is that the authors optimistically assume that pick-up points are located close enough to the end consumer, so that there is no need for customers to revert to the car. As shown before, related studies suggest that estimations are very sensitive to this factor. Despite the modelling limitation, the authors conclude their study with a highly relevant question, namely if pick-up points appear to be the most sustainable alternative for E-commerce, who should be responsible for the investment in and support of the network?

In alignment with that question, other authors started to investigate how pick-up point networks develop. As a first option, Junjie & Min (2013) propose that real-estate developers, jointly with public authorities, could start establishing a public pick-up service network. Foregoing, the authors analyse the drivers that potentially would make such an investment and network profitable. Morganti, Dablanc, & Fortin (2014a) then again show that pick-up point networks are already growing in Europe ad-hoc, and parcel companies “develop” such networks themselves. The claim is based on the observed rise of pick-up points in number and in use from customers. As in previous contributions, the authors however also still question to what extent the customers’ pick-up trips offset the environmental gains.

Related to the previous question and in order to address concerns about the relevance of customer collecting trips, Brown & Guiffrida (2014) advanced the modelling of home deliveries versus customer pick-up. The authors model the home delivery distribution from a central depot confirming it follows the form:  $k \frac{\sqrt{n}}{A}$  already proposed by Beardwood, Halton, & Hammersley (1959). Furthermore, the authors model the expected distance to be travelled by a customer to the depot during a pick-up trip and how the VKT depends mainly on the trip chaining and mode choice. Using parameters from the US, they find thresholds for the number of customers to be served to make home delivery more environment-friendly compared to pick-up points. While the findings mainly relate to an E-commerce vs. traditional retail situation, the proposed modelling approach can be also used as a basis to analyse the usage and efficiency of pick-up points.

In previous studies, surveys to customers were only performed as a contingency to get some insights on how customers react to the pick-up point networks. Collins (2015) performs one of the first investigations on pick-up points fully centered on customers using a survey design. Specifically, he

applies a stated choice survey to investigate the factors influencing the choice of pick-up points and how customers pick up the goods (i.e. mode choice and trip chaining behaviour). One of the main findings is that a higher density of the pick-up point network causes a modal shift towards cleaner modes of transport by the customers. The author points out specific claims that deserve to be analysed in further studies. First, that trip chaining behaviour can be influenced by pairing pick-up points with common destinations for customers such as shopping malls or train stations. Additionally, that the number of days that a parcel is available at the pick-up point influences the trip chaining behavior in that the longer the parcel is available, the more likely the trip will be chained by the customer with other activities.

The findings from this literature review are summarized in Figure 9 in order to provide a more comprehensive understanding of the milestones in the evolution of research about pick-up points in the last-mile. As becomes visible, the topic of pick-up points as a solution for last-mile delivery in E-commerce gained traction during the last years. The networks of pick-up points are expanding, regardless of evidence suggesting that many factors should be considered before proclaiming that pick-up points alleviate the environmental impact from last-mile E-commerce distribution. The expansion of the number of pick-up points has been fueled because of mainly two reasons in the last years: the need of companies to provide a better service for the customers receiving their parcels and the interest of public authorities, who regard pick-up points and lockers as a viable alternative to keep delivery vans away from residential streets.

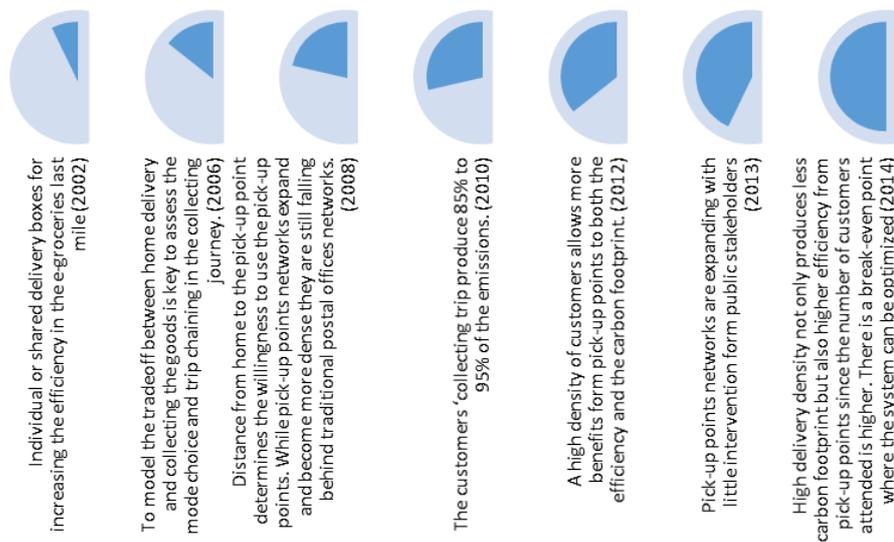


Figure 9. Evolution of research in pick-up points from an urban logistics perspective

Source: Own Composition

In conclusion, the previous research attempts on pick-up points have shed light into the factors that influence the potential benefits from pick-up points; however, the research efforts have focused on the attitudes toward pick-up points but few focused on logistics aspects such as the design of the pick-up point network (Thompson, Cheng, & Kun, 2018). This situation leaves room to develop models assessing the potential of pick-up points that depict, with higher accuracy, the operations as they currently take place. Furthermore, there is still much room to investigate the specific conditions under which pick-up points constitute a sustainable solution for the last mile.

# Chapter 3

## Research Design

## 3.1 Research Questions

The previous chapter explained how logistics is the function in charge of the complexities needed to guarantee whatever is required, whenever and wherever. It also reflected on how new technologies have changed the way that logistics is configured especially with respect to the new physical distribution needs in the last mile. It also reviewed the existing academic literature on this topic including the elaboration of a number of solutions, which have been proposed to improve the E-commerce last mile. Scholars, practitioners and public authorities have turned their attention to how to achieve sustainability in the last mile and cope with the challenges of E-commerce. Among the outlined options, however only pick-up points appear to constitute a viable distribution alternative, which also gets reflected by their growing popularity over the past decade.

However, based on the available literature, it had to be concluded that, although pick-up points have received attention from scholars, the practical and implementable knowledge is still limited to mainly approximations applying very restrictive assumptions. Granulated estimations, in contrast, are still largely missing. Consequently, incorporating data and micro-modelling could provide a deeper understanding on the extent that pick-up points improve last mile distribution towards a more sustainable operation. The antecedent leads to the following main research question.

*How does the design of a distribution system containing pick-up points provide economic and environmental gains in the last mile distribution of E-commerce?* The previous question follows a normative approach: the aim is not only gathering facts to understand and provide a description of the phenomenon “as it is”, but furthermore, to define “what it is ought to be” or, in other words, how to improve the current situation. As “improvement” from an urban logistics perspective, the dissertation regards here a smaller negative

impact on the society while at the same time minimizing an increase in costs for the involved economic actors.

In order to propose a normative point of view, the chapter starts by understanding how the current physical distribution of E-commerce works in urban areas. The aim is to dissect the system and show how it works, to identify the key components of the system, to analyse which inputs are needed and which logistics processes take place. Furthermore, we also aim to understand how innovations applied to the system evolve over time and which are the main trends to improve the system.

*What are the characteristics of the logistics in the last mile distribution of E-commerce?*

With a better understanding of the system, the gathered information must lead to a simplified representation of the system to be analysed. Since this thesis is embedded in the field of transport economics, the second step aims to measure the costs caused by the logistics operation in the E-commerce last mile, both for the economic agents involved and for the society as a whole.

*What are the operational and external costs of the last mile distribution of E-commerce?*

As discussed in the previous chapter, it was hypothesized that a certain set of conditions will permit pick-up points to become a distribution model that on the one hand reduces negative impacts and on the other hand increases the efficiency in the last mile of E-commerce. Therefore, the last part of the research emphasizes on the use of pick-up points and on what are the thresholds that could materialize a better version of the system.

*How pick-up points contribute towards a more sustainable last mile distribution of E-commerce?*

## 3.2 Methodology

The research strategy in this dissertation considers empirical and analytical research to acquire a knowledge base and to be able to eventually conclude on the research process with the proposition of a norm for the design of such distribution systems. The proposed methodology is depicted in Figure 10. It is composed of three different stages, aiming to answer each of the specific questions, using a different methodological approach: the first stage, based on gathering empirical evidence, aims to gain an in-depth understanding about the reality of the system. The second stage, based on analytical methods, aims at analysing the system. Finally, the third stage, relying on normative methods, aims at discerning how to achieve a desirable future.

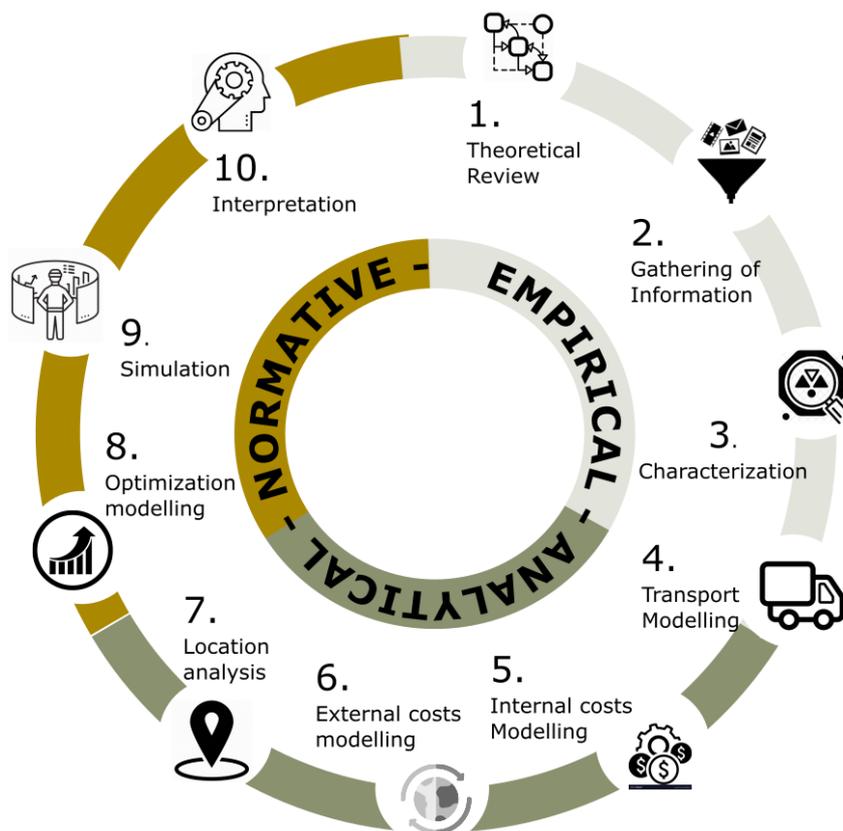


Figure 10. Proposed methodology of the research

Source: Own composition

### 3.2.1 Stage 1: Empirical Evidence

#### *Step 1: Theoretical Review*

This step is done via secondary sources of information. The aim is to get a basic understanding of the context in which the distribution system is operating. It is split into two different activities. In the first, a review of the relevant existing literature in urban logistics takes place. More than 100 papers published between the years 2009 and 2014 are analysed, with a particular focus on studies that deal with logistics in the last mile. The aim of the literature review is to identify the currently dominant theories and advances in E-commerce last mile but also to identify the researchers that were working on a similar topic than the subject of this research. After the literature review, 10 different context alerts are created to automatically identify newly published work related to the subject of research and update the literature review recurrently.

In parallel, a second activity is performed: three different alerts are set up with the keywords: “E-commerce logistics” “last mile E-commerce” and “parcel delivery” on Google Scholar. In parallel, news alerts were placed on the search engine Google to identify and stay updated on innovations taking place globally and that could be associated to the subject of research. The results from these alerts are stored on a weekly basis using the data managing software NVivo<sup>®</sup>.

#### *Step 2: Gathering of Information*

Once the research scope narrowed by reviewing the state of theory and practice, the process of gathering data takes place. Firstly, the geographical scope is defined to be in the country of Belgium. This decision is made mainly for practical reasons: close contact with the relevant stakeholders, and because the country already presents enough complexities in the last mile of

E-commerce (high density of population, a growing market, awareness to the negative impacts from transport) making it an interesting case of analysis.

Semi-structured interviews with all the main logistics players of E-commerce deliveries in the last mile are carried out. The objective of these interviews is to address the research questions and, in the process, verify their relevance while getting insights on the operation. At the same time, some companies express willingness to share data and others share contacts who could provide data. Subsequently, the data provided is cleaned and organized in spreadsheets for analysis. To this end, the following data are gathered to carry on with the investigation:

- Delivery data

This data comprises the deliveries from e-shops to locations in Belgium from two different carriers. The observation window is for hundred days. In the raw data, the observations sum up to 500,000 deliveries. The owners of the data request signing non-disclosure agreements, and because of this, the source of the data will be kept anonymous in this dissertation.

- Cost structure data

Protected by a non-disclosure agreement, one of the companies agrees to share the cost structure of their operations in the last mile. Consequently, there is access to the cost structure used by companies to account for the costs in the last mile tours.

- E-shoppers data

The Belgian representative of trades and services COMEOS provides us with data from the yearly e-shopper survey 2015 and 2016. In this data, 3000 individuals are surveyed about preferences on E-commerce, and, especially relevant for this study, delivery preferences. The data also contains socio-

economic information and some questions even further detail the type of goods.

- Pick-up points data

The Belgian Institute for Postal Services and Telecommunications (BIPT) provides us with access to the raw data collected from the location of pick-up points for all companies in Belgium in 2018. This dataset includes the exact coordinates where pick-up points are located for each of the companies that participate in the Belgian courier, express and parcel sector.

#### *Step 3: Characterization*

Once the data acquired, visualization techniques are applied to get acquainted with the underlying structure of the data and to better understand how to analyse it. Three different methods are applied in this step:

- Cartography: to understand the spatial arrangement and relations in the deliveries and pick-up points data.
- Descriptive statistics: To get statistics indicators from the e-shopper data especially in the behaviour of ordering online.
- Context analysis: to understand the environment in which E-commerce last mile operates; this method is applied to the context data collected through the interviews and the secondary sources in the first step of this methodological design.

### **3.2.2 Stage 2: Data Analysis**

#### *Step 4: Transport Modelling*

In this step, we estimate the kilometres and time necessary in a route. The duration of a route connecting different points has been intensively studied under the travelling salesman problem (TSP), where a salesman must visit a number of points in the most efficient way. The TSP is further generalized

with the vehicle routing problem (VRP), where a vehicle must visit a given number of points starting and finalizing the tour in the depot. The capacitated vehicle routing problem (CVRP) is a variant that imposes a capacity restriction to the vehicles delivering in the tour. This set of problems belongs to the realm of NP-hard problems, because the running time increases super-polynomially as the number of points increases. To mitigate the complexity of this type of optimization models, different heuristics have been proposed to achieve a “good” solution close to the exact optimum. To simplify the calculations for this step, we use a combination of heuristics and partitioning to estimate the distance needed to circuit the points in an area.

In an ordinary route, two components can be distinguished among in the VRP (Carlsson & Behroozi, 2016). The first is the “radial” cost, associated with the distance between the depot and the customers. The second is the “circular” cost, associated with the costs of travelling between the customers. In contrast to the former, the latter is independent of the capacity of the vehicle, therefore this approximation follows the classical TSP.

Approximations for the TSP were first introduced by Beardwood, Halton and Hammersley (1959) who represented the expected length  $L$  of a TSP tour visiting  $N$  customers in an area  $A$  by  $\lim_{N \rightarrow \infty} [L(N, A)] = k\sqrt{NA}$ , where  $k$  is a constant term that approximately is 0.765 (Stein, 1978). By taking advantage of the computational easiness from this, we model the tour taking into account that the main restriction in capacity is not the volume or the weight of the vehicle; normally, the routes are restricted because of the duration. The duration of the tour is dynamic: it will depend on the demand density of the designated area. We construct blocks aggregating smaller area units to model the area assignation from a given tour. From the approximation, we deduct that for a large number of stops:  $D \approx k\sqrt{sA}$ . Where  $A$  is the area of distribution, and  $k$  is a constant that has been estimated at  $k \approx 0.765$  under certain conditions (Figliozzi, 2009).`

It must be noted that the estimations on distance and duration of the tours based on the TSP approximation may be subject to an error on the calculations, to discuss this approach we propose the following three propositions. (i) Real tour data corresponding to the tours made by E-commerce last-mile vans is completely unknown. It must be considered that most of the drivers are independent and therefore companies cannot exert control in such a detail level. (ii) The goal of this transport model is to “replicate” the routes. Even if we apply a “good” optimization model to construct the routes, is still uncertain how it will differ from the real routes. (iii) Numerical examples show that the approximation, even with a small number of replications, has a Mean Absolute Percentage Error of less than 10% (Holguín-veras, 2011). For this reason, the use of approximation to estimate multi-stop tours is becoming more common in the transport literature (Figliozzi, 2009; Merchan & Winkenbach, 2017; Robusté, Estrada, & López-Pita, 2007);

The choice of spatial units is based on a partition of the total area in smaller blocks, inspired by the strategy proposed by Huang, Savelsbergh, & Zhao (2018). The area,  $\mathcal{R}$ , is partitioned on blocks where  $B_R$  is the set of blocks for a region  $r$ . Each block  $b \in B_R$  satisfies a target block capacity, which stands for the expected duration of a tour. Blocks are assigned in such way that the total duration remains similar to a daily journey (i.e. 8 hours). Consequently, the traditional Clarke and Wright heuristic (G. Clarke & Wright, 1964) is applied on each block to estimate the distance and number of points to be visited.

The estimated distance is compared to rough estimations made by the carries to check its accuracy. The use of this method enables us to replicate the cost structure of companies in a simple but functional way. As the purpose of this dissertation is to verify how the transport changes when pick-up points are in

use, in a further stage of the methodology, more powerful and detailed methods of transport modelling will be applied.

*Step 5: Operational costs modelling*

Once able to develop a model to estimate the distances and time for a tour, then calculations of the necessary costs to perform such routes take place. The importance of obtaining the costs is to set a benchmark for the “as-is” situation and therefore compare it with new alternatives. The unitary cost is calculated per parcel delivered. This benchmark allows estimating the effect of pick-up points for the costs in the last mile. To perform this calculation, the following cost model is used.

$$\frac{B2C \text{ Last Mile internal costs}}{Stop} = \frac{2D_{lh} \left( d + \frac{t}{\overline{sp}_{lh}} \right) + D_d d + T_d t + f c_v}{S(1 - f)}$$

Where:

$S$  is the number of daily stops

$d$  is the vehicle costs distance coefficient in monetary units per kilometre

$t$  is the labour costs time coefficient in monetary units per hour

$D_{lh}$  is the one way distance between arrival terminal and starting point of the route in kilometres

$\overline{sp}_{lh}$  is the average speed of the line-haul leg in kilometres per hour

$T_d$  is the average time spent delivering the goods from the first to the last stop in hours

$D_d$  is the delivery tour total distance from the first to the last stop in kilometres

$f c_v$  is the vehicle usage fixed costs per day in monetary units

$f$  is the failed delivery rate

This calculation is based on the basic formulation of transport (Blauwens, De Baere, & Van de Voorde, 2014). The proposed calculation adds to the basic form the inclusion of the effect of failed deliveries. We opt to include this variable because it shows to be relevant in the cost calculations of companies. As the failed deliveries are in the denominator of the equation, they increase the costs affecting the price per parcel. This calculation is subject to validation with the companies in order to test its accuracy and if the obtained values were in the same range than the values companies observed in practice.

#### *Step 6: External costs modelling*

The external costs correspond to the costs of transport caused to a third party and for which the companies do not pay (Blauwens et al., 2014). The importance of calculating the external costs per delivered parcel is twofold. Firstly, as the operational counterpart, it is a benchmark for checking the effect of pick-up points on external parties such as the society and the environment. Secondly, it acts as an estimation of the negative effects from the E-commerce last mile and therefore assesses the relevance of finding alternatives to mitigate those externalities.

As a basis for calculating the external costs, we use the distance and time parameters obtained in step 2.2.2., then transforming those values into external costs using the different categories proposed by Korzhenevych et al. (2014). The following categories are included: congestion, accidents, air pollution, noise and climate change.

#### *Step 7: Location analysis*

Finally, in this step, we perform a critical analysis on how good the location of pick-up points networks is with regard to the final customer. Different logistics carriers are considered because each carrier develops its own network. This analysis is based on the demand model for Belgian e-shoppers (Beckers, Cardenas, Dewulf, & Verhetsel, 2017).

The analysis is comprised of four different analyses. In a first analysis, the service area for each pick-up point was calculated: following the observations from Weltevreden (2008), the threshold for defining service is the area from which a pick-up point is reachable in five minutes' walking time. Two indicators are calculated from the service area. A first indicator, showing the percentage of the city's total area that falls within the five-minute distance to the pick-up point network from each company. In addition, a second indicator, measuring the percentage of the inhabitants of the city who can reach a pick-up point of the company by foot in the five-minute period. The assumption is that if the walking distance is longer than five minutes, people are more reluctant to be delivered to the pick-up point or, in case they are, the car becomes the preferred means of transport for retrieving the items, increasing the net VKT.

The second analysis identifies the type of retail establishment where the pick-up point is located. For this purpose, each pick-up point was categorised into seven different retail categories based on the main purpose of the store where it is located. The categories are daily goods, fashion stores, leisure articles, household articles, transport establishments, general services establishments, and leisure stores. The rationale behind this analysis is that the modal choice and the chances of trips chaining depend on the type of goods sold at the pick-up point. At the same time, the availability (i.e. opening and closing hours) varies between different retail categories, encouraging or discouraging the use of pick-up points.

The third analysis focuses on testing whether the pick-up point locations are clustered or not. To assess the clustering of each carrier's network, a test measures the average distance between each pick-up point and its nearest neighbour. The value is compared with the same measure in a randomised network with similar characteristics.

Finally, in the fourth analysis, the focus is on the availability of the establishments. For this analysis, two different characteristics are checked: firstly, the average number of days that each pick-up point is open secondly, the number of hours the establishments are open on average. Since traditional home deliveries take place during working hours, by extending those periods, customers find more availability and therefore encouraging non-vehicle trips and/or trip chaining (Collins, 2015).

### 3.2.3 Stage 3: Normative proposition

#### *Step 8: Optimization modelling*

The issues in the last mile can be simplified to a trade-off between the costs for the society caused by the transport and the costs for the logistics companies who aim to do the operation in the most efficient way. The aim is to have a system with pick-up points where the costs caused to society are minimized. The following optimization model is proposed to guide the “norm” of the system where the external costs will be minimized.

Following the notation of the covering salesman problem (CSP), the objective is to satisfy all the customers’ demand by visiting or covering them (Shaelaie, Salari, & Naji-azimi, 2014). In this problem, a network  $G = (V, A)$ , has a set of nodes  $V$  partitioned as  $V = V_F \cup V_H \cup V_{PP}$ .  $V$  represents the set of nodes. On its turn  $V_D = \{0\}$  represents the company’s depot,  $V_H = \{1, 2, 3, \dots, N\}$  represents the  $N$  addresses to be visited and  $V_{PP} = \{N + 1, N + 2, N + 3, \dots, N + M\}$  represents the  $M$  pick-up points.

The set of arcs  $A$  is defined as  $A = A_1 \cup A_2$ .  $A_1 = \{(i, j) | i, j \in V\}$  represents the arcs connecting each pair of nodes in  $V$ . The costs caused to society or external costs produced by E-commerce  $ec_{ij}$  are denoted as a factor associated to travelling each arc  $(i, j)$ . At the same time, each arc has associated an operational cost  $oc_{ij}$  representing the costs the companies have

by delivering E-commerce goods. In addition,  $A_2 = \{(m, n) | m \in V_H, n \in V_{PP}\}$  represent the set of pick-up arcs from the address  $m$  to the pick-up point  $n$ . Each customer travels the arc  $(m, n)$  to collect the parcels. Each arc is associated with an external costs  $ce_{mn}$ .

The customers decide in advance if they want the parcel delivered at home or not. Two binary variables characterize this decision if the customers want the parcel delivered at home  $H_m = 1$  and  $PP_m = 0$ . Otherwise, the parcel is delivered in a pick-up point and the variables are set to the opposite values.

The decision variables of the problem are the following:

$$x_{ij} = \begin{cases} 1 & \text{if the arch } (i, j) \text{ is part of the tour} \\ 0 & \text{otherwise} \end{cases} \quad \forall i, j \in V$$

$$z_{mn} = \begin{cases} 1 & \text{if the demand of customer } m \text{ is allocated to the pickup point } n \\ 0 & \text{otherwise} \end{cases} \quad \forall m \in V_H, n \in V_{PP}$$

The problem is formulated as:

$$\min \sum_{i \in V, j \in V} ec_{ij} x_{ij} + \sum_{m \in V_H, n \in V_{PP}} ec_{mn} z_{mn} + \sum_{i \in V, j \in V} oc_{ij} x_{ij}$$

Subject to:

$$\sum_{j \in V} x_{0j} = 1 \quad (1)$$

$$\sum_{i \in V} x_{im} = H_m \quad \forall m \in V_H \quad (2)$$

$$\sum_{n \in V_{PP}} z_{mn} = PP_m \quad \forall m \in V_H \quad (3)$$

$$\sum_{j \in V} x_{ij} = \sum_{h \in V} x_{hi} \quad \forall i \in V \quad (4)$$

$$z_{mn} \leq \sum_{i \in V} x_{in} + \sum_{i \in V} x_{ni} \quad \forall m \in V_H, n \in V_{PP} \quad (5)$$

$$x_{ij} = \{0,1\} \quad \forall i, j \in V \quad (6)$$

$$z_{mn} = \{0,1\} \quad \forall m \in V_H, n \in V_{PP} \quad (7)$$

The objective function minimizes the net external costs produced by the deliveries from both the van couriers and the customers collecting the parcels. Constraint (1) guarantees the tour starting in the depot. Constraint (2) ensures that only customers who opted for receiving the parcel at home will be visited. Constraint (3) does similarly by ensuring that only customers who want the parcel in a pick-up point are assigned to a pick-up point. Constraint (4) guarantees that each visited point has an arch leaving from it. Constraint (5) ensures that only pick-up points that are visited by the tour can be assigned to customers. Finally, constraints (6) and (7) define the binary variables.

#### *Step 9: Simulation*

Solving the above optimization mathematic problem poses a challenge because of the complexity of the problem. An analytical solving method for the optimization is out of the scope of this dissertation and therefore, the chapter opts for using simulation to study the components from the different models that the dissertation comprises. For the simulation model, the chapter constructs a computational model that evaluates how changes in the different variables impact on the performance of the system, in other words a

sensitivity analysis. The architecture of the simulation model is depicted in Figure 11

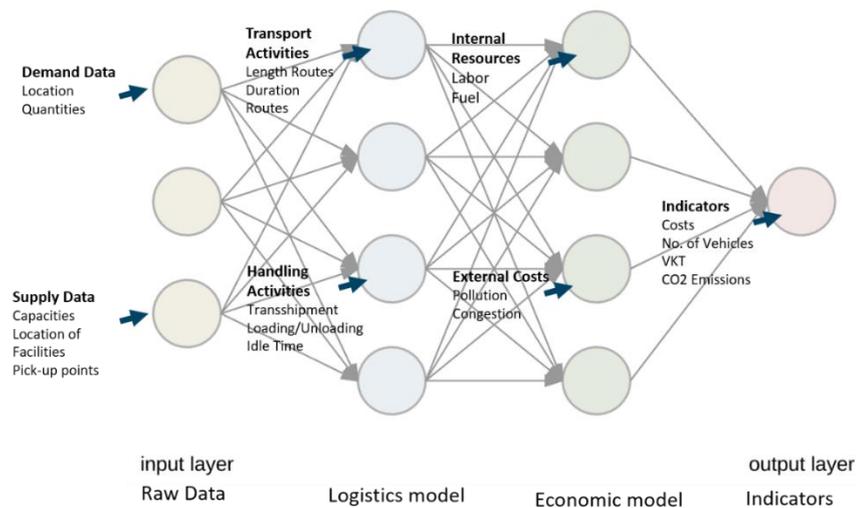


Figure 11. Architecture of the simulation model

Source: Own composition

The chapter generates random instances of demand points. To follow the characteristics of the operation, a partition from the demand points is created. Three subsets are created: the first, with normal home deliveries; the second, with receivers who want to receive their parcels in a pick-up location; and a third one, with failed deliveries that will have to recover their parcels at a pick-up point. The chapter uses the current locations of pick-up points each carrier has in the city. Indifferent of the optimization model, each customer is assigned automatically to the nearest pick-up point. Then, a routing procedure is executed at each block, with the heuristic proposed by Clarke and Wright (1964) obtaining the sequence in which every vehicle will visit the receivers.

Additionally, the distance is calculated that every customer needs to cover to retrieve items at the pick-up locations (group 2 and 3). Since this distance can be travelled by motorized or non-motorized means, and the probability of such depends on the distance to travel, the stepwise function proposed in I.

Cardenas, Dewulf, Vanelslander, Smet, & Beckers (2017) is used. This procedure allows estimating how many VKT are travelled in the city on a given day not only by delivery vans but also for the customers retrieving the parcels. The simulation is programmed and run in MATLAB software. Finally, an experimental design is constructed with aim to assess the sensitivity of the indicators to the following scenarios:

- The usage of pick-up points:

The number of customers is varied who want to receive their parcel at home as a first option to explore the impact by this decision.

- The number of pick-up points available

The number of pick-up points is varied who compose the network, aiming to understand how the distances and VKT are affected by the type of configuration.

#### *Step 10: Interpretation*

The final step copes with the need of translating the findings from the research into knowledge for society. Mainly, the discussion about the interpretation of the results is contained in the conclusions section of this dissertation.

The four following chapters contain the papers that came as output from this research. Chapter 4 (*The E-commerce parcel delivery market and the implications of home B2C deliveries vs. pick-up points*), combines the results from the characterization and the transport and operational costs to show how pick-up points affect the cost structure in Belgium. Chapter 5 (*E-commerce last-mile in Belgium: developing an external cost delivery index*), uses the external costs calculation to develop an index of this cost for the country, aiming to estimate the impacts from deliveries to the society. Chapter 6 (*A location analysis of pick-up points networks in Antwerp, Belgium*) shows the results from the spatial analysis. Finally, Chapter 7: coordination in delivery

points networks for the E-commerce last-mile proposes a network design that impacts positively on operational and external costs.

## Chapter 4

# The E-commerce parcel delivery market and the implications of home B2C deliveries vs. pick-up points<sup>5</sup>

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<sup>5</sup> This chapter is originally published as Cardenas, I., Dewulf, W., Vanelslander, T., Smet, C., & Beckers, J. (2017). The E-commerce parcel delivery market and the implications of home B2C deliveries vs pick-up points. *International Journal of Transport Economics*, 44(2).

## 4.1 Introduction

E-commerce is referred to as the trade of products and services through a computer network, mainly the internet. In 2017, the yearly global online sales grew by 19.5% to a total of US\$2,860 billion (Statista, 2019), with an average yearly spending per customer of €1,582 (E-commerce Europe 2016). In Europe, E-commerce is a fast-growing sector, accounting for a total of €363.1 billion in sales, showing a growth rate of 16.3% (E-commerce Europe 2016). E-commerce may also re-inforce many important drivers of development. Some countries owe 25% of new jobs to electronic commerce, and the consumer welfare gains in terms of lower online prices and wider choice in Europe are estimated at around €11.7 billion (European Commission 2012a). Other expected benefits are: fostering competition and innovation, a more specialized human capital and better-performing ICT infrastructure (Manyika & Roxburgh 2011). E-commerce also offers the possibility of enhancing the Digital Single Market, providing accessibility to isolated areas, reaching vulnerable populations and encouraging eco-friendly practices with lower CO<sub>2</sub> consumption (European Commission 2012b).

On its turn, logistics has been recognized as one of the crucial drivers to support the accelerated growth of E-commerce (European Commission 2012a). In 2013, 3.7 billion parcels were delivered in Europe (E-commerce Europe 2016) with a larger share of sales in urban areas and of home deliveries (Copenhagen Economics 2013). Moreover, the dynamics of E-commerce are coupled with the demand for home deliveries (FTI Consulting 2011).

However, home deliveries have posed new challenges for logistics carriers who were used to do business-to-business (B2B) deliveries. In contrast with B2B, the business-to-customer deliveries can be more challenging from a company's perspective (Vanelslander et al. 2013). Three challenges can be

identified in the current distribution of E-commerce home deliveries : (i) the fragmentation of shipments (Morganti, Seidel et al. 2014), (ii) the failed attempts to deliver (Visser et al. 2014 ; Gevaers et al. 2014), and (iii) the return of goods (Gevaers 2013 ; Pei et al. 2014 ; Rotem-Mindali & Weltevreden 2013).

The fragmentation of shipments is related to the lack of consolidation in the B2C deliveries. While logistics carriers used to deliver a high number of units per stop, with E-commerce, these shipments are fragmented to the level of a single parcel on each stop. This also implies longer routes because of a higher number of locations to visit.

The delivery process also requires a certain degree of coordination between the two parties involved. Basically, the receiver must be present at the time of the delivery, also known as an attended delivery. Since the receivers cannot be at home all the time, and providing time windows for deliveries may cause even more costs, a relevant percentage of the deliveries fail and must recur to various attempts in order to be successful (Fernie et al. 2010).

Finally, due to regulations on distant selling, the customers have the right to return unsatisfactory items. For transport, this implies organizing a reverse distribution system. Unfortunately, the route of return rarely matches the route of delivery, increasing the complexity of synchronizing both processes. In practice, return items move through a different stream than forward distribution, implying even more costs and kilometres.

At the same time, the sustained growth of home deliveries is resulting in changes in the freight transport within urban areas (Browne 2001). Some authors have pointed out that the negative impacts on congestion and pollution to the inhabitants might outpace the benefits of E-commerce (EY 2015). Since the above-mentioned challenges of E-commerce also negatively impact on the number of kilometres driven in urban areas, finding solutions

to reduce the total amount of VKT in cities derived from E-commerce has been subject of research in the last years (Cherrett et al. 2012).

Pick-up or collection points are a valuable solution for these challenges. They offer the possibility of conducting a non-attended delivery (i.e. deliver the goods without a receiver), thereby reducing the number of failed deliveries. They consolidate the demand of different customers at one point, increasing the ratio of deliveries per stop. And finally, they can be used as both delivery and collection points, where the customer can return unsatisfactory items. Extensive literature has been devoted to analysing the potential savings from the utilisation of pick-up points (Collins, 2015; J. Edwards et al., 2010; Song et al., 2009; Weltevreden, 2008) Most authors agree that the benefits of pick-up points will be undone if the pick-up points attract private cars trips from the customers. While outcomes vary according to different circumstances, most analyses are made from a theoretical perspective without a full understanding of “the state of the practice”. In consequence the actual urban parcel delivery market remains understudied (Ducret, 2014).

The objective of this chapter is two-fold. Firstly, to characterise the Belgian E-commerce deliveries market, using information gathered from interviews with logistics companies in the country. This involves discussing the structure of the network, the agents participating and the most relevant operational cost drivers. Secondly, using the framework proposed in the first part of the chapter and numerical data from a case study, the costs of the last mile are determined and a cost calculation method is proposed to compare the costs between home deliveries and deliveries through the pick-up points.

The article is structured as follows. Section 2 proposes a typology of the E-commerce parcel delivery market, considering past contributions and the opinion of different logistics companies in Belgium. Section 3 outlines general issues about the process of parcel delivery and the main cost drivers.

Section 4 proposes a quantitative framework to compare the cost of two most popular E-commerce delivery solutions. Section 5 applies the approach by using empirical data for the city of Antwerp in Belgium. Finally, Section 6 makes some concluding remarks and summarizes the findings.

## **4.2 The E-commerce delivery market**

### **4.2.1 Market Definition**

The E-commerce parcel delivery market can be defined as the one providing the transport services for an online retailer. However, some additional clarifications have to be made. Firstly, the term ‘parcel’ has an ambiguous meaning, and there is no formal definition. It is commonly defined as “*any shipping unit that can be handled by one person without support*”. Generally, a parcel’s weight is no more than 30kg, and its volume is less than 450 cubic inches, but larger than a single letter (Dennis 2001).

Secondly, E-commerce implies shopping for goods and services through the internet. In this chapter, the scope is the delivery, and for that reason, the analysed market takes into account only the physical goods purchased on the internet, excluding services such as flights, insurances, among others.

Thirdly, there is a big difference between business-to-consumer (B2C) products and business-to-business (B2B) products. Many companies active in the delivery market are present in the B2B market as well. Estimates show that B2B represents almost 60% of the E-commerce turnover, while B2C covers around 30% (FTI Consulting 2011), and the remaining 10% should correspond to C2C. The latter are not explicitly discussed in the study. In contrast, in terms of number of shipments, the estimations show a 29% share of B2B, while B2C represents 56% (Copenhagen Economics 2013). The number of shipments seems to be a more coherent KPI for analysis in urban

logistics rather than the turnover, which may explain the attention of this and other publications to B2C E-commerce.

Fourthly, customers of the parcel delivery service must be identified. In contractual and financial terms, the customer is the retailer who ships the parcel. However, the companies also have to deal with the final customer, who mainly is the one who decides on the delivery place and time, complains about damage, loss or delay, and demands value added from the parcel delivery company (DHL, 2014).

#### **4.2.2 Market Typology**

Different contributions have described the changes in the parcel delivery market. Gevaers (2013) develops a typology for the B2C last-mile market. The author thereby focuses on Belgium. In his work, he defines three distinguishable players: postal companies, express operators / integrators and B2C parcel companies. Copenhagen Economics (2013) mentions three types of players: National Post Operators (NPO's), global integrators and couriers, and other express parcels specialists. Borbon-Galvez *et al.* (2015) divide the European parcel market into six different types of players: global integrators, European parcel operators, operators in European alliances, operators with their own intra-European regional networks, NPO's with national networks and operators with local networks.

Ducret (2014) describes and analyses the future of the courier, express and parcel sector, focusing on France. The author concludes that three changes are creating a market for urban parcel deliveries: E-commerce and the changes in the retail market; the increasing service levels demanded by B2C deliveries; and the awareness of public authorities over urban logistics. The author also proposes a typology comprising two different families of players to describe the current parcel delivery market: the heirs, referring to traditional players of the market (e.g. NPO's, express providers, couriers),

and the new players, referring to the companies aiming to cope with the changes mentioned above.

Although different types exist in the literature, in this chapter, a typology is proposed summarizing previous contributions and showing the dynamism in the sector. From a critical point of view, Ducret's work differs from the two others' because the distinctive factor is the behaviour of the players. NPO's and integrator companies assume a more defensive behaviour than small companies that are more innovation-focused. Ducret further divides these two families into ten sub-families; however, with so many types, further distinctions are not totally clear.

While it is important to distinguish among the degree of innovation in the typology, it is also important to highlight the differences between the NPO's and integrators, as the other authors did. The typology proposed in this chapter consists of four different types of players: NPO's, integrators, parcel carriers and last mile specialists.

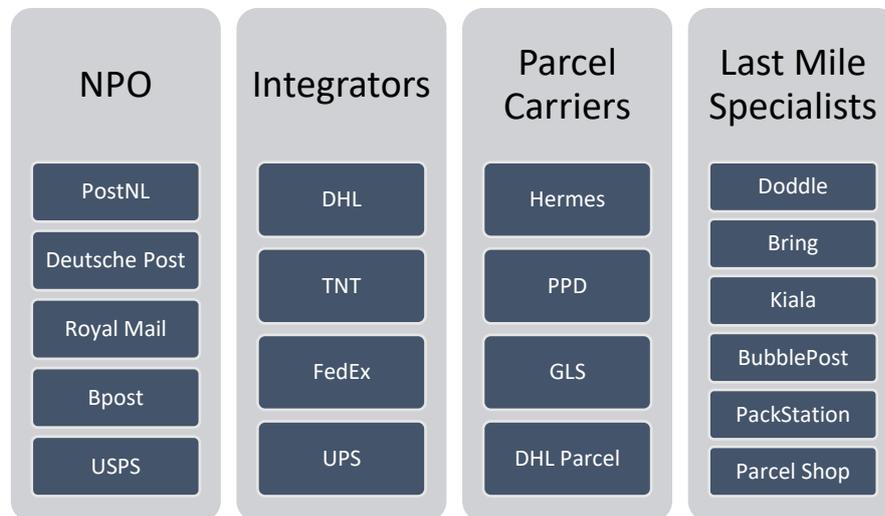


Figure 12. Proposed typology for the E-commerce parcel delivery market.

Own composition, based on (Gevaers 2013 ; Ducret 2014 ; Copenhagen Economics 2013).

### *The NPO*

NPO's are present in every country to provide the postal services under the Universal Services Obligation (USO), referring to the baseline service to every resident of a state. In recent years, the postal services in Europe are under a liberalisation process: the NPO's must satisfy the standards of the national USO, and face more competition. Estimations indicate that the number of parcels covered by the USO accounts for 5 to 8% of E-commerce parcels, and in many countries, these deliveries are subject to price restrictions (Copenhagen Economics 2013).

Generally, the NPO's operations are limited to one country. However, on some occasions they serve different countries (e.g. PostNL in Belgium), or are integrated with firms in other groups to reach more markets (Deutsche Post with DHL, La Poste with PPD, Royal Mail with GLS). Another important trend is the fact that some NPO's are separating their mail and parcel operations in separate companies, with different cost structures and a different legal structure. However, it is not yet clear how these differences occur in practice.

The share of the NPO's in terms of volumes is not clear because the availability of information varies from one country to another (ERGP 2014). Estimations indicate that NPO's account for 10 to 35% of the shipments (Copenhagen Economics 2013; FTI Consulting 2011), and serve 65% of the e-retailers in domestic shipments, (Copenhagen Economics 2013). Note that these estimations include USO and non- USO schemes.

With a decrease of the postal volumes, the business model of these companies has gradually been moving towards the parcel deliveries market. While they inherit the infrastructure to deal with high volumes, therefore reducing average costs, they lack experience in a more service-oriented service like E-commerce deliveries, in comparison to other players. In recent years, NPO's are widening their service portfolio to become important players in the parcel

delivery market, offering Saturday deliveries, last-mile solutions and improving their tracking systems.

### *The Integrators*

Integrators have a worldwide presence. They are vertically integrated, providing services from door to door, and owning the fleet of aircraft and trucks (Onghena 2013). In order to offer an integral service, they own extensive worldwide networks, enhanced with subcontractors. Currently, this category is composed of the so-called “big three”<sup>6</sup> : DHL, UPS and FedEx.

The integrators are commonly known as *express* companies. The ‘express’ characteristic is because they are traditionally the faster counterpart of postal offices and couriers, providing same-day or two-day services at higher fee. In the parcel delivery market, the integrators are mainly in charge of the express delivery.

However, E-commerce express deliveries only account for 10% of the total shipments (Copenhagen Economics 2013). For this reason, in the E-commerce delivery market, these companies mainly act as integrators for international shipments, leaving the standard deliveries to parcel carriers companies, or to parcel divisions within the same integrator company. Estimations indicate a 29,2% share of the global E-commerce delivery market in 2018 (Studium@ScalDIM data Research, 2019).

### *Parcel Carriers*

It is important to clearly distinguish parcel carriers from the others because they represent, with the NPO family, the core of the E-commerce delivery market, in terms of volume. These companies are specialized in parcel deliveries. Their background however comes from the B2B market, and is

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<sup>6</sup> Following the merge between TNT and FedEx.

slowly adapting to the B2C market, facing the constraints of its capacities, and the strong competition of NPO's and a wide array of last-mile specialists.

These companies usually cover a regional area and in most of the cases are subsidiaries of an NPO or an integrator, becoming mainly an extension of NPO's in other countries. Because of the degree of competition in the E-commerce market, these companies tend to assume a defensive strategy (Ducret 2014), hereby following the rules of the market and avoiding the risks of innovative ventures.

### *The Last-Mile Specialists*

This is a completely new family of players introduced by Ducret (2014), as a response to the intersection between the E-commerce last mile problem and the issues concerning urban logistics. This family is composed of small and innovative companies providing solutions for urban settings. They cover a local area, and are often subsidiaries of an NPO or of an integrator. When the demand volume starts to rise, they also tend to be absorbed by NPO's or integrators, to become part of the local delivery services of a larger network.

Two different groups can be distinguished among in this family. First, a group, with the objective of reducing the failed delivery attempts. They provide alternative solutions to coordinate the presence of the receiver at the moment of delivery. Delivery / pick-up points, parcel boxes, automated lockers, among others (Ferne *et al.* 2010) fall in this group. Second, another group focuses on cleaner vehicles. Here, the objective is to provide a sustainable delivery method avoiding the use of vans. Bikes, drones, car-pooling, crowd logistics and neighbours are examples of the means being used by these companies for the last mile delivery in an attempt to reduce the negative externalities of transport.

## 4.3 Operational description

### 4.3.1 The distribution network

The E-commerce parcel distribution strongly depends on the distribution network used by the shipper. Based on the type of network for parcel deliveries, different players participate (Durand & Gonzalez-Feliu 2012 ; Helm 2015). The distribution network in use for E-commerce depends on specific characteristics of the product: for example groceries demands a different network than an E-commerce clothing because of the characteristics of the products (Lin & Mahmassani 2007 ; Kämäräinen *et al.* 2001), However, despite the specific characteristics, E-commerce distribution shares a structure in the logistics process that can be seen in Figure 13.

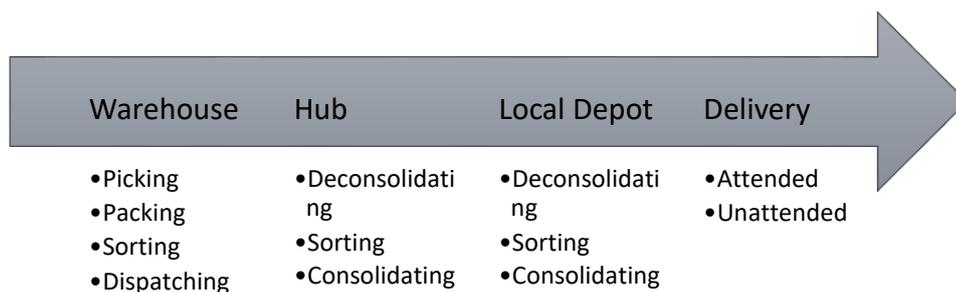


Figure 13. The E-commerce distribution network

Source : own composition.

The main distinction between distribution networks is between those companies choosing to outsource their logistics process to logistics providers (3PL's) and those who perform these activities themselves. A 3PL can consolidate goods from different shippers, yielding economies of scale and deploying complex and robust network designs. In the E-commerce sector, the vast majority of the logistics processes are outsourced. However, companies with high volumes or supplying goods with specific logistics

requirements are a common example of *in-house* logistics. Below, a brief description of the E-commerce distribution network is provided.

The *warehouse stage* is the one where the inventories of the e-shop are held, waiting to fulfil the demand. The parcels can be under the ownership of the supplier company, an internet retailer (e.g. Amazon) who consolidates inventories from several shippers, or a 3PL company, better known as an e-fulfilment centre. At the warehouse stage, automation is highly valued due to the presence of large volumes to be picked, packed and sorted to multiple locations.

The transport process can be divided in two different stages: a first stage composed of a leg of point-to-point transport or long-haul, and a second stage where a multi-drop distribution takes place to deliver the goods to multiple locations.

The *hub stage* is part of the long-haul transport. The hub is the first terminal where the goods arrive to be distributed to smaller areas. Depending on the network scale and the distance to be travelled, more than one hub can be visited. Cross-border shipments usually visit a hub in the origin country, where the parcels are consolidated with same-destination parcels. Then, the parcels visit another hub when they arrive at the destination country to be sorted and consolidated with other parcels travelling to the same region within that country. The complexity of these networks depends on the volumes and the distances: small companies using their own fleet bypass these stages. Large 3PL's or integrators can take advantage of their capacity in the long-haul by using large vehicles such as trucks, ships or planes (Ferne *et al.* 2010).

The *local depot* is the point where the long-haul transport terminates and the multi-drop distribution starts. Its primary function is to de-consolidate large shipments into a multi-drop transport in a more suitable vehicle and a small

area. Here, the light goods vehicles are more suitable to make the distribution, so the more common practice is the use of small vans, by which between 50 and 150 parcels can be transported. It is important to note that this transport combines B2B and B2C goods, which are decoupled at the *delivery stage* where the main distinctions occur.

At the final stage, the parcel is delivered to the customer. There are two different and possible practices to perform this process: attended or unattended. An attended delivery occurs when the customer receives the shipment personally. Attended deliveries require an effort to coordinate the time of delivery. Due to the uncertainties, the carrier can miss the customer, meaning one or more extra trips needed to deliver. It is also problematic particularly when the delivery arrives during working hours, obliging the receiver to stay at home (Fernie *et al.* 2010).

Unattended deliveries are almost exclusive for specialized carriers. These are deliveries to locations in the proximity of customers' ordinary routes, (for instance gas stations, train stations, grocery stores). The carrier benefits from consolidation by delivering multiple parcels at the same location, as well as from distance and cost reduction of failed delivery attempts. However, the trade-off is the distance costs transferred to the customer, who is losing the convenience of receiving the goods at home.

### **4.3.2 Costs drivers of E-commerce delivery**

When referring to the costs, two different types of logistics processes can be considered in the urban goods distribution (Adarme Jaimes *et al.* 2014). Firstly, handling processes, related to warehousing, where the goods are stored, sorted, picked and packed. Secondly, distribution processes, related to transport, where the goods are moving from one point to another.

In urban E-commerce parcel delivery, as described above, the handling processes occur at the local depot stage, where the goods are collected from

long-haul vehicles, sorted and de-consolidated in smaller vehicles, serving specific areas. Distribution processes occur at the *delivery stage*, with a multi-node distribution and delivery in the last mile.

Sorting facilities face fixed costs related to the allocation of the facility, such as land, labour, tax, required capacity, equipment, IT, and so on. External costs are associated with typical inconveniences of industrial facilities in urban areas, such as noise, vehicle congestion at the entrance, and other social costs.

Distribution is a process where variable costs tend to be more representative because it is a labour-intensive activity. In the E-commerce parcel delivery market, a common trend is to outsource the delivery process to self-employed drivers (Ducret 2014). This implies an even more variable environment, because the cost is calculated exclusively by stop. Gevaers (2013) found five different types of cost drivers in the E-commerce parcel distribution. In this chapter, eight relevant cost drivers were identified, Figure 14 organizes the drivers in relation to the corresponding logistics process. Below, detailed descriptions of these drivers and how they affect the current cost structure are provided.

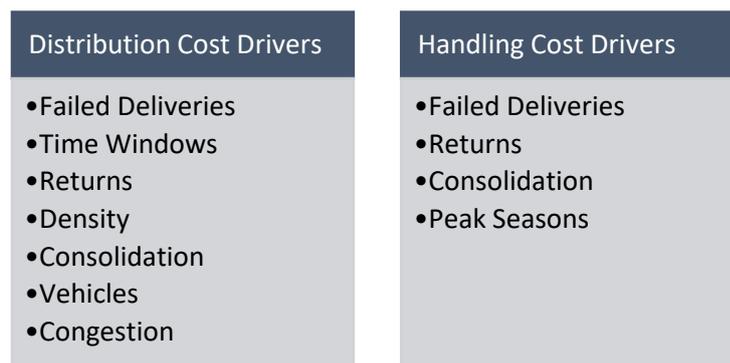


Figure 14. Main cost drivers in the E-commerce parcel delivery market.

Own composition, adapted from (Gevaers 2013)

*Failed deliveries* occur when the carrier attempts an attended delivery, and no one is there to receive it. Earlier estimations show a 15% failure rate for the B2C deliveries at home (Gevaers 2013). This issue has been one of the main concerns for the companies involved. For this reason, new delivery alternatives have been put forward and according to the carriers interviewed, the current failed delivery rate is around 9%. The most popular alternative is the use of drop locations in the neighbourhood of the customer. These locations can be attended or unattended (Morganti, Dablanc *et al.* 2014a). Another alternative implemented by the carriers is to deliver to neighbours of the receiver. Failed deliveries affect the transportation costs, because of the need of a re-delivery, generally the next day, incrementing the total number of kilometres travelled.

*Time windows* are the feature where the receiver can set a desired time frame of the day to receive the parcel. However, allowing the choice of a time window creates a more complicated and inefficient routing, incrementing the number of kilometres travelled (Gevaers 2013 ; Fernie *et al.* 2010 ; Deflorio *et al.* 2012).

According to European distance selling directives, the consumers can withdraw the contract, return the product and be reimbursed. *Returns* are therefore an intrinsic part of E-commerce, allowing the customer to return defective or unsatisfactorily purchased goods. While many e-retailers offer a free-return policy with some restrictions, the cost of picking up an item from the customers has to be considered. Similarly to a failed delivery, a return implies an extra trip, and additional sorting to deliver the item upstream in the supply chain.

Another cost driver is related to the *density*, measured as the number of deliveries per area. With higher densities, the distance between consecutive stops is reduced; therefore, the total number of kilometres per trip is reduced,

just like the costs. Density is an important characteristic of the urban setting, where lower costs can be achieved in contrast with a rural setting (Gevaers 2013)

Delivery *consolidation* is the opportunity to achieve economies of scale by delivering a large shipment to the same location. B2C E-commerce has reduced the consolidation factor, implying more stops per tour. Solutions such as delivery points can provide some degree of consolidation.

The type of *vehicles* also determines the costs of transport. While the use of vans is a generalized practice in the sector, some companies are starting to use alternative transport means like electric vehicles, bikes and drones among others. Costs are the key factor to make a logistics model based on alternative vehicles feasible.

*Congestion* hinders the benefits of delivering in urban areas, because the speed during the tour determines its total duration. While in rural areas, the distances are greater because of the lower density, a higher speed can help alleviate the costs of the tour.

Finally, *peak seasons* have shown the effect of seasonality in this market, and the costs associated with the lack of capacity of companies for dealing with variations in the demand. This cost is more related to the handling process. Having a more fixed structure implies a large effort to expand current capacity to react in high-demand seasons. Once the peak season is over, resources have to be reallocated, becoming an important cost for logistics companies.

#### **4.4 Calculating the last mile costs**

As announced before, in the last part of the chapter, the concepts discussed before can be integrated in order to compare the last mile costs of home deliveries and pick-up point deliveries (Weltevreden, 2008). In this

comparison, we assume the last mile as the leg from the last distribution centre to the customers and back.

While different indicators can be used in this type of comparison (Gonzalez-Feliu, Toilier, Ambrosini, & Routhier, 2014), the average cost per parcel allows analysing the relation between demand and costs. The costs per parcel are given by Equation 1. The equation shows the basic relation between the tour length  $D$ , the duration of the tour  $T$ , and the corresponding cost factor for distance  $d$ , time unit cost  $t$  and the total number of parcels delivered  $\theta s$ . The consolidation factor ( $\theta$ ) represents the average number of parcels delivered per stop ( $s$ ).

$$Cp = \frac{D * d + T * t}{\theta s} \quad (\text{Eq.1})$$

#### 4.4.1 Duration

The duration of distribution must be split in two different components (Equation 2).

$$T = T_t + T_s \quad (\text{Eq.2})$$

A first component is the travel time ( $T_t$ ) which is the time during which the vehicle is travelling from one point to the other. It is proportional to the total length of the tour ( $D$ ) and inversely proportional to the average speed ( $v$ ) in the distribution area (Equation 3).

$$T_t = \frac{D}{v} \quad (\text{Eq.3})$$

The second component is the service time ( $T_s$ ). The service time is composed of the time spent parking, the unloading time and the reception time of the parcels. It depends not only on the number of stops ( $s$ ), but also on the number of parcels per stop. Thus, the service time has to be divided further into two different components. In Equation 4, these effects are reflected by using two

different parameters: a fixed service time ( $T_{sf}$ ) independent of  $\theta$ , and a variable component ( $T_{sv}$ ) which varies with  $\theta$ :

$$T_s = (T_{s,f} + T_{s,v} * \theta) * s \quad (\text{Eq.4})$$

#### 4.4.2 Distance

It is clear that the distance of the tour depends on the number of stops ( $s$ ), the distance from the distribution centre and the routing sequence. Extensive literature has been devoted to developing better algorithms to minimize the total cost of a tour under the CVRP. As this falls outside the scope of this chapter, other academic contributions to approximate the length of a tour are considered.

As depicted in Figure 15, two components can be distinguished in the solution of the CVRP (Carlsson & Behroozi, 2016). The first is the “radial” cost, associated to the distance between the depot and the customers. The second is the “circular” cost associated to the costs of travelling between the customers. In contrast to the former, the latter is independent of the capacity of the vehicle; therefore, the approximation follows the classic TSP.

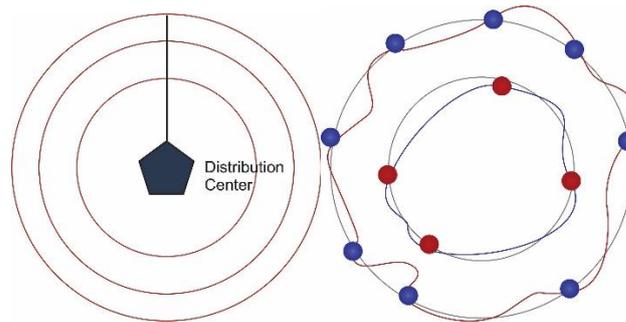


Figure 15. Radial and Circular Length of the Route

*Own Composition*

There are some practical reasons to exclude the CVRP formulation in this modelling approach. First, traditionally, the urban distribution centres are

located outside the cities. As one of the goals of this chapter is to compare distribution methods *inside* the boundaries of the distribution area (i.e. the city), it is possible to assume that the “radial” costs will remain similar for both scenarios. The implication of this assumption is that the “long-haul”, and in consequence the capacity of the vehicles bringing the goods to the city, is neglected.

Estimations for the TSP can be tracked back decades ago (Beardwood et al., 1959). In that paper, the authors demonstrate that the length of a TSP tour asymptotically converges to:

$$D \approx k\sqrt{sA} \tag{Eq.5}$$

Where  $A$  is the area of distribution, and  $k$  is a constant that has been estimated at  $k \approx 0.765$  under certain conditions (Figliozzi, 2009). The approximation proposed by Beardwood have been used in several studies in transport providing a simple but robust estimate of the distance covered in multi-stop tours (Holguín-veras, 2011).

#### 4.4.3 Failed Deliveries

As discussed earlier, failed deliveries play an important role in the cost structure of B2C deliveries (Gevaers, 2013). Even when logistics carriers are experiencing an outbreak of collection points (Deloitte, 2015; Morganti, Dablanc, & Fortin, 2014b), these stops are not planned and add extra time and distance to normal routes. It is important not to confuse contingent collection points and dedicated pick-up points, since the former are “extra” stops additional to the normal stops, while the latter are “planned” stops in the distribution tour. To reflect this pattern, let us assume a failed delivery rate  $f$  which represents the probability of having a failed delivery. The “real” number of stops  $s'$  will be equal to  $s' = s(1 + f)$ . The length of the tour with failed deliveries is then:

$$D \approx k\sqrt{s'A} \quad (\text{Eq.6})$$

The total duration of the tour is affected by the failed deliveries only in the fixed service time per stop ( $t_{s,f}$ ), since the total number of parcels  $\theta s$  will remain unchanged.

$$T = \frac{k\sqrt{s'A}}{v} + (T_{s,f}s' + T_{s,v} \theta s) \quad (\text{Eq.7})$$

Finally, after substitution in Equation 1, the cost per tour considering failed deliveries is given by:

$$Cp = \frac{dk\sqrt{s'A} + t \left[ \frac{k\sqrt{s'A}}{v} + (T_{s,f}s' + T_{s,v} \theta s) \right]}{\theta s} \quad (\text{Eq.8})$$

#### 4.4.4 Pick-up points

The cost model for the second scenario in this chapter includes two extra variables. From the previous formulation, the total number of parcels to be delivered is equal to ( $\theta s$ ). Assume a number of pick-up points ( $pp$ ) with a number of deliveries per stop equal to ( $\theta x$ ), where  $x$  is the consolidation factor of the pick-up points. Then in the second scenario a number equal to  $pp * x$  home deliveries will be substituted for pick-up point deliveries. From Equation 2 the total duration of the tour with pick-up points is:

$$T = \frac{D}{v} + (T_{s,f}(s - pp(x - 1)) + T_{s,v} \theta s) \quad (\text{Eq.9})$$

Similarly the length of the tour now should be estimated as:

$$D \approx k \sqrt{(s - pp(x - 1))A} \quad (\text{Eq.10})$$

Since the pick-up points do represent a failed delivery rate of zero, only the home deliveries will be increased by the failed deliveries (i.e.  $s - pp(x)$ ). The cost per stop including failed deliveries is obtained by substituting Equation 10 into Equation 8.

$$Cp = \frac{\left(d + \frac{t}{v}\right) * k \sqrt{((s - pp(x))(1 + f) + pp)A + (T_{s,f}((s - pp(x))(1 + f) + pp) + T_{s,v} \theta s)}}{\theta s} \quad (\text{Eq.11})$$

Since  $pp(x) > pp$ , the value for Equation 11 will always be lower than for Equation 8. It means that if the establishment and operations costs of the pick-up point network are lower than the difference in costs between the two solutions, the logistics companies will have incentives to develop such a network. However, the costs of a more efficient route are transferred to the receivers: they have to allocate time and travel to the pick-up point to receive their shipment, losing the convenience of receiving the goods at home.

#### 4.4.5 External costs

External costs are costs that the transport user causes to a third party and for which he does not pay (Blauwens et al., 2014). They are related to the distance travelled and are traditionally measured via the VKT. In a home delivery scenario, only the delivery vans contribute to transport external costs, whereas in the pick-up point scenario, movements from customers are triggered, and must be considered as well. These external costs will depend on the distance travelled by the customer  $D_c$ , the distance travelled by the vans  $D$ , and their corresponding external cost factors  $Ed_v$  and  $Ed_c$ .

$$\text{External costs per parcel} = \quad (\text{Eq.13})$$

$$\frac{Ed_v D + Ed_c D_{c,car}}{\theta s}$$

#### 4.4.6 Customer trips

Explorative research shows that home deliveries can be more beneficial than pick-up points in terms of VKT (Brown & Guiffrida, 2014; Collins, 2015; J. Edwards et al., 2010). The distance travelled by a customer ( $D_c$ ) depends on the consolidation factor  $x$ , the number of pickup points  $pp$ , and the area of distribution  $A$ . Assume that the area of distribution  $A$  is divided in  $pp$  sub-regions of equal area  $a$ , and each of these sub-regions is attended by a pick-up point.

To ease the calculations, assume that the area of distribution has a radius of size  $R$ , then each of this sub-areas have a radius  $r$  where  $r = R / \sqrt{pp}$ . If each pick-up point is assumed to be located in the centre of the sub-region, the average distance from a point to the centre is given by (Stone, 1991):

$$\bar{d}_c = \frac{2R}{3} \quad (\text{Eq.14})$$

Then, the total number of kilometres travelled in a two-way trip to all the pick-up points equals:

$$d_c = \frac{4Rx\sqrt{pp}}{3} \quad (\text{Eq.15})$$

To obtain the total VKT, the *mode choice* has to be considered. The mode choice determines which mode is used by the travellers. Since external costs from motorized modes are the most relevant, it is interesting to make explicit when car transport is used by the customers. The variable  $m(\bar{d}_c)$  is a function

of the average distance to the pick-up point and defines the percentage of customers using a car depending on the distance to the pick-up point.

Finally, the distance travelled by customers by car can be summarized as:

$$d_{c,car} = \frac{4m(\bar{d}_c)Rx\sqrt{pp}}{3} \quad (\text{Eq.16})$$

## 4.5 Numerical Case Study

The equations developed above allow comparing and analysing the use of pick-up points. Numerical data for the parameters were gathered through non-structured surveys with two of the biggest parcel logistics companies in Belgium, and a number of secondary sources. Below the parameters used for this estimation are explained. Do note that these cost factors vary from country to country and depend on the local context.

### 4.5.1 . Data Source

For distance-related costs ( $d$ ), a value of €0.22/km was estimated based on the costs declared by the carriers surveyed. The main drivers for this costs are the prices of fuel, tires, maintenance, and other components in use while the vehicle is traveling (Vanelslander *et al.* 2013). The estimated cost factor for time ( $t$ ) was €0.302/minute. This cost is based on the labour costs declared by the companies.

The surveyed companies agree that the marginal time contribution from an extra parcel ( $T_{s,v}$ ) is around 0.5 minutes. At the same time, by observing the behaviour of the drivers, a fixed service time per stop ( $T_{s,f}$ ) of around two minutes was derived.

Assigning external costs of transport is a more complicated task. An extensive literature has been dedicated to accurately monetizing different impacts of transport. Since this is not the goal of this chapter, the calculations in Korzhenevych *et al.* (2014) are followed. Assuming uniform characteristics of the vans, the external cost factor for a van in an urban setting in Belgium ( $Ed_v$ ) is €0.66/km. As discussed above, only the car trips are taken into account for the customer trips. For these trips, an external cost ( $ED_{c,car}$ ) of €0.58 per kilometre was used.

Using empirical data from Cools, Declercq, Janssens, & Wets (2009) the function of modal choice  $m(\bar{d}_c)$  is calculated as a piecewise linear function:

$$m(\bar{d}_c) \left\{ \begin{array}{ll} 0.708 \bar{d}_c & 0 - 0.2 \text{ km} \\ 1.141(\bar{d}_c - 0.35) + 0.242 & 0.3 - 0.5 \text{ km} \\ 0.723(\bar{d}_c - 0.75) + 0.423 & 0.6 - 1 \text{ km} \\ 0.367(\bar{d}_c - 1.5) + 0.606 & 1.1 - 2 \text{ km} \\ 0.137(\bar{d}_c - 2.5) + 0.675 & 2.1 - 3 \text{ km} \\ 0.090(\bar{d}_c - 4) + 0.765 & 3.1 - 5 \text{ km} \\ 0.002(\bar{d}_c - 6.25) + 0.794 & 5.1 - 7.5 \text{ km} \end{array} \right.$$

Finally, the failed deliveries rate  $f$  obtained from the companies is 9.3%, while the average number of parcels per stop  $\theta$  is 1.23. The numerical example uses data from the city of Antwerp. With over 500,000 inhabitants, this is the second largest city in Belgium. It has a radius  $R$  of 8.07 km. and an average car speed  $v$  of 15.61 km/h.

The figures below (see from Figure 16 to Figure 23) show the results after applying the model for the case study in the city of Antwerp. The figures display the resulting last mile costs for the logistics carrier and the external costs of E-commerce distribution. In the results, different levels of the percentage of parcels consolidated in pick-up points  $\left(\frac{ppx}{s}\right)$  and the number of pick-up points ( $pp$ ) were simulated. Varying these parameters allows

observing the sensitivity of the costs to different configurations and consolidation rates in the network.

At the same time, different values for the demand expressed in the number of stops are considered. The lower bound represents the average number of stops per day of a single carrier (around 350 stops). The upper bound is the double of the current daily demand of the city for all carriers (around 4,000 stops). By varying the demand, the impact when considering a single carrier or all the firms can be compared. It also allows observing the long-term behaviour when the demand for E-commerce increases.

By analysing the out-of-pocket costs of the carriers, the relevance of the consolidation factor is explicit. Maximum reduction of costs is achieved in a scenario of only one pick-up point and full consolidation. This scenario represents a central depot where all the customers can pick up their parcels, a rather idealistic situation since the customers will have no incentive to perform E-commerce under this condition. Therefore, it is interesting to analyse different percentages of parcels consolidated in pick-up points.

With regard to the number of pick-up points, the results show an increase of about €0.2/parcel moving from few pick-up points to a very dense network of pick-up points. While the difference is significant, the marginal contribution of an additional pick-up point may not be a sufficient incentive to pursue a denser network. The sensitivity analysis of the demand indicates a reduction of costs due to economies of density for different scenarios. To analyse the increase of the demand, it is useful to understand the implications of the structural growth of E-commerce and the aggregation of the demand of the carriers. This aggregation can be achieved by using shared infrastructure (e.g. shared pick-up points).

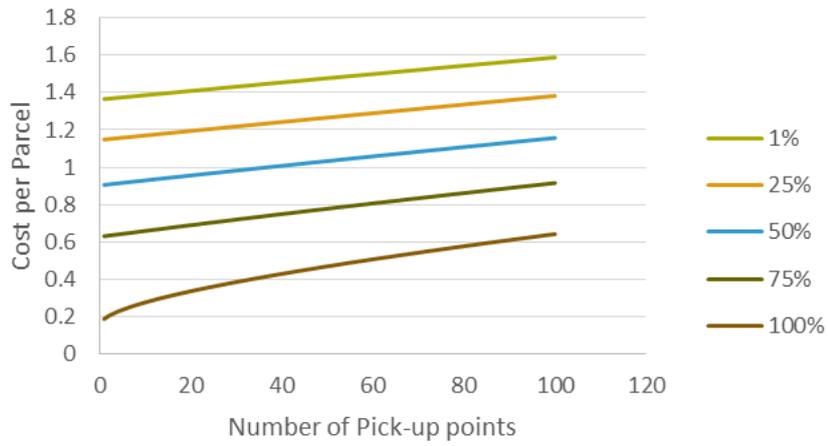


Figure 16. Operational cost per parcel vs. Number of Pick-up Points,  $s = 350$

Own composition

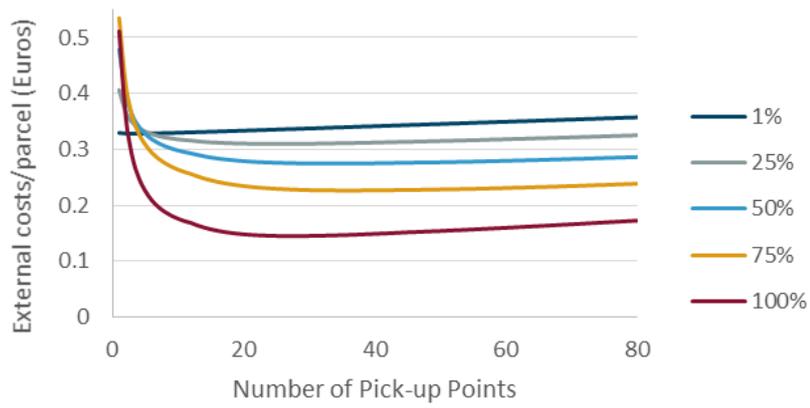


Figure 17. External cost per parcel vs. Number of Pick-up Points,  $s = 350$

Own composition

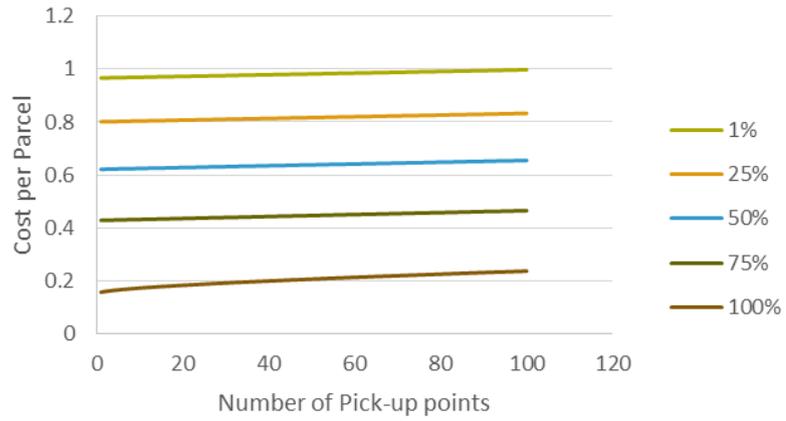


Figure 18. Operational cost per parcel vs. Number of Pick-up Points,  $s=2000$

Own composition

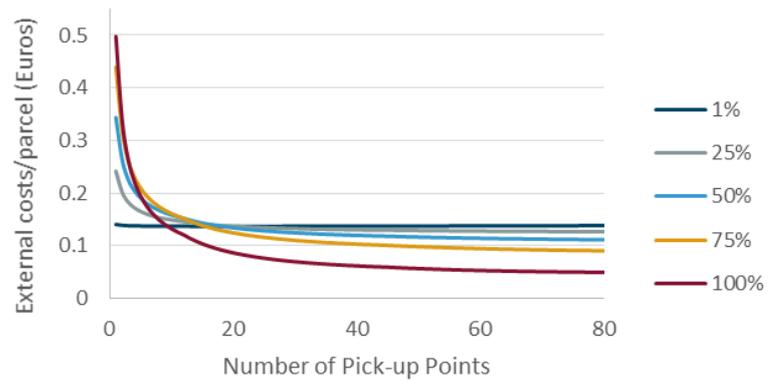


Figure 19. External cost per parcel vs. Number of Pick-up Points,  $s=2000$

Own composition

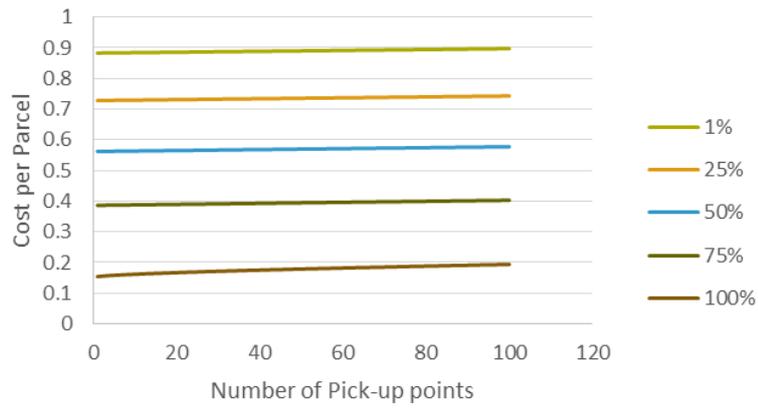


Figure 20. Operational cost per parcel vs. Number of Pick-up Points,  $s=4000$

Own composition

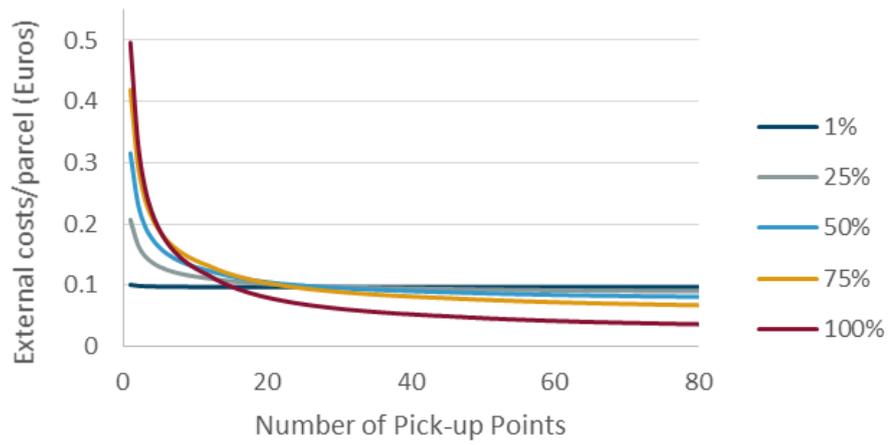


Figure 21. External cost per parcel vs. Number of Pick-up Points,  $s=4000$

Own composition

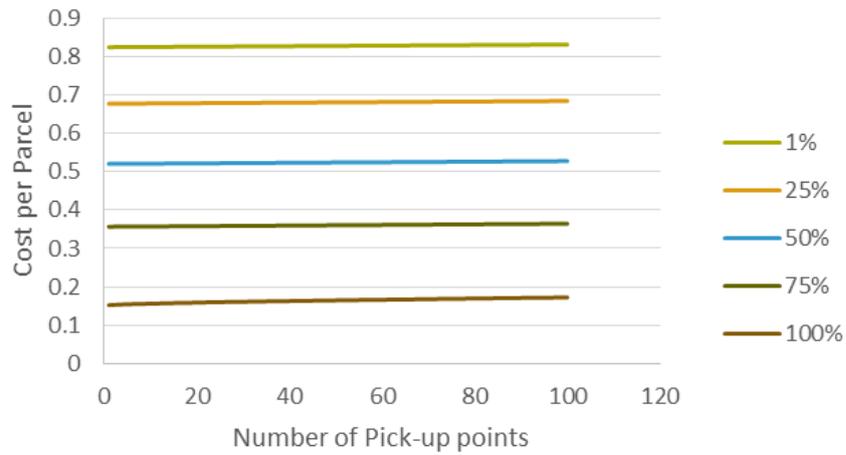


Figure 22. Operational cost per parcel vs. Number of Pick-up Points,  $s=8000$

*Own composition*

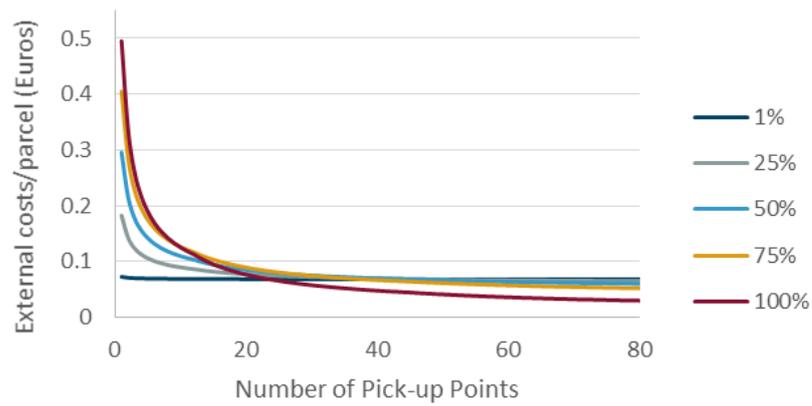


Figure 23. External cost per parcel vs. Number of Pick-up Points,  $s=8000$

*Own composition*

The external costs provide insight about the trade-off between having long routes performed by vans with relatively fewer private trips on the one hand and shorter van routes but longer movements from customers on the other. As discussed above, the calculated external costs correspond only to customer trips by car.

#### 4.5.2 Conclusions

From the results, it is possible to conclude that, as opposed to the out-of-pocket costs analysis, the worst scenario for external costs is having only one point of consolidation. The distance from the pick-up point to the customers as well as the externalities caused by the customers are maximized. In addition, these longer distances will yield a higher percentage of customers that will choose the car as the preferred mode to reach the pick-up point.

It can be concluded that in general, higher values of consolidation at pick-up points is beneficial for external costs. While consolidation in few pick-up points still implies higher external costs, the exponential decrease of the curves results in a strong decline of external costs with a limited increase of the number of pick-up points. Lower external costs are achieved by the combination of high percentages of consolidation in a limited number of pick-up points. The optimal value of pick-up points depends mainly on the level of demand, but due to the exponential decrease of the curve, a win-win situation can be achieved with few pick-up points.

The curves also show the sensitivity to the demand. The results of this analysis show that the external costs tend to become stable with increasing demand. It means that with the growth of the demand, the consolidation rate and the number of pick-up points will have less influence on the external costs.

Parcel carriers used to fewer stops per route in the B2B distributions are now struggling to reduce costs of B2C home deliveries. By using pick-up points, companies can reduce the length and travel time of the tours, which results in savings in the cost structure. In addition, this type of delivery will help alleviating the problem of the failed deliveries attempts. Some companies have opted for developing a dense network of pick-up points but less attention has been paid to the drop rate in each of these points. The results of this

analysis show the importance of the consolidation in the company's cost structure.

The demand for deliveries also plays an important role. Since demand is shared by different logistics providers which all invest in individual networks of pick-up points, the costs of investment will offset the benefits. Last mile specialists acting as white label carriers, can aggregate the demand and achieve economies of scale, not only reducing costs but also providing a more convenient and tailored service to customers.

The implication for E-commerce customers comes from the loss of convenience. Customers will have to spend time picking up the goods. However, if they already have to purchase goods from retail stores, they can combine those activities. For public stakeholders interested in achieving benefits in external costs, facilitating the combination of shopping activities by promoting strategic locations as retail stores, metro and railway stations or shopping malls will enhance the reduction of the number of private trips.

The customers' willingness to pay for home deliveries is an influencer that has not been explored in depth. Most websites do not differentiate the shipping price between pick-up points or home delivery. Therefore, aligning pricing policies with the logistics cost structure will also help achieve a more beneficial scenario.

Finally, the results prove that the external costs savings by the adoption of pick-up points is decreasing with the growth of the demand. This result may discourage a long-term involvement from public stakeholders. New schemes should be investigated to improve external costs in scenarios with high demand.

## 4.6 Conclusions

In this chapter, the novel and growing sector of E-commerce parcel deliveries was analysed. By identifying the structure of the market, it was possible to understand its complexity and the differences and similarities between different players. Another implication of the proposed typology is that a new segment defined as last-mile specialists are taking care of the complex distribution in cities. Special attention should be paid to the initiatives of urban delivery proposed by this segment.

The distribution network for E-commerce parcels was also described. Based on interviews with logistics carriers, the cost drivers were identified and analysed. The most relevant cost drivers were then used to develop a last-mile cost based model which allows comparing the benefits of two different alternatives for delivery: home delivery and the use of pick-up points.

The model considered several variables: the density of deliveries and its impact on the distance travelled; the consolidation factor and the individual trips to pick up the parcels; and finally, the failed delivery rate which was identified by the companies as a major issue hindering the efficiency of delivery.

The results proved that benefits can be achieved by using pick-up points when they consolidate a large percentage of the total number of parcels. The results also show that the contribution from the density of the network diminishes with larger networks of pick-up points. Therefore, the costs reduction can be achieved with a relatively low number of pick-up points.

There are limitations in the model that should be addressed to develop a more accurate evaluation. One is the assumption of a uniform distribution of the demand in the area. This assumption eases the estimations of distance but in practice, cities are heterogeneous, and depending on socio-economic and

morphological patterns, the demand will follow a different distribution. Under a heterogeneous demand, routing simulation may provide better estimations for length and travel time.

The travel time is also influenced by the average speed, which was assumed constant in this chapter. Again, cities are heterogeneous not only in space but also in travel time. Depending on the day and the time window of distribution, the vehicles will face different levels of congestion. Congestion not only affects the travel time but also the external costs, since less congestion in the city will lead to lower values of external costs. Considering the time factor in the model by defining time windows and including traffic data will allow for a better assessment and useful insights of the interaction between other transport activities and B2C E-commerce deliveries.

From the cost perspective, the fixed costs of deploying a network of pick-up points should be included. This cost was not considered because of the lack of data, but is important to correctly analyse the benefits of a shared network or a white label company. On the other hand, from the service level perspective, the implications on the receiver should be further explored. As discussed above, the loss of convenience can be associated with the willingness to pay, but this variable should be coupled with the type of product. This is because the customer's preference of pick-up points will vary according to the type of product.

Finally, further research can include trip chaining estimations for private car trips. Past contributions already discussed this issue, and it will add more accuracy since car trips sometimes are part of a chain of trips and pick-up points can be only one of the destinations.

# Chapter 5

## E-commerce last-mile in Belgium: developing an external cost delivery index <sup>7</sup>

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## 5.1 Introduction

During the last years, E-commerce has been growing at a two-digit rate, and an increasing number of customers use the business-to-customer (B2C) E-commerce channel to order products online and have them delivered at home. However, this raises new challenges for logistics since the supply chain has to cope with the increased fragmentation to satisfy the needs of customers. High competition, a consumer-driven economy, failed delivery issues, reverse logistics and environmental measures taken by policymakers are factors that increase the costs of delivering online orders. The consequence is that the last mile is regarded as the most expensive section of goods distribution (Fernie, Sparks, & McKinnon, 2010; Gevaers, Van de Voorde, & Vanelslander, 2014). Because of the complexities present in the delivery of E-commerce goods, improving the availability, quality and affordability of delivery solutions has been identified as one of the objectives to stimulate E-commerce growth (European Commission, 2013).

B2C E-commerce implies individual shipments, resulting in an increasing number of trips and kilometres (Eiichi Taniguchi & Kakimoto, 2004). E-commerceThe negative impact of B2C E-commerce last-mile has raised interest from urban logistics researchers, transport and retail geographers as well as practitioners and public decision makers (Weltevreden & Rotem-Mindali, 2009). The relevance of this discussion is that delivering the last mile is a trade-off between internal costs, externalities and the density of the deliveries. On the one hand, customer density is essential for achieving efficiency in the last-mile. Therefore, rural deliveries can be three times more expensive than urban ones (Boyer, Prud 'homme, & Chung, 2009; Gevaers et al., 2014). In the urban areas, the density is higher and logistics carriers benefit from lower costs. However, the residents undergo more negative impacts such as congestion, noise, and emissions than rural areas (Holguín-Veras, Thorson, & Zorrilla, 2008; Zito et al., 2013). At the end, the various

stakeholders have to manage different externalities in different regions, which underlines the difficulties associated to the last mile.

Still, little is known about the effects E-commerce has on transport and logistics. An unresolved issue remains whether urban areas generate higher transport demand for transport than their rural counterparts. Boschma and Weltevreden (2008), who were analysing the evolution of the retail sector, mention the incubation hypothesis in E-commerce adoption, highlighting cities as early centres of innovation. However, Clarke, Thompson, & Birkin (Graham Clarke, Thompson, & Birkin, 2015) find that B2C E-commerce is expanding rapidly and conclude that at least for the UK, B2C E-commerce is not exclusively restricted to urban areas anymore.

Linked with this discussion is the observation that while urban areas are more sensitive to the negative impacts of transport, spreading the externalities can result in an even worse situation. For example, Dablanc & Rakotonarivo (2010) argue that the CO<sub>2</sub> emissions are increasing dramatically because of the geographical dispersion of E-commerce usage in Paris. The very complex nature of E-commerce deliveries and the fact that it is a relatively new phenomenon imply that neither the spatial distribution of B2C E-commerce nor its impacts on the society are fully understood.

The aim of this chapter is threefold. Firstly, shedding light onto the spatial distribution of the demand of B2C deliveries by exploring where in Belgium the deliveries occur. Secondly, proposing a methodology to estimate the share of each region in the total amount of travelled kilometres to deliver B2C E-commerce goods. Finally, quantifying the negative impacts of the transport used to deliver in the last mile.

The analysis is performed based on data from a parcel delivery company in Belgium who will remain anonymous for privacy issues. Based on the data, we derive the number of vehicle-kilometres needed to deliver E-commerce

goods. Moreover, values for external costs are assigned based on the total travelling distance and depending on the morphological characteristics of the regions. Because of the high urbanization present in the country, is important to distinguish between rural, semi-urban and urban areas and weight the impacts on these different types of areas.

This chapter is organised as follows. Section 2 introduces the methodology, available data and the different parameters. Next, the approach used to derive the total VKT from the original dataset as well as the external costs included in the externalities index are elaborated. Section 3 presents the results and discusses the key findings of the study and the externality index based on the calculation of external costs. Finally, Section 4 concludes on the research, and identifies directions for further research.

## **5.2 Data and Methodology**

### **5.2.1 Data Source**

To estimate the impacts of B2C E-commerce transport for Belgium, we face the challenge of estimating the routes used for delivering (Gonzalez-Feliu, Ambrosini, & Routhier, 2012). Since this information is not easily available, those trips are estimated based on the location of parcel deliveries. The data used in this chapter corresponds to the B2C deliveries at address level performed by a logistics carrier in a four-month time window in 2015 in Belgium. For each address, the number of parcels is known. In total, 1,143 parcels were delivered during this period. The data is assumed to cover a share of about 10% of the total delivery market. A spatial bias could nevertheless exist because of regional differences in E-commerce behaviour and, therefore, logistics carriers. Due to the unavailability of information from other logistics carriers, we consider the available data as a proxy for the total Belgian population.

Predicting where the deliveries occur imposes some difficulties. The demand for B2C E-commerce is not spatially contiguous and depends on socio-economic characteristics such as age, income etc. (Graham Clarke et al., 2015). Two alternatives can be chosen to determine the destination of deliveries. One alternative is identifying the role played by socio-economic characteristics and indirectly predicting what the destination of the parcels is. The problem with this method is that in addition to the normal uncertainty in the predictions, many E-commerce deliveries do not occur at the home address (Gardrat, Toilier, Patier, & Routhier, 2016). In Belgium, around 30 per cent of deliveries occur in a different location than where the customer lives (Comeos, 2014). This percentage is even higher in other countries (Morganti, Dablanc, & Fortin, 2014c; Morganti, Seidel, Blanquart, Dablanc, & Lenz, 2014). A second alternative is therefore to directly use data from the deliveries executed by the carriers. This data provides a unique insight into the spatial pattern of deliveries.

The data is aggregated to the level of zip code. Therefore, the country is divided into 1,153 spatial units with an average area of 26.8 km<sup>2</sup>. The costs of external impacts will be calculated at this scale. For refinement of the external cost parameters, we attach the geographical morphology to each zip code based on the definition by Luyten and Van Hecke (2007). The authors identify Belgium's main urban agglomerations based on population density. These agglomerations, together with the functionally related suburban areas, form a city region. To ease international comparisons, these city regions are identified as urban regions. The communities surrounding these city regions, but tightly linked due to commuting flows, are classified as semi-urban. The remaining areas fall under the rural category.

### **5.2.2 Methodology**

In this chapter, we assess the external costs of E-commerce deliveries. The main objective of the external costs calculation is to reveal the hidden costs in the cost structure of the market. By monetizing the different impacts of transport, we can assess the external costs as a transversal indicator of the negative impacts of transport. Through the calculation of the impacts, we are able to weigh properly the number of total vehicle-kilometres travelled in rural, semi-urban or urban areas. Moreover, this allows developing a sustainability index for the entire country.

Because of the wide range of transportation impacts, various external cost calculations can be identified in the literature (Collins, 2015; Durand & Gonzalez-Feliu, 2012; J. B. Edwards et al., 2010). The common denominator amongst them is calculating the total VKT since more kilometres almost always imply more externalities. However, VKT can bring more or less externalities, depending on the population density of the area where they occur. For this reason, we try to consider this effect by not only calculating the VKT but by weighting them based on the affected area. In this section, we therefore firstly present the framework depicted in Figure 24 to calculate a cost index per parcel for different areas in Belgium.

### **5.2.3 Parameter Inputs**

In the first stage, parameters for the characteristics of the vehicles are obtained via the logistics companies, mainly the capacity and the average duration of the tours. The capacity is fixed at 100 parcels per van per day, which is an appropriate estimation from daily operations of the company. Next, the distribution centres are located. While the location of distribution centres from the carrier is known, in order to not disclose the data provider indirectly and to broaden the generalisation of the analysis, distribution centres are assumed to be located in the centroid of regions similar to the

distribution zones used in practice by various logistics carriers. Seven distribution centres are assumed to perform the delivery process in Belgium; this assumption is based on the current networks of different carriers. Finally, the addresses in the dataset were geo-located and an aggregated number of deliveries per zip code was obtained. Based on this, an expected number of deliveries per day was averaged.

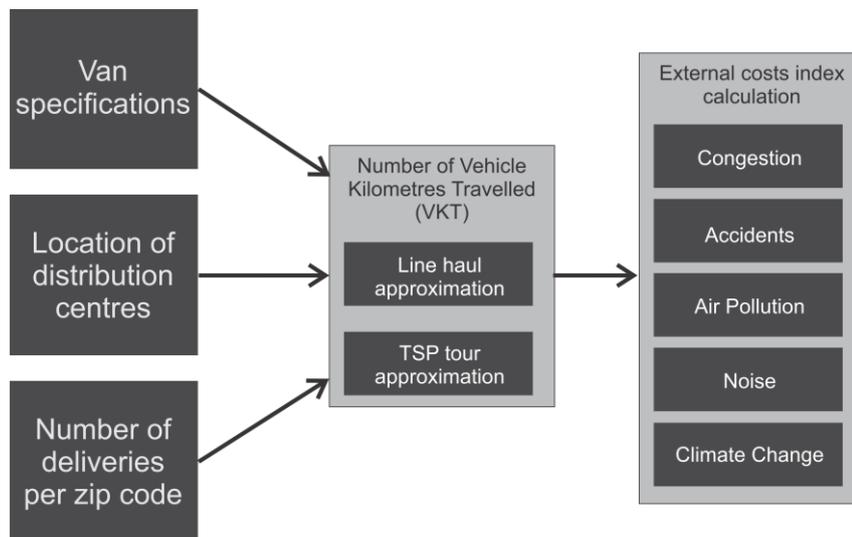


Figure 24. External costs index calculation framework

Source: Own Composition

#### 5.2.4 Calculation of total vehicle-kilometres travelled

The purpose of this estimation is to distinguish among the travelled distances from delivery vehicles in rural and urban regions at the zip code level. The total distance to deliver parcels consists of two components: one is the distance from the depot to the customers, known as line-haul. This part of the tour is traditionally dealt with by the capacitated vehicle routing problem (CVRP). The other part is related to the distance between customers, which is traditionally related to the travelling salesman problem (TSP).

However, to estimate the distances over the entire study area, we opt for an aggregated distance estimation instead of simulating the actual routes. For this purpose, Daganzo (1984) proposes the following intuitive formula for calculating the length of the line-haul when the distribution centre is located outside of the customers' area:

$$d_{lh} = \frac{2rn}{Q} \quad (1)$$

Where

$r$  = the distance between the distribution centre and the area

$n$  = the number of customers to be served

$Q$  = the capacity of each delivery van.

The number of vans is then represented by  $\frac{n}{Q}$ . Note that this expression is not necessarily an integer and  $\left\lceil \frac{n}{Q} \right\rceil$  would be the correct expression. However, the aggregate number will be a close approximation to account for the total kilometres in the long run.

For the second component, approximations for the TSP can be found in (Beardwood et al., 1959). The authors demonstrate that the distance to travel between a set of points  $n$  in area  $A$  converges to  $k\sqrt{nA}$ , where  $A$  is the area containing the customers expressed in square kilometres. The constant term has been estimated at  $k = 0.765$ , assuming compact and convex shapes for the areas where the tour is circumscribed (Figliozzi, 2009; Stein, 1978).

### 5.2.5 Calculation of external costs

Several types of external costs can be distinguished among in the literature. However, the figures proposed by the authors differ significantly. The variations in the factors are caused by differences in methodology and input values. In the following sub-sections, we discuss the selection of values to be used in this calculation. We choose to include the external effects of congestion, accidents, air pollution and noise, since the scientific discussion around those costs is in a later stage providing better figures for using in this analysis.

#### *Congestion Costs*

Congestion costs represent the decrease in speed caused by every additional vehicle using the road (Blauwens et al., 2014). In general, the calculation of these costs is done based on the characteristics of the road, the value of time for users of the road, and the relation between the number of cars and the changes of their speed. Since these characteristics are specific for every road, the analysis for this paper distinguishes among four different types of roads, inspired by previous studies on external costs of congestion in Belgium (Delhaye, Griet, & Sven, 2012; Gérard, Struyf, Sys, Vanelslander, & Van de Voorde, 2015)

The authors also distinguish among peak and non-peak periods, since the marginal impact by a single car will differ between these periods. Certainly, more detailed data is needed to capture the driving patterns of each van. When inquired about this topic, different carriers agreed that delivery routes start early in the morning, and resultantly high congestion is encountered in the line-haul. The delivery tours take place in off-peak periods during the day. This assumption is a major limitation on this study and should be addressed with detailed information on the average route timing and average speed statistics for the route.

### *Accident Costs*

Accident costs account for the risks that society bears when a vehicle is travelling. The most widely used methodology is proposed by Lindberg (2006). The authors define the marginal costs of accidents according to equation (2).

$$MCA = r(a + b)(1 - \theta + E) + rc(1 + E) \quad (2)$$

In Equation (2), three different cost components can be discerned: the costs for the person exposed to the risk ( $a$ ), the costs for the relatives and friends of the person exposed to the risk ( $b$ ) and the costs for society such as police, medical and output losses costs ( $c$ ). The term  $r$  considers the risk of a given vehicle to be involved in an accident calculated as the ratio between the number of accidents involving that vehicle and the number of VKT of that type of vehicle. The elasticity of the risk  $E$  estimates how much an increase in VKT will increase the risk. Finally, the parameter  $\theta$  calculates which share of these costs are already internalised by the insurance. Delhaye et al. (2012) estimate the risk of the number of accidents for vans in Belgium based on statistics of the BIVV (2010). The authors assume an elasticity of risk of -0.25 and an internalisation ratio of 0.22 based on the calculations from (Lindberg, 2006).

### *Air Pollution*

Air pollution from freight transport activities is a major concern for society. Four types of pollutants can be distinguished among as the most harmful: particulate matter (PM), nitrogen oxides (NO<sub>x</sub>), sulphur dioxides (SO<sub>2</sub>), and the toxic volatile organic compounds (VOC) (Korzhenevych et al. 2014). A number of studies have addressed the composition, emission, and dispersion

of these particles; however, attempting to monetize the damage made by these emissions remains a challenge (Blauwens et al. 2014).

Costs for the different types of particles in euros per tonne are investigated by the NEEDS project (Preiss & Klotz 2008). As such, they include a larger number of countries in Europe and consider not only health effects but impacts on crops, biodiversity, and other materials as well. An important cost differentiator among countries is the density of the population since it means a different degree of exposure to the contaminants. Finally, to find unit costs, these values are combined with the typical emissions produced by a van. In this model, we use the values proposed by Korzhenevych et al. (2014). As for the calculations, we assume a standard diesel Euro V light goods vehicle and, as before, we differentiate based on the characteristics of the area (urban/semi-urban/rural) and assume motorways for the line haul.

#### *Noise*

Typically, noise costs represent the annoyance and, in situations where it exceeds 60dB, health damage for the people exposed to it (van Essen et al. 2011). In contrast to air pollution, limited research has been conducted on this subject. Even more, data about noise levels is also scarce, with most modelling efforts based on the NOISE database, which is built based on the statistics reported by European Member States. The total noise costs are calculated by multiplying the number of people exposed to noise by the costs per person. While values for this cost are not easily obtained, Delhaye et al. (2012) suggests 10 euros per person. Finally, the costs are assigned to the different modes of transport based on the share of the modes and assigning a weighting value proposed by van Essen et al. (van Essen et al., 2011).

#### *Climate Change*

The climate change costs represent the damage caused by greenhouse gas (GHG) emissions. In Europe in 2015, 23.2% of the GHG emissions are

caused by the transport sector (European Commission 2016). Two different approaches can be used to estimate those costs. One is calculating the total damage costs caused by the emissions, while the other is calculating the necessary costs to achieve a given reduction level. The problem with the former is that the effects of climate change remain unknown, like the effect of other initiatives to tackle the problem. The second approach, known as avoidance costs, aims at determining the least cost option to achieve a given climate change reduction goal (van Essen et al. 2011). Since these goals already exist, it is more practical to estimate the latter costs.

The estimation of the avoidance costs allows setting a “carbon price” (CO<sub>2</sub>-equivalent). Once the carbon price is acknowledged for, similar calculations as for air pollution render the costs for the main pollutants (i.e. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O). We use the values proposed by van Essen et al. (van Essen et al., 2011) using the central value of 90 euro / ton proposed by (Korzhenevych, Dehnen, Brocker, et al., 2014) based on the current goal required to stabilise the global warming at 2°C.

#### *Other costs not included*

It is worth mentioning that a number of external costs were not taken into consideration in this analysis. The up- and downstream processes and the costs to the infrastructure (Korzhenevych, Dehnen, Brocker, et al., 2014), the lack of benefits from active modes (Delhayé et al., 2012), the scarcity of space, the contamination of water and soil or the energy dependence costs (van Essen et al., 2011) are topics that are still at an early stage of research. For this reason, the absolute number of the total external costs can vary significantly from one study to another.

#### *External cost per delivery index*

To analyse how the last mile of E-commerce deliveries impacts on the environment, we propose an index representing the average external cost to

deliver a parcel in each zip code. Different characteristics, such as the density of inhabitants, the number of goods demanded and the area's morphology, are considered when calculating the costs. The index corresponds to:

$$\frac{ec_m VKT_i}{n_i} \quad (3)$$

Where  $ec_m$  is an external costs coefficient based on the different costs for the each morphology  $m$  (i.e, urban, sub-urban or rural),  $VKT_i$  the number of kilometres travelled in the  $i$ -th zip code by the delivery van(s). The total costs of the tour are averaged by dividing by the number of stops/deliveries on each tour (assuming a delivery/stop ratio of 1:1).

## 5.3 Results and discussion

This section subsequently deals with the spatial distribution of B2C E-commerce deliveries, the VKT, and the externalities of B2C E-commerce transport, by applying the equations and using the data from section 2.

### 5.3.1 Spatial distribution of deliveries

Figure 25 displays the spatial distribution of the B2C E-commerce deliveries. At first glance, these deliveries seem to be concentrated in urban areas. As expected, the number of deliveries per zip code is highly correlated with the population per zip code. In fact, both variables show a correlation factor of 0.808.

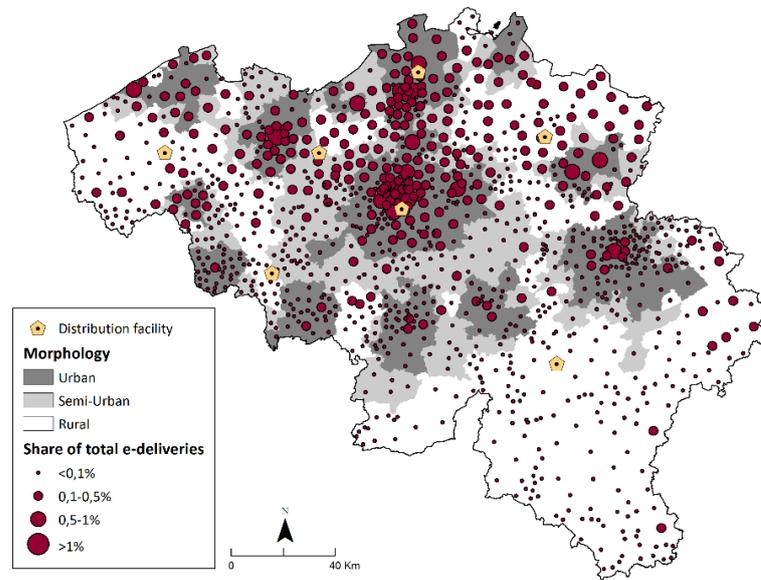


Figure 25. Spatial distribution of deliveries and location of simulated distribution centres

Source: Own Composition

Table 3 summarises the densities of population and deliveries according to the different morphological characteristics. Densities per square kilometre were calculated instead of absolute values to avoid the modifiable areal unit problem (MAUP) (Openshaw, 1984). Note as well that these values correspond to the owner of the data and therefore reflect its market share. By comparing these values, it can be seen that the average urban delivery density is double that of the rural one.

Table 3. Densities of population and deliveries per square kilometre.

	Average population density (habitant/sq.-km)	Average delivery density per day (deliveries-day/sq.-km)	Average daily deliveries per capita (deliveries-day/ thousand habitants)
Urban	1299.17	0.43	0.33
Semi-urban	345.19	0.25	0.72
Rural	219.59	0.20	0.91

Source: Own composition

However, some question may arise. The nationwide share of urban deliveries is 56%, whereas urban areas are populated by 76% of the population. In Table 3, the calculation of deliveries per capita is also shown. This value indicates that while more deliveries flow to urban areas, it is only a consequence of more people living in urban areas since rural areas are characterised by a higher number of deliveries per capita. This evidence is in line with the observations of other authors such as Clarke (Graham Clarke et al., 2015), who found high E-commerce usage in rural areas of the UK.

### 5.3.2 Vehicle kilometres travelled (VKT)

This section analyses the spatial distribution of the VKT. Two different scenarios can be expected a priori. One is that the urban deliveries may cause more VKT, because of their higher amount. On the other hand, rural deliveries are more scattered and further from the distribution centres, causing a higher number of VKT as well. As mentioned, we decompose the total VKT in two different components. The first is a line haul, which is the leg from the distribution centre to the zip code. The second is a tour, which is the loop between customers.

The line haul results in Table 4 show that the number of VKT in this leg of transport is significantly higher for the combined urban deliveries. One of the reasons behind this may be that the higher demand results in a higher number of vehicles, increasing the number of VKT.

*Table 4. Line-haul VKT estimation*

	Total VKT (km)	% of total
Urban	552.36	43%
Semi-urban	284.62	22%
Rural	432.86	34%

*Source: Own composition*

Another finding is that the regions with a higher number of VKT are located in the east of the country (i.e. the border with Germany and Luxembourg). The number of VKT in these regions can be biased by the selection of the distribution centres. It is also relevant to note that for this reason, some companies may deliver to these regions from the neighbouring countries, which is not taken into account in our analysis.

The results of the VKT in the delivery tours are shown in Table 5. Higher distances for the rural tours were found, despite the many stops in urban areas. This is the result of the combination of a high demand but rather low density in rural areas, due to the large distances between addresses. The total distance of the rural tours thus outweighs the total distance of the shorter but more frequent urban delivery tours.

Table 5. Delivery tour VKT estimation

	Total VKT (km)	% of total
Urban	2327.64	36%
Semi-urban	1627.83	25%
Rural	2473.92	38%

Source: Own composition

The VKT of delivery tours largely exceed the VKT of the line haul. In fact, for urban deliveries, the delivery tour represents around 80% of the total VKT. For semi-urban and rural deliveries, the share of the delivery tours reaches on average 85% of the total VKT. This only proves again the importance of the last mile, and how resource-demanding the final leg of transport is.

Finally, Table 6 summarises the total VKT to deliver B2C E-commerce goods in the different regions of Belgium. The results show that there is almost no distinction between urban and rural VKT. A number of factors were considered in this analysis, and both increasing and decreasing factors were encountered in urban and rural areas.

Table 6. Total VKT estimation

	Total VKT (km)	% of total
Urban	2880.00	37%
Semi-urban	1912.45	25%
Rural	2906.78	38%

Source: Own composition

As intended from the beginning of this chapter, the VKT themselves only measure the distance travelled, but the main concern lies with the negative

impacts of transport. The next sub-section therefore checks how these impacts are different among urban and non-urban areas.

### **5.3.3 Impact of B2C E-commerce transport on externalities**

As shown in previous sub-sections, urban agglomerations attract the majority of deliveries, and therefore, it would be plausible to infer that higher negative impacts from transportation occur in those areas. However, during these analyses, we included additional considerations resulting in an indication that E-commerce deliveries are not limited to urban areas but are dispersed around the country, resulting in an equal share of VKTs for urban and rural deliveries.

In this last step of the analysis, we construct an index to quantify the negative impacts in each zip code. This index represents the external cost per delivery by the data provider, per zip code. The results of this index are shown in Figure 26. The map shows that the negative impacts of E-commerce deliveries surprisingly tend to be more significant in the southern part of the country, which have a lower density of inhabitants.

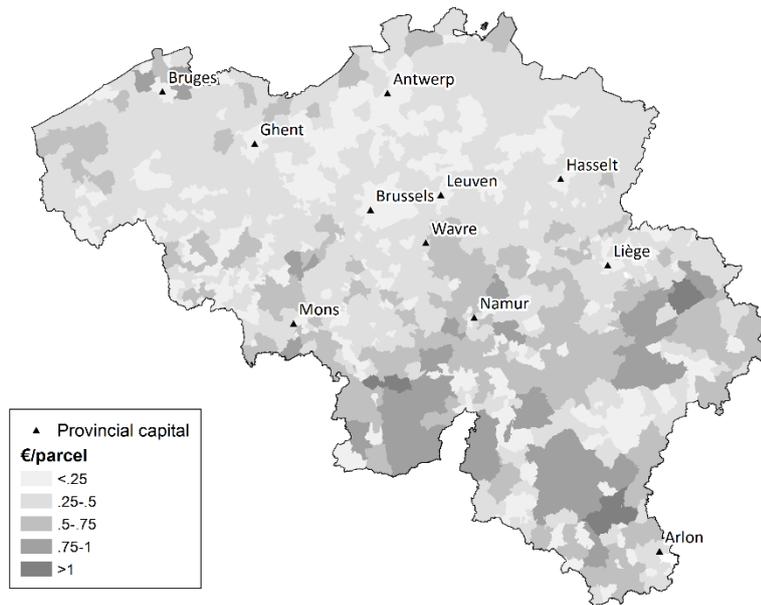


Figure 26. Total external costs of E-commerce per parcel delivered

Source: Authors' elaboration

If we assign a cost factor to represent the external costs based on the morphology of the different regions, the results indicate that the relative shares change considerably compared to when we consider VKT alone. Table 7 shows that the urban areas account for 50% of the total external costs caused by the deliveries of B2C E-commerce. The average costs per parcel and the share of the total external costs for each type of morphology indicate that, at least in terms of external costs, due to the economies of scale, the burden of delivering a parcel is higher in rural areas than in urban areas. These results can be useful for decision makers to estimate the negative impacts caused by a single delivery and to know where to focus the efforts to reduce negative impacts.

Table 7. External costs estimation

	Average cost per parcel (Euro/parcel)	Share of total costs
Urban	0.26	50.07%
Semi-urban	0.33	20.39%
Rural	0.37	29.54%

Source: Authors' elaboration\*

## 5.4 Conclusions and further research

In this chapter, data from B2C E-commerce deliveries in Belgium are examined to estimate the negative impacts of transporting those goods. We develop an external costs index to check the relation of externalities caused by the transport used to deliver E-commerce goods and the places where those deliveries occur. The geographical analysis of our data shows that urban areas still absorb most E-commerce freight transport. More than half (56%) of the deliveries in the country occur in urban areas and, according to our estimations, 50.07% of the total external costs derived from E-commerce for the country arise in urban areas. Therefore, the analysis shows that, at an aggregated level, urban areas are the most problematic place, in terms of external costs for E-commerce deliveries. Besides the exception of some border areas, most regions with a high sum of external costs are located near the largest cities.

Our results also show that the E-commerce consumption per capita is higher in rural areas. In other words, people living outside the city buy more online. At the same time, the total VKT in rural areas are comparable with urban ones, contrasting the hypothesis that rural areas have considerably more

kilometres due to their peripheral location. However, urban areas can also contribute to the VKT due to higher volumes and especially when they are not close to the distribution centres.

Finally, according to the index proposed in this chapter, the higher external costs per stop occur in rural areas (Table 7). This result reveals that even when the external costs per kilometre are lower in rural areas, the amount of VKT in rural areas, due the low density, will cause a higher negative effect. It is important to note the evolution of the spatial distribution of E-commerce deliveries since greater imbalances between urban and rural deliveries may shift the majority of the impacts to the latter regions.

The results from this chapter contribute to raising the awareness of managing the negative impacts of E-commerce logistics in urban and rural areas. Decision makers need to be aware of the importance of urban areas for both logistics carriers and population. The results of this analysis contribute to the assessment of different practices aiming at a more sustainable/efficient organisation of logistics in cities. The results also give an indication, based on the hypothetical growth of rural deliveries (Graham Clarke et al., 2015), on how the impacts of rural deliveries will evolve in the future.

For business practice, the findings in this chapter show potentials to reduce negative externalities of E-commerce goods transport. The evidence from this chapter shows that the majority of negative externalities are taking place in urban areas, and specifically in the last mile which is on average, according to our results, 83.6% of the total VKT of a tour. Nonetheless, the urban last mile also offers the possibility of aggregating and consolidating demand via alternatives such as delivery or pick-up points reducing in this way the total number of VKT. To this end, the composition and current practices of the market seem to merit special attention, because of the high pressure on delivery costs the market is experiencing.

To estimate the externality impacts, this chapter followed a bottom-up approach based on distance approximations at a zip code level. This can be a more efficient alternative to estimate the length of tours when only the origin and destinations are available. The chapter also discussed the selection of the external cost factors to be used. Significant research must be undertaken to have a “standard” source of external costs for transport. Another interesting question remains about the mismatch between the deliveries and the current customers. If customers receive their parcels at work or at a delivery point, the deliveries will not follow the demographics. This may result in an even larger share of the deliveries going to the urban areas as attractors of additional E-commerce deliveries demand.

Limitations of this research should be addressed in future academic exercises. The discrepancies between the distance approximations used in this chapter and the real distances travelled should be further investigated. Assumptions on the congestion levels can significantly affect the external costs factor; data from traffic at both regional and local level is needed to overcome this limitation. At the same time, a higher level of detail can be achieved by selecting a smaller spatial unit of analysis than the zip code level. The coupling with analysing alternatives for delivery such as reception at proximity points (Durand & Gonzalez-Feliu, 2012; Gonzalez-Feliu et al., 2012), bike deliveries (Anderluh, Hemmelmayr, & Nolz, 2016; Maes & Vanelslander, 2012; Schliwa, Armitage, Aziz, Evans, & Rhoades, 2015), off-hour deliveries (Holguín-Veras et al., 2005; Holguín-Veras, Wang, Browne, Hodge, & Wojtowicz, 2014; Li, 2015), or electric vans (Margaritis, Anagnostopoulou, Tromaras, & Boile, 2016; Roumboutsos, Kapros, & Vanelslander, 2014) would provide more insights for managing E-commerce logistics in cities.

## Chapter 6

# A location analysis of pick-up points networks in Antwerp, Belgium<sup>8</sup>

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<sup>8</sup> This article is originally published as Cardenas, I. D., & Beckers, J. (2018). A location analysis of the pick-up points networks in Antwerp, Belgium. *International Journal of Transport Economics*, 14(4), 557–570.

## 6.1 Introduction

E-commerce has been growing at a fast pace over the last years. Therefore, logistics services are challenged to provide home deliveries to the end-customer. Among those challenges is delivering in the last mile, which has been regarded as one of the most inefficient and expensive segments of the supply chain (Gevaers, Van de Voorde, & Vanelslander, 2011). The costs of the last mile of E-commerce are even higher because of three main factors: the fragmentation on shipments, the amount of failed deliveries and the need of return items (I. Cardenas, Dewulf, et al., 2017). At the same time, concerns about the sustainability of deliveries in cities are also increasing, driven by the steep growth of light goods vehicles (LGV) transporting parcels in urban areas (J. Visser, Nemoto, & Browne, 2014).

In recent years, the pick-up points have been rising as the main solution to tackle the cost challenges and sustainability issues of E-commerce (Morganti, Dablanc, et al., 2014b). From a pure efficiency perspective, pick-up points counter failed deliveries by offering an available place of reception. Moreover, these alternate locations potentially can increase the number of deliveries per stop while offering a place for receiving returning items. However, from a sustainability perspective, the opinions are mixed. While pick-up points can relieve the number of kilometres travelled by vans in residential areas, there are concerns about extra motorized trips triggered to collect items at such locations (J. Edwards et al., 2010).

The main problem is that while these alternative locations have been increasing exponentially in many countries, there is no alignment between the growth on the number of pick-up points and strategic or long-term planning. On the logistics companies' side, the pick-up points follow a contingency rationale where the companies aim to provide more options to the customers rather than a strategy to reduce the costs. On the public sector perspective,

urban planning for the growth of these logistics spaces is almost null and isolated from the mobility, economics or environmental agendas. While this is not necessarily a problem, the potential for sustainability gains can be hampered if the implementation of pick-up points is not harmonised with the freight management at the city level.

So far, few studies have analysed the spatial pattern of these new locations. Moreover, the accessibility in terms of distance and the availability in terms of time for these points has not been accounted for. To understand these characteristics for the pick-up points network, it is crucial to forecast how the customers will interact with the pick-up points. Therefore, the aim of this chapter is to perform a critical analysis of how well located these networks are with regard to the final customer. It considers different carrier networks given that normally each carrier develops its own networks. At the same time, it considers the demand in the study area by using a model that takes into account the socio-demographic aspects of the customer (Beckers, Cardenas, & Verhetsel, 2017). Finally, it analyses the current situation and provide recommendations to private and public stakeholders.

The rest of the chapter is organized as follows. Section 2 reviews the discussions around pick-up points in urban logistics studies. Section 3 explains the source of the data and the methodology used for the analysis. Section 4 presents the results from the analysis. Finally, section 5 draws conclusions from the analysis and provide recommendations.

## **6.2 Literature Review**

Unattended reception in the last mile has drawn the attention of researchers from the beginning of the 2000s. By calculating efficiency indicators, different papers have explained the attractive of delivering in an unattended location (Kämäräinen, 2001; Mikko Punakivi & Saranen, 2001). Song, Cherrett, McLeod, & Guan, (2009) calculate the potential cost reduction

provided by pick-up locations in contrast to home deliveries. However, these benefits do not consider the trade-off with customers using motorized vehicles to pick-up their parcels. In a study conducted in the food sector, Punakivi & Tanskanen (2002) identify the opportunities for unattended deliveries but argue that the demand for half-way deliveries is unknown. At the same time, the effects on traffic caused by customers picking up their goods are uncertain, because many customers could either chain daily trips with the picking up or choose non-motorized models for that purpose.

A number of papers have calculated the total number of VKT when delivering to pick-up points instead of traditional home deliveries. Durand & Gonzalez-Feliu (2012) analyse the impacts on the total VKT by using different network configurations in the e-grocery sector. The authors find that the best scenario is achieved when pick-up points are located close to residential neighbourhoods where the distance will discourage the use of picking-up by car. Similar results are found by Brown & Guiffrida (2014), this time calculating the carbon emissions of last mile delivery compared to pick-up by customers. Finally, Edwards, McKinnon, Cherrett, McLeod, & Song (2010) calculate carbon dioxide emissions from failed home delivery scenarios, finding that the majority of emissions come from personal trips to pick-up the parcels

Independently of the environmental impacts, during the last years, companies are moving toward delivery with pick-up points. Weltevreden (2008) provides insights in the growth of the number of pick-up points in The Netherlands, explaining that accessibility seems to be key for the success of these methods and customers expect at least a five-minute distance to such locations. Similarly, Morganti, Dablanc, & Fortin (2014c) analyse the spatial distribution of pick-up points networks on France and Morganti, Seidel, Blanquart, Dablanc, & Lenz (2014) compare the French situation to the one in Germany. In their findings, the authors stress the importance of locating

the points next to existing transport nodes such as railway stations and claim that pick-up points may reduce congestion and pollution caused by urban home deliveries.

Different authors agree that the behaviour is one of the main determinants for urban logistics (Holguín-Veras et al., 2005; Marcucci & Gatta, 2013). For example Collins (2015), observes the characteristics where pick-up points can encourage sustainable practices. The author concludes that short distances and convenient locations are key to alleviate the transport to the pick-up points. At the same time, he finds that fewer closing days and wider opening windows stimulate integrating into existing trips. Pick-up points have been studied from an economic and environmental perspective, however, still little is known on how these networks are growing, how their characteristics are linked to the customers and how they can provide environmental benefits.

This chapter describes with different indicators the main characteristics of the current pick-up network in Belgium from three different companies.

### **6.3 Data and Methodology**

Data for this research comes from the demand of home delivery services (i.e. the customers) and data from the suppliers of home delivery services (i.e. parcel delivery companies) provided in the city of Antwerp during 2016. The demand for E-commerce is calculated in Beckers et al. (2017). It estimates the total amount of potential buyers based on a survey of over 1,500 respondents concerning their online shopping behaviour (Comeos, 2016). The potential buyers are estimated at the level of the statistical sector. The average size of the spatial unit is 1.54km<sup>2</sup> (Jamagne, 2001), making it the highest detailed spatial unit of analysis available in Belgium. For this geographical visualisation, the total number of buyers are placed randomly within the sectors. Finally, the supply side data is represented by a sample of three companies that altogether account for an estimated share of about 10%

of the total market. From these three companies, the location of pick-up facilities is collected together with the opening and closing hours of the point.

This data is used in a transversal analysis. In a first analysis, the service area was calculated: the service area was defined as the area from which a pick-up point is reachable in only 5 minutes' walking time (Weltevreden, 2008). If the walking distance would be longer, people would be more reluctant to be delivered to the pick-up point and, in case they are, the car becomes the preferred means of transport, increasing the net VKT. Two indicators were calculated for measuring the service area. A first indicator, showing the share of the city's area that falls within the catchment area of all the pick-up points of each company. In addition, a second indicator, measuring the percentage of the inhabitants of the city who can reach a pick-up point of the company by foot in the five-minute period.

A second analysis consists of identifying the type of retail establishment where the pick-up point is located. Identifying what category of retail accommodates the pick-up points is important for two different reasons. Firstly, because the modal choice and the chances of trip chaining are partly a consequence of the type of goods sold at the pick-up point. Secondly, because the availability (i.e. opening and closing hours) vary between different retail categories, encouraging or discouraging the use of pick-up points. For this purpose, this chapter categorises each pick-up point of the different carriers into seven different retail categories based on the main purpose of the store where it is located. The categories used are the following: daily goods, fashion stores, leisure articles, household articles, transport establishments, general service establishments, and leisure stores. This is possible through the availability of the Locatus dataset.

The third analysis focuses on testing whether the pick-up point locations are clustered or not, compared to the others. To assess the coverage of each

carrier's network, a Clark and Evans test is done. The test measures the average distance between each pick-up point and its nearest neighbour. The value is compared with the same measure in a randomised network with similar characteristics. If the resulting ratio  $R$  is lower than 1, it points to a clustering of pick-up points in the network. A ratio exceeding 1 corresponds to an ordered pattern. The null hypothesis tests for a random organisation of the points, i.e.  $R=1$  with  $R < 1$  or clustering as the alternative hypothesis.

Finally, the fourth analysis is focused on the availability of the establishments during the day. This analysis checks two different characteristics. Firstly, the amount of days the pick-up points are open: the more days the point is open, the more likely it will be convenient for receivers. As an indicator, the average number of days for each carrier was calculated. Secondly, the number of hours the establishments are open in average for each carrier: this characteristic is important because traditional home deliveries are carried out during working hours, and one of the main benefits provided by pick-up points is extending those periods.

## **6.4 Results and Discussion**

The location of the pick-up points from the three carriers in the city of Antwerp is shown on Figure 27. The amount of pick-up points per carrier is depicted in Table 8. Some of the pick-up points are shared by two of the carriers, mostly in less dense areas. Simultaneously, in the map, the predicted number of E-commerce or potential E-commerce buyers is shown. The distribution of buyers is associated with the density of population, but other socio-economic variables such as income, age and education are in play. In the map, the match between buyers and number of pick-up points is explicit. While areas close to the city centre are well covered by pick-up points, areas with a large number of buyers but located

outside the centre are not well covered by the pick-up point networks from the carriers.

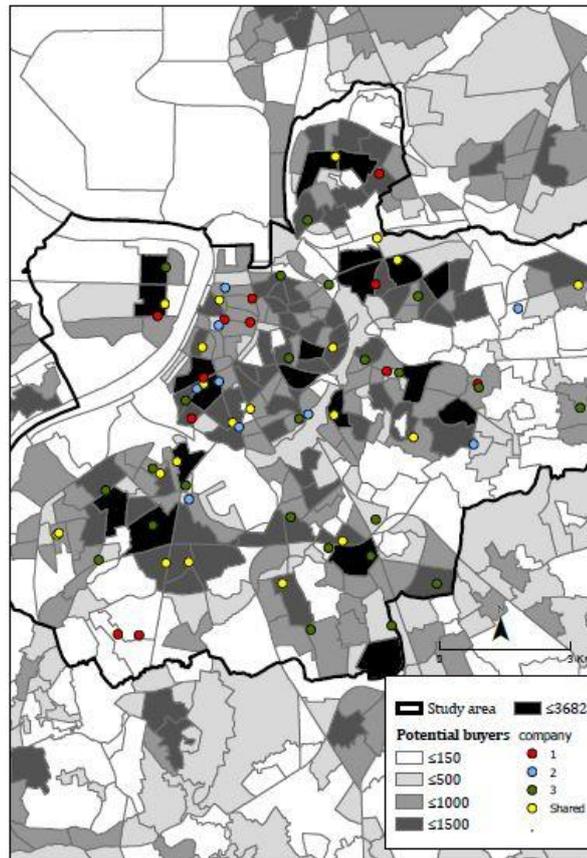


Figure 27. Selected carriers pick-up points networks in Antwerp

*Own composition*

Table 8 Total number of pick-up points for the selected carriers

*Own composition*

Carrier 1	Carrier 2	Carrier 3	Total
17	26	46	89

As indicated before, this chapter analyses the service area from the pick-up points located in the city by measuring the catchment area within five minutes

from the potentials buyers. Figure 28, Figure 29 and Figure 30 map the service area for the three different carriers. What is notable on the visualization of different areas is that the difference of spatial coverage between carrier 1 and 2 is much bigger than between carriers 2 and 3, while the amount of points is not as different. The coverage is quantified in terms of a five-minute walking distance in order to examine how well the demand is covered under that condition. Table 9 summarizes the findings. Firstly, it is clear that Carriers 1 and 2 have few pick-up points in the study area. In addition to that, some of those points are located in industrial environments without many potential buyers living nearby. These two combined observations explain the low amount of total population and within a five-minute walking radius. The analysis stresses also a more efficient coverage per pick-up point from carrier 2 compared to the other two carriers. However, the results also show that even with a large network from carrier 3, only 20% of the customers are located five minutes from the pick-up points; this could be a reason why the usage of the points remains less interesting as an E-commerce delivery alternative.

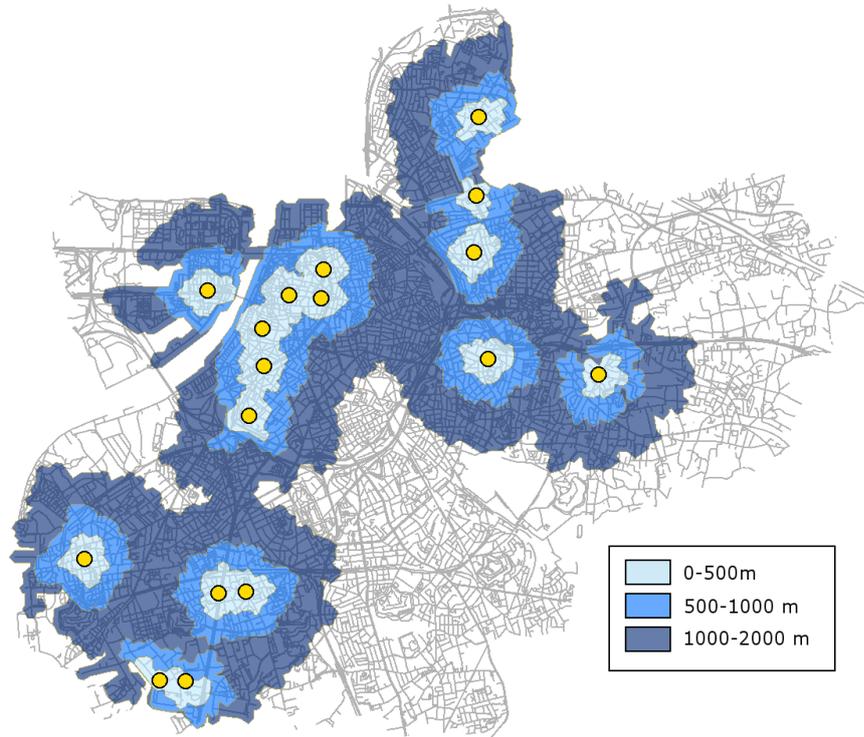


Figure 28. Service area for carrier 1  
Own composition

Table 9. 5-minute walking distance to pick-up points coverage for the different carriers.

Own composition

	Carrier 1	Carrier 2	Carrier 3
Area	3%	5%	9%
Population	8%	13%	20%

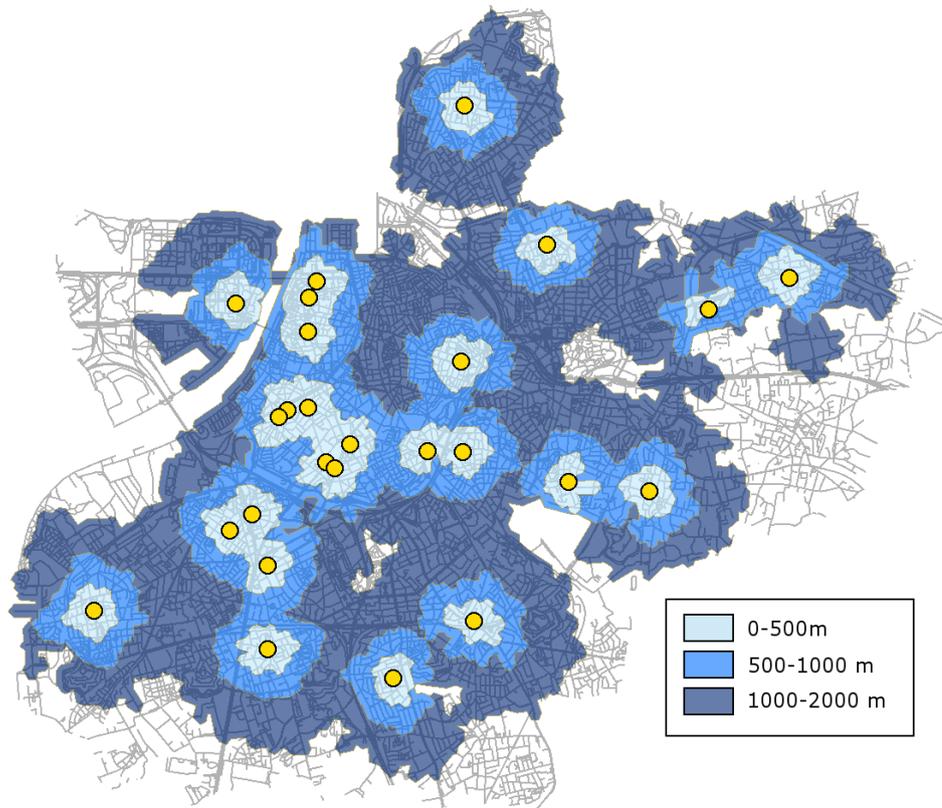


Figure 29.. Service area for carrier 2

*Own composition*

Next, the retail type of the establishment where every pick-up point is located is analysed. The results in Table 10 show that most of the pick-up points are hosted in daily goods stores, as seen in other countries (Morganti, Seidel, et al., 2014; Weltevreden, 2008). However, the majority of pick-up points from carrier 1 are located in service stores like copy shops, car rentals, and vendors of office material. These stores have two problems, firstly they tend to be located in the commercial part of the city. And secondly, the demand for the services is not in a frequent base, making it more likely that pick-up trips become dedicated trips. This of course holds more potential to reduce the number of car trips, assuming the parcels will be picked-up in combination with a shopping trip.

Table 10. Retail type of pick-up points.

Own composition

	Carrier 1	Carrier 2	Carrier 3
Daily goods	14%	85%	67%
Fashion	7%	12%	0%
Leisure articles	29%	0%	4%
Household articles	7%	0%	11%
Transport	0%	0%	7%
Services	43%	0%	7%
Leisure	0%	4%	4%

The section furthermore tested the relative concentration of pick-up points among the three carriers. With all p-values  $> 0.05$  for the Clark-Evans test, we can conclude that no carrier network exhibits spatial clustering. The results are shown in Table 11. Yet, the R-values do point to a slightly lower distance between the pick-up points for carrier 2. Given the latter's already lower amount, this tendency to clustering further lowers their overall coverage.

Table 11. Clark-Evans test results.

Own composition

	Carrier 1	Carrier 2	Carrier 3
R ratio	0.846	0.984	1.054
p-value	0.1128	0.4384	0.7561

Finally, the availability of the points was also quantified. In this indicator, Carrier 1 performs below the two other carriers. At least six days open will be a desirable option for customers wanting to pick up their parcels outside

working days, however, the average amount of days that pick-up points are open for Carrier 1 is less than six. The indicators pointing to the opening and closing hours slightly favour Carrier 2 and show how poorly Carrier 1 scores on this indicators. Also, it is notable that the frequency of late closing time is higher than an early opening time. However, given the variance on the type of retail where the pick-up points are located, it is difficult to standardise the thresholds for early opening or late closing times.

*Table 12. Availability of pick-up points.*

	Carrier 1	Carrier 2	Carrier 3
Average days open	5.5	6	6.0
% open <8AM at least 1 day	35%	80%	72%
% open $\geq$ 7PM at least 1 day	18%	18%	24%

*Own composition*

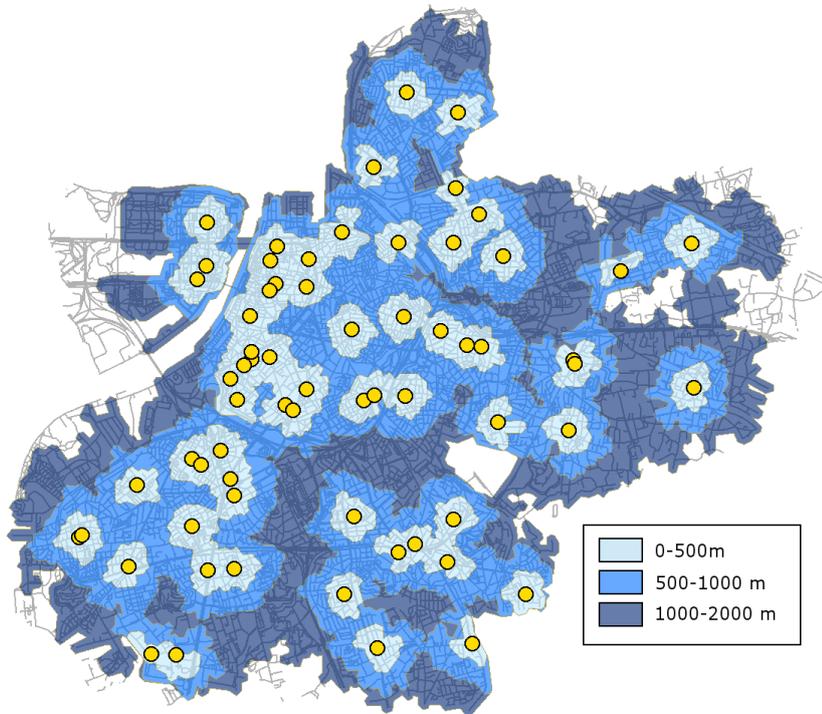


Figure 30. Service area for carrier 3

*Own composition*

## 6.5 Conclusions and recommendations

The concerns on the fast growing pace of online shopping, coupled with the explosion of light goods vehicles in urban areas, has shifted the attention towards sustainable methods to handle the last mile of E-commerce. One of the options that has received more attention is the unattended delivery and posterior pick-up by the customer at specific locations established by the different carriers. Pick-up points not only counter the failed deliveries but also can aggregate several customers in one place, therefore reducing the number of driven kilometres by the delivery vans, a desirable effect from a sustainability perspective. However, research has indicated that these effects

may not be realistic or even counterproductive under certain conditions where the personal pick-up trips are neglected.

The pick-up points pose then a trade-off situation for urban logistics. On the one hand, the carriers can see their productivity enhanced with points where the time to deliver a parcel reduces significantly (i.e. more parcels per stop). From the receiver perspective, the utility is mixed, logistics companies deliver the parcel at a pick-up point instead of at home and some receivers lose convenience because of that; however, for another kind of customers, it even increases the convenience when they can receive the parcels at different time windows than the ones from logistics carriers. For the public authorities, it represents a new challenge; accommodating logistics facilities within the inner cities. Two questions should be considered. First, is an explosion of these locations sustainable, moreover sometimes overlapping among them? Second, are pick-up points attracting more personal motorized trips than the normal shopping trips?

The challenge with the personal trips has to deal with two different behaviours: firstly, the likelihood of combining picking-up trips with other activities, and secondly, the likelihood of not using motorized vehicles to retrieve the parcels. Both behaviours, as shown in the literature, are affected mainly by the decision of where the pick-up points are located. Unfortunately, this decision most of the time does not follow a sustainability rationale, instead, it follows short-term goals from the carrier companies who pursue cost reduction and offer more appealing options to their customers.

This chapter proposes a set of indicators based on variables that in turn, affect directly the customers and their mobility behaviour towards pick-up points. It focused on the distance to the customers, the availability of the points and the type of retail where the pick-up point is located. The inspiration for these variables came from different papers around the subject of sustainable

practices for pick-up points. While the battery of indicators was tested in the city of Antwerp, the estimations can be easily extrapolated to another context with a minimum requirement of data. At the same time, should sustainable strategic planning be part of the decision process to locate pick-up points, the variables investigated in this chapter provide a framework to achieve those objectives.

In the analysis in the city of Antwerp, it is clear that pick-up points networks are in an immature state, and convenience for a sustainable mobility for customers is poorly addressed. It was found that on average, pick-up points are available six days of the week, decreasing the chances to combine the pick-up with other activities the receivers may need to do. Also, the opening hours of the pick-up points follow the working time schedules generally. In conclusion, an asynchronous schedule with regard to working time is desired since this will increase the likelihood of combining the trips to retrieve the parcels with other activities the customers do normally.

There was no indication of clustering among the different networks from the carriers. This should be avoided since the efforts for reducing the number of VKT will overlap in some areas of the city while neglecting other parts. At the same time, discussion about which type of retail is better to allocate pick-up points should be extended. From the analysis here, a tendency is observed towards daily goods stores similar to what was observed in the Netherlands (Weltevreden, 2008). Nevertheless, the schedules of these stores may not be the most suitable for the customers' convenience. Unfortunately, automated parcel lockers were not considered in this analysis, the reason for this is that the volume of the carriers is not high enough to own such a network, because of the investment to deploy it is considerable. However, it is true that lockers are independent of retail schedules and therefore have higher availability than the pick-up points.

From the results, it is advisable to share the pick-up points among different carriers. This would allow the consumer to receive parcels via multiple carriers at one place, reducing the total amount of pick-up trips. At the same time, the grouping of deliveries at the final destination would provide consolidation opportunities between the carriers. Moreover, it can better perform in terms of reaching a larger amount of people within a five-minute walking radius. With a better notion of where pick-up points should be located and with a dedicated purpose, a better urban planning can be achieved equipping pick-up facilities with loading and unloading bays, convenient schedules and accessibility for picking-up.

This study can be useful for the different stakeholders that might be involved in the decisions regarding the implementation of pick-up point's networks. Carriers can better address customers with a set of indicators more coherent with the needs of e-shoppers. Recommendations for practitioners are various. Firstly, companies should work on the availability of the pick-up points, especially focusing on making the time windows different to the office hours, because that is exactly the main benefit of the pick-up point. Secondly, they need to work on collaborative schemes where parcels can be picked up at a few strategic points or "pooling" the pick-up points. This type of schemes have different implications. It can be translated in an increase in the productivity by reducing the time to deliver a parcel; it can reduce the kilometres travelled by the customers to pick up a shipment in different points. In any case, logistics companies will have to offer another differentiation factor on the last mile.

At the same time, many carriers are aware that the current last mile of E-commerce is inefficient and unsustainable. In this chapter, we aim to describe the rationale that will lead to a more efficient last mile by using pick-up points. For public stakeholders, the contribution of this chapter lies in shedding light on the relation between the location of the points and the

sustainability they may bring. Moreover, this chapter also intends raising awareness and recommends including these type of logistics platforms in the logistics and mobility planning instruments.

Different questions about the operation in pickup-points remain for further research. Can pick-up points provide the features of a consolidation centre at a smaller scale? Research has shown that only by harmonising the conflicts between different stakeholders, this type of organizations can be successful (Nordtomme, M. E., Andersen et al., 2015). However, to which extent can collaborative urban logistics concepts (Gonzalez-Feliu, Morana, Grau, & Ma, 2013) be applied in the pick-up points concept? Is it better if different carriers pool their deliveries at a single point? Can customers of the same neighbourhood provide the very last mile? Can a single logistics carrier take care and organize the returns for different e-shops?

Additionally, research should address the following specific limitations on the current study. The variables affecting each stakeholder (i.e. receivers, carriers and public authority) can be monetised as internal and external costs in order to be compared. In this way, new research can aim for an optimal configuration of pick-up points. The largest carrier in the country was not included in the study; incorporating higher volumes will allow having a better view of the situation and to provide better recommendations. Finally, modelling the implications of different locations and configurations and estimating the number of VKT could provide better scenarios where both carrier efficiency and sustainability objectives are met.

# Chapter 7

## Coordination in Delivery Points Networks for the E-commerce Last-mile<sup>9</sup>

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<sup>9</sup> This chapter is a work in progress, it was published in the proceedings of the last City Logistics Conference as: Cardenas, I., Sanchez-Diaz, I., & Dewulf, W. (2017). Coordination un delivery points networks for the E-commerce last-mile. In *City Logistics Conference X, Phuket Island, Thailand*.

## 7.1 Introduction

Over the last decade, E-commerce shopping has been growing at two-digit rate year on year. Because of such a buoyant growth, logistics have been facing new challenges to keep the pace of E-commerce. For the last mile of the distribution, logistics providers had traditionally focused on finding the most efficient solutions for the business to business (B2B) segment with good results; but home deliveries pose a new set of barriers for efficiency, such as, failed deliveries, fragmentation in the deliveries and reverse flows (Ferne et al. 2010). As a result, the rise in home deliveries is entailing additional costs and a higher level of complexity for the last leg of the supply chain that logistics providers are still seeking to cope with (Song et al. 2009; Gevaers 2013). First, not all the shopping trips can be assumed to be substituted for, a number of studies have found that E-commerce demand is complementary rather than substitutive (Weltevreden 2007). Second, the number of light goods vehicles (LGV) in densely populated areas is becoming an issue and city authorities are taking measures to control the traffic of these vehicles especially during peak hours (Browne et al. 2010). Third, e-tailers are using short lead times and high delivery speed as a competitive difference and next-day, same-day or even one-hour options are becoming more often available. Ensuring shorter lead times and fast deliveries lead to lower consolidation, higher frequency of shipments and therefore, more transport demand.

As a response to the last mile challenges, pick-up points networks have become a growing phenomenon all over the world. For logistics providers, pick-up points are mainly used as a backup location when the recipient is not present at the moment of delivery, reducing in this way the number of failed deliveries. It is common that receivers are allowed to return their parcels in some pick-up points to alleviate the management of reverse flows. But more importantly, if the pick-up points is chosen as the final delivery point for a

number of receivers, companies could increase the number of deliveries per stop, reducing significantly the delivery costs.

From a sustainability perspective, different studies have addressed the impact of pick-up points on the environment. So far, the result of these studies is ambiguous. Most authors agree that pick-up points deliveries may not perform well compared to home deliveries because collection trips trigger individual car journeys, worsening the impacts on the environment. However, factors such as the trip chaining in those trips (Edwards et al. 2010) and the usage of other modes of travel (Brown & Guiffrida 2014) are yet to be fully integrated into the analysis. Finally, in addition to the negative impacts, additional collection trips are inconvenient and transfer the costs of the last-mile to the final receiver. Most studies are limited to a single perspective either from the companies or a sustainability perspective. The drawback of analysing this problem from a single perspective is that there can be a conflict between the objectives of the different stakeholders and only the coordination of those objectives can lead to a better system. Moreover, most analyses consider pick-up points as a contingent solution for failed deliveries, while observation suggests that current pick-up points are a component of the network. The aim of this chapter is to propose a framework to analyse the performance of pick-up points, not just as a contingency solution but as a functional part of the distribution network. At the same time, to assume more holistic perspective considering the utility functions of the different stakeholders participating in E-commerce deliveries' logistics.

The remaining of this chapter is organised as follows. Section 2 reviews the previous literature. Section 3 describes the modelling framework. Section 4 builds a numerical example with data from the case and discuss the results from the case. Section 5 presents the conclusion, implications and research directions.

## 7.2 Literature Review

Solutions for home deliveries logistics have been explored since the dawn of E-commerce. The success of e-tailers has been very much dependent on its capability of providing a reliable logistics service and the companies supplying goods faced a number of challenges in the “last mile”. One of the characteristics that has received the most attention is the attended/unattended delivery problem. Coordination between the seller and the receiver must be achieved to deliver the order when is needed but, attempting to agree on a specific delivery window with the receiver, leads inevitably to inefficiencies in the routing, increasing the costs (Gevaers et al. 2014; Ehmke & Mattfeld 2012).

Particularly, in the groceries sector, early research shows the benefits of allowing unattended deliveries to decrease the costs in the last-mile. Punakivi, Yrjölä, & Holmström (2001) explored two different alternatives for unattended deliveries: one locating at receivers’ house reception boxes, and the other delivering with a secured and isolated container which can be left unattended. By conducting a simulation study in Helsinki, their results showed that with unattended deliveries, a 60% reduction is achieved in logistics costs. The authors also suggest that unattended deliveries will be interesting for receivers because it reduces the constraints of an agreed time window.

As pick-up points expanded in different countries, in the final years of the last decade, interest in the impacts of pick-up points raised among the academic community. One of the first studies was conducted by Brummelman, Kuipers, & Vale (2003) in The Netherlands. The authors survey critical variables when evaluating the performance of pick-up points: the mode choice of receivers to pick up the parcels, the accessibility and the trip chaining. According to their findings, 89% of the receivers use a car to pick-up the parcels, the pick-

up points is located 6 kilometres away on average and 56% of the respondents chains the pick-up with other trips. The results show a positive reduction of net kilometres by using pick-up points.

A common assumption for most of the evaluations is that when a failed delivery occurs, the receiver should collect the parcel at the logistics provider's depot. McLeod, Cherrett, & Song (2006) contrasts this situation with the use of pick-up points to collect a failed delivery. In a survey performed in the city of Winchester, they find that 48% of the respondents would walk to the pick-up points and 43% would use the car. While the distance for receivers decreases, the travelling distance of the LGV is in most cases higher because of the addition of extra stops. A similar analysis by Esser & Kurte (2007) in Cologne to evaluate the benefits of the DHL *Packstation* finds reductions for both receivers and LGV. However, in another similar study by Song et al. (2009), this time in West Sussex, UK, the authors find that for failed deliveries rate 30% the travelling costs for the logistics provider when visiting pick-up points are greater than making the redeliveries. This result occurs because deliveries and redeliveries can be organised in an efficient way within the tour, while pick-up points are additional locations that suddenly appear when a failed delivery occurs.

Sustainability is also considered in the evaluation of the pick-up points, mainly by measuring the net kilometres travelled by both LGV and receivers. Edwards et al. (2010) expand the analysis in West Sussex to include the CO<sub>2</sub> emissions produced by the net travelling. The authors explain that emissions coming from failed deliveries are dominated by the individual trips made by the receivers to collect the parcels. In that sense, the emissions will be negatively correlated to the distance from the pick-up points to the final receiver. Using an analytical model, Brown & Guiffrida (2014) explore the trips to collect deliveries at the logistics provider's depot. In contrast with previous publications, parameters for trip chaining and the modal choice of

the receivers are included. The authors find that when a low number of receivers (around 40) are served, lower emissions are achieved if all of them collect the parcel in a central depot. However, once the demand is higher than the break-even demand, home deliveries are strictly better in terms of emissions.

Weltevreden (2008) analyses the current pick-up points network in The Netherlands. In the study, indicators of accessibility are constructed based on the spatial distribution of population and the location of the pick-up points. The author argues that a five-kilometre distance between pick-up points and receivers is critical to the success of pick-up points, but with the current network in The Netherlands, only 50% of the population can reach a pick-up points within that distance. It also discussed that a more dense network will allow higher adoption at the expenses of higher distribution costs for the logistics providers. Since the density of the network is crucial for both economic and environmental indicators, the question that arises is related to the cost of deploying such a network. At a first glance, deploying a network requires investment from the companies (Durand & Gonzalez- Feliu 2012), however, a pick-up points can also be located in an existing network. Carriers are deploying their pick-up points networks by using existing small stores (Morganti et al. 2014). In this business model, the logistics provider pays a fee per parcel delivered (Weltevreden 2008), easing the deployment of a denser network.

An issue that has been not completely attended is the behaviour of the receivers towards the pick-up points. Weltevreden (2008) constructs a regression model to investigate the relation between socio-economic variables and the adoption of pick-up points, finding that the experience on E-commerce, the number of working hours in the household, and a distance of fewer than five kilometres are the main variables explaining the use of pick-up points. Finally, Collins (2015) investigates several attributes of the pick-

up points and how these attributes are related to the impacts on the environment. By using stated choice survey data in Sidney, the author concludes that the density of the pick-up points network will have beneficial changes in the mode choice of the receivers, and, at the same time, locating pick-up points together with existing shopping centres will also have beneficial impacts because of the chaining of activities. Time windows for collecting parcels at the pick-up points has also positive effect since it facilitates the trip chaining. The author also discusses that a modelling effort that incorporates the behaviour of receivers will allow a better understanding of the environmental impacts from pick-up points.

As seen above, the analysis of pick-up points as an alternative for E-commerce deliveries has received attention in the urban logistics literature. The literature has been focused on the additional trips caused by failed deliveries, and from the results discussed above, pick-up points seems to be beneficial in the net VKT. Many of the previous efforts compare the pick-up points with the collection at the depot of the logistics provider. However, this assumption may be not longer realistic. pick-up points are already part of the distribution networks and they are being used not only as a contingency for failed deliveries but as a chosen place of delivery. For logistics providers in a very competitive market, this situation is an advantage: delivering multiple parcels at the same pick-up points reduces significantly the costs of delivery. If the total VKT are reduced when using pick-up points, a win-win situation may be achieved.

As shown in the literature review, there is a lack of a holistic approach that considers the cost and benefits of the different stakeholders. At the same time, the objectives of receivers, society and logistics providers have not been fully integrated as parameters to design or assess the networks to distribute E-commerce deliveries. In this chapter, we contribute to filling this gap by proposing a network design model for E-commerce goods that includes pick-

up points and conciliates the benefits and drawbacks for the different stakeholders involved in E-commerce city logistics.

### **7.3 Conceptual Framework**

Both the literature review and the field observation reveal some conflicts among stakeholders with regard to the implementation of pick-up points in the network design. The purpose of this section is to identify the factors affecting the decision of pick-up points density, and how this decision affect the different stakeholders. Analysing the factors that affect the design of a pick-up points network for each stakeholder will provide a better understanding of the implications of such design. It will also allow exploring the trade-offs between the different objectives and support the decision-making process for pick-up points density/location both in the cases when logistics providers are the ones deciding and when the public sector can participate in this decision.

#### **Receivers**

In the current early stage of development, the receiver has a significant market power over the sellers, and customer satisfaction is critical for sellers that want to increase their market size. This situation has led to sellers ensuring free shipping, free returns, fast delivery and several attempts to deliver as a common practice, placing an enormous burden on E-commerce logistics providers. In essence, the receivers' market power requires sellers to ensure a high service level, sellers pay to logistics providers to ensure this service level, and logistics providers design a distribution network that satisfy these requirements. As E-commerce market is becoming more mature, the service level depends on the price the receiver is willing to pay for and logistics companies are rapidly adapting. Based on the analysis of the literature from

the perspective of the receiver, the following factors are relevant for structuring the pick-up points network.

- *Shipping costs*: the costs of shipping are mainly a part of the marketing strategy when it comes to E-commerce. A number of e-tailers offer free shipping for orders over a given amount, and for many e-tailers return shipments are also free. However, in cases when the receiver can set up its own service level based on the costs of shipping, this factor becomes particularly relevant for logistics decisions. For instance, Amazon Prime enables receivers to pay a subscription in order to improve delivery time. Therefore, Amazon has to adjust its logistics to fulfil such requirement. In some countries, the pick-up points is part of the options available for receivers and the receiver decision plays an important role defining the willingness to pay for travelling to collect the parcel. However, few websites offer a reduced price for being delivered in a pick-up points, thus, at this moment, most of the times the receiver does not have an incentive for choosing not to receive the parcel at home.
- *Accessibility*: The level of accessibility determines how far and for how long the receiver must travel to collect the parcels. This factor is associated with the morphological characteristics of the location (i.e. rural or urban), and the availability of transport. pick-up points can be easily located closer to urban receivers than to rural receivers, but requirements are different, modes of transport vary and their value of time also changes drastically from one place to the other. The same applies to receivers with reduced mobility which value proximity higher.
- *Availability*: Finally, the routine and total working hours in the household have an impact on the decisions over pick-up points (Weltevreden 2008). Some receivers do not have time to receive personally their E-commerce deliveries. Since for these receivers home delivery is not an option, the location for the pick-up points is the main criteria. It is common that each

logistics provider operates its own network and receivers have to collect goods from different pick-up points. This situation can lead to undesirable situations because numerous—often motorized—extra trips to the pick-up points are being generated. However, if the pick-up points is located in train stations, shopping centres, or other common locations, the receivers can chain the trips with other activities, and not allocate extra time for collecting the parcels.

The main motivation of the receiver is to have a convenient access to the goods purchased via E-commerce. The value of time seems to be a determinant parameter. As discussed above, nowadays, receivers lack of incentives to go to a pick-up points other than restrictions, but if the costs are internalised (i.e. reducing the price of shipping when it is in a pick-up points), then the decision of the receiver will impact even more on the pick-up points network design. The utility function for receivers can be summarised in the following expression:

$$U_R(x) = \alpha + \beta_1 C(x) + \beta_2 Acc(x) + \beta_3 Av(x) \quad (1)$$

Where  $x$  is the number of pick-up points,  $C$  is the shipping cost,  $Acc$  is a measure of accessibility and  $Av$  is a measure of availability.  $\beta_i$  are parameters to be calibrated, and  $\alpha$  is a part of the utility not explained by these factors.

## 7.4 Logistics providers

So far, the picture for logistics providers has been the opposite than for receivers. Logistics providers operate in the traditional competitive market with numerous buyers and sellers of logistics services, but with the further difficulty of having the more disperse base of receivers that E-commerce entails. As the cost of delivering in the last mile depends on the economies of

density (i.e. deliveries per km), getting the most receivers is the chief premise; even if the profit margins are not high, it is a long term investment. With E-commerce deliveries, the logistics providers struggle with single drops per stop which are cost-inefficient for many reasons:

- *Delivery costs in rural areas:* Obviously, the main factor for the logistics companies is the cost, the costs of delivering in the last mile are mostly determined by the duration of the tour. In its turn, the duration of the tour affects the most important cost driver which is the labour cost of the driver, at the same time, even if the physical capacity of the vehicle can accommodate more parcels, the tour must have a feasible duration. That is the reason for many light goods vehicles (LGV) driving at a less than full capacity.

Rural areas represent a big challenge because normally, they are far from the distribution centre and since the density is low, the distance between receivers makes it very extensive. In rural areas, the costs can be almost triple those of urban deliveries (Gevaers et al., 2014). In regard to pick-up points, because these nodes can be located close to the highways the logistics provider vehicles do not need to use secondary roads, reducing the length significantly.

- *Delivery costs:* The length of a typical tour in urban areas is usually not extremely long in terms of VKT. However, delivery vehicles can stop more than 100 times, imposing a set of complex challenges. Every stop requires different activities: the vehicle driver has to park in every stop, unload, wait for the receiver, in many cases the receiver is not at home, then the driver must try to deliver to neighbours, and often get a signature. Home deliveries are regarded as time-consuming and even if the costs per stop are low, the total costs of the tour can be very high. pick-up points can easily reduce these activities

inherent to households. But more importantly, they reduce the number of stops when people from the same area is delivered at the pick-up points, working as a consolidation terminal at a smaller scale.

- *Failed deliveries:* Extensive literature has already dealt with the problems from failed deliveries. In fact, pick-up points is a natural solution for failed deliveries. However, many receivers still order goods online and miss the delivery. When this happens, normally the logistics provider schedules further attempts and ultimately leaves the parcel at a pick-up points. This extra effort for coordinating the delivery could be absorbed if the initial delivery would have been scheduled to the pick-up points from the first time.

For logistics providers, as opposed to receivers, the optimal solution leans towards a network of pick-up points. Developing a coherent network where every package is delivered via pick-up points, means significant reductions in costs, therefore increasing the very limited current margins of profit. However, the costs of the last mile will be shared with receivers that will need an incentive to accept their parcels at a pick-up points. The utility function for logistics providers can be summarised in the following expression:

$$U_R(x) = \alpha + \beta_1 C(x) + \beta_2 F(x) \quad (2)$$

Where  $C$  is the delivery cost, and  $F$  is the cost of failed deliveries.

## 7.5 Public Sector

Finally, in terms of urban logistics, the public sector is concerned with the externalities from goods transportation, but also facilitates a good provision of goods to the inhabitants. Some studies have already alerted that shifting from home deliveries to pick-up points deliveries may increase the total

transport because of the generation of new trips by receivers collecting the goods. The following factors may have an impact in E-commerce logistics from the public sector's perspective

- *External cost of LGV*: Public authorities are concerned of the negative impacts of freight transport. Pollution, congestion, noise, infrastructure damage and accidents are some of the common externalities in cities. As E-commerce grows, so the number of LGV and big cities (e.g. London) are already taking measures to mitigate the impacts of these vehicles in dense areas. When using a pick-up points network, the density of the network determines how close to the final receiver the vehicle must go. Therefore, the denser the network the more kilometres LGV have to travel, the less kilometres will be travelled by receivers to collect their deliveries.
- *External cost of motorized collecting trips*: When parcels are collected from a pick-up points, the main concern is that new motorized trips are being generated. However, those trips do not have to be strictly negative, if the trip is done by CO<sub>2</sub>-friendly modes or if it is combined with other activities (Brown & Guiffrida, 2014; Rotem-Mindali & Weltevreden, 2013), then impacts are lesser. The public sector can encourage pick-up points to be located in places where other activities take place such as shopping centres or train stations, and then pick-up points-collecting trips can be complementary. At the same time, the distance from the receiver to the pick-up points determines the mode choice. The more accessible the pick-up points is, the less likely the receiver will collect the parcel in a motorized trip.
- *Competitiveness and accessibility*: Finally, the city is a hub where not only destinations but origins of goods take place. Therefore, not only the negative impacts of logistics are of the concern of public authorities. For inhabitants of urban areas, to have access to E-

commerce is part of the competitiveness of the city. Because of that, logistics decisions from the public perspective should also consider the factors influencing the logistic providers, and facilitate the infrastructure to let freight flows be transported into the city. If receivers use pick-up points to send and receive, then the access to this infrastructure determines how well-connected they can be with online markets. Also, home deliveries can be seen as an accessibility enabler for urban dwellers that have limited mobility (e.g. ageing or disabled population)

The utility function for the public sector can be summarised in the following expression:

$$U_R(x) = \alpha + \beta_1 E(VKT_r)(x) + \beta_2 E(VKT_{LP})(x) + \beta_3 Acc(x) \quad (3)$$

Where  $VKT_r$  are the vehicle kilometres travelled by motorized collection trips,  $VKT_{LP}$  are the vehicle kilometres travelled by delivery vehicles,  $E(VKT)$  are the external costs produced by the  $VKT$  by  $i$ , and  $Acc$  is a measure of accessibility.

## 7.6 Typology

Figure 31 summarizes the factors affecting the structure of the pick-up points network for the different stakeholders. In the third column of the figure, the desired configuration of each stakeholder is depicted. Receivers will be pursuing convenience and accessibility, leading to only home deliveries or at least a network where the distance of the pick-up points is as close as possible to their home. For logistics providers, the trade-off with costs will cause the contrary effect since they can achieve higher efficiency in a network where

more deliveries are consolidated in a single pick-up points. Finally, for the public sector, a hybrid configuration is desired. The density of the pick-up points network depends mainly on the mode choice: more use of motorized vehicles will require less distance to the pick-up points since it will encourage more collecting trips. But on the other hand, if the network is too dense, LGV will cause a higher impact on urban conurbations.

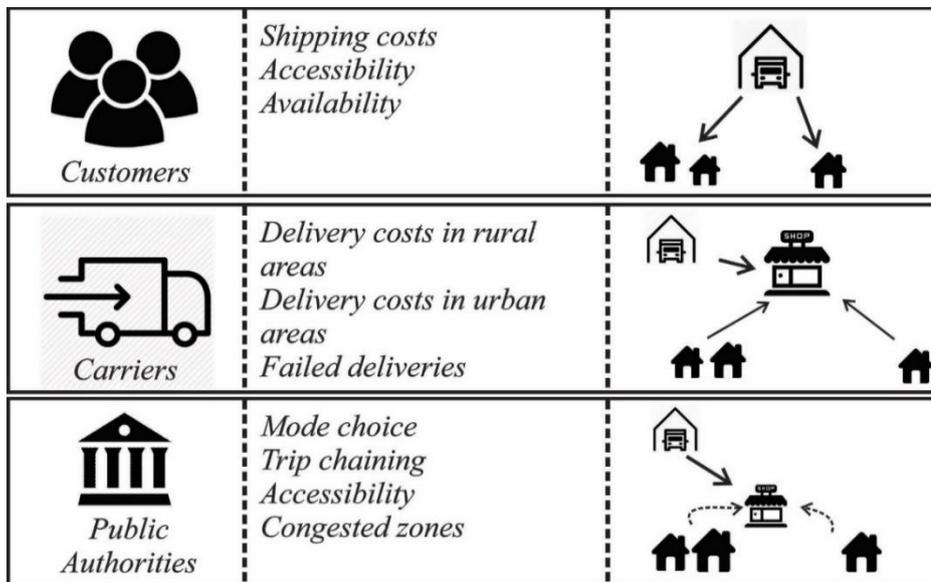


Figure 31. Conflicts in the pick-up points network

Source: Own composition

In the following section, these trade-offs are explained further by using a case study in the city of Brussels. In the example, simplified indicators for the utility of each stakeholder are constructed and the effects of varying the density of the pick-up points network are explored. While assumptions on some parameters need to be investigated further, the example sheds light onto the possible outcomes from different configurations and identifies the directions to improve the accuracy of the modelling.

## 7.7 Case Study

To illustrate the different trade-offs occurring in the E-commerce distribution when using pick-up points, a numerical example with data from a logistics provider in Brussels was developed. For each stakeholder, simplified utility functions will determine how the density of the pick-up points network will affect each stakeholder. The data for the example comes from a logistics provider based in Belgium who delivers both B2C and B2B parcels. A visualisation of the data is presented in Figure 32. It noteworthy that it corresponds only to e-tailers (e.g. Amazon, Zalando, etc.), therefore, it is expected to be B2C on the origin, but the destination can be a residential household, a working place or a business.

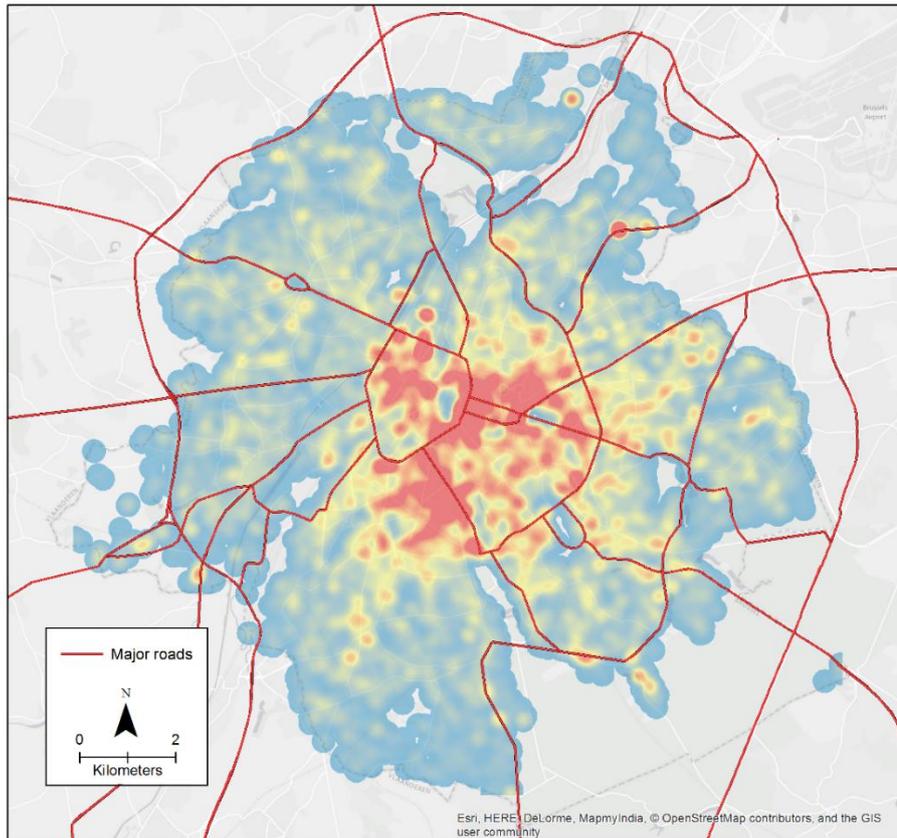


Figure 32. B2C deliveries in Brussels

Source: Own Composition

The data was collected for 100 days and the carrier has an average demand of 350 parcels per day in the B2C stream. To delimitate the city, the capital region area was chosen, the total area is 161 km<sup>2</sup>. The model begins by finding  $m$  gravitational centres in the deliveries data, then the catchment area and the location of a number  $m$  of pick-up points is identified. With this method, the total area is partitioned into  $m$  sectors of receivers who will use a given pick-up points.

First, to evaluate the receiver's perspective, the utility function is simplified to the accessibility of the pick-up points, which is measured in terms of the distance to the receiver. This is done by simply measuring the Euclidean

distance from each receiver to the  $m$ -th pick-up points in the sector where the receiver is located. Finally, the average of the distances ( $\overline{d_{ij}}$ ) serves as an indicator. Figure 33 shows the receiver's utility measured in terms of distance to the customer as a function of the number of pick-up points in the network. As expected the function decays fast, but shortly after 60 pick-up points, the marginal decrease in distance reduces significantly. This is because the network is already saturated and additional pick-up points have a limited marginal contribution to the indicator. In a scenario without pick-up points, the service will be the highest possible (i.e. zero kilometres), for the customers that can attend a home delivery.



Figure 33. Distance to receiver

Source: Own composition

The utility function for the logistics provider is estimated using only the costs of delivery; the cost of failed deliveries is assumed to be null after the first pick-up points. Costs of delivery depends mainly on the length of the tour. With higher consolidation in less pick-up points, the tour length will decrease and in consequence the costs will decrease. The reader is referred to (I. D. Cardenas, Dewulf, & Vanelslander, 2016) for a full description of the method and parameters to estimate the cost as a function of the number of pick-up

points. In essence, the utility function is expressed as the delivery cost per parcel is calculated. Figure 34 shows the variation of delivery costs per parcel when using a different number of pick-up points. It is clear that, for the logistics provider, a situation with fewer pick-up points is desirable. In a scenario without pick-up points, the last mile costs can go up to 1.75 Euros per parcel because of the number of deliveries and failed deliveries that are not accounted in this simulation. This means that delivery costs per stop in an ideal scenario (1 pick-up points) can be as low as 12% of the costs of conventional single home deliveries.

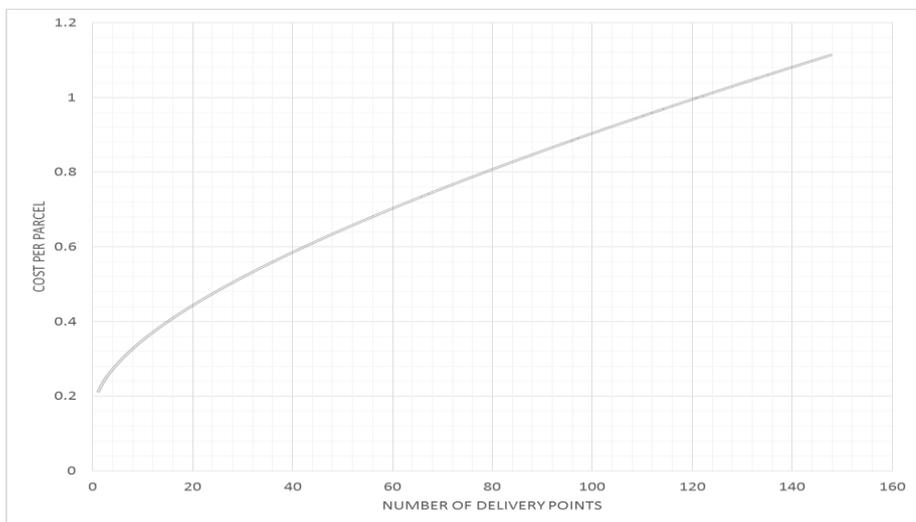


Figure 34. Logistics provider delivery costs per parcel

Source: Own composition

Finally, to evaluate the utility function of the public sector the external costs produced by the VKT from the collecting trips ( $VKT_r$ ) and the LGV ( $VKT_{lp}$ ) together are calculated as shown in Equation 1. As not every receiver's collecting trip is motorized, the total distance is weighted by the share of customers who do a motorized trip.

$$VKT_r = \overline{d_{ij}} * mc(d_{ij}) \quad (4)$$

$$mc = 0.1881 \ln(d_{ij}) + 0.4865 \quad (5)$$

Figure 35 shows how external costs change with the number of pick-up points. Similar to the receiver's utility function, the graph also shows an exponential decay until the number of pick-up points is saturated. Failed deliveries are not part of this analysis because with pick-up points, there will be no failed deliveries. Thus, if a situation without pick-up points is analysed, the external delivery costs per parcel will be higher. This simulation shows that benefits for all stakeholders are achieved when the saturation threshold is reached. In a situation where the receivers benefit from appropriate lower differentiated prices when using pick-up points, logistic providers save delivery costs, and external costs are reduced because of no failed deliveries, and a better situation can be achieved for all stakeholders.

Equation 4 is the mode choice function, which is an exponential function dependent on the distance from the receivers to the pick-up points. Parameters for the mode choice function ( $mc$ ) come from fitting empirical data collected by (Cools, Declercq, Janssens, & Wets, 2009) in Belgium. The parameters to convert the total VKT to external costs are computed using the values from (I. D. Cardenas et al., 2016).

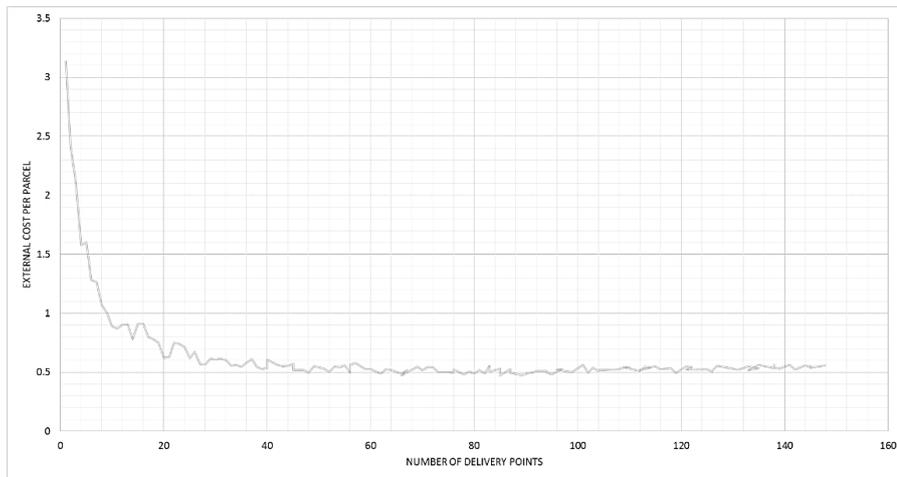


Figure 35. External delivery costs per parcel

Source: Own composition

Finally, Figure 36 shows how the utility indicators of each stakeholder overlap. It can be seen that the objectives of the public sector are mostly convergent with the objectives of the customers, because both stakeholders will look for a higher accessibility and low VKT travelled for delivery collection. In contrast, the utility of the logistics provider conflicts with the other two. However, a balance seems to be achieved when the density is close to 40 pick-up points for this case because the objectives of public sector and receiver are close to its lower point. Nevertheless, the weight of the different utilities should be investigated further, and the exploration of a Pareto efficient frontier between stakeholders' utility to provide good insight can be pursued in further research endeavours. A better understanding of the utility function of the stakeholders and studying their trade-offs can support the design of policy instruments from the public sector (e.g. pick-up points provided by the public sector, regulation of mandatory pick-up points for new high density developments) and monetary incentives from shippers and logistics providers to receivers to reach an appropriate number of pick-up points that benefit all stakeholders.

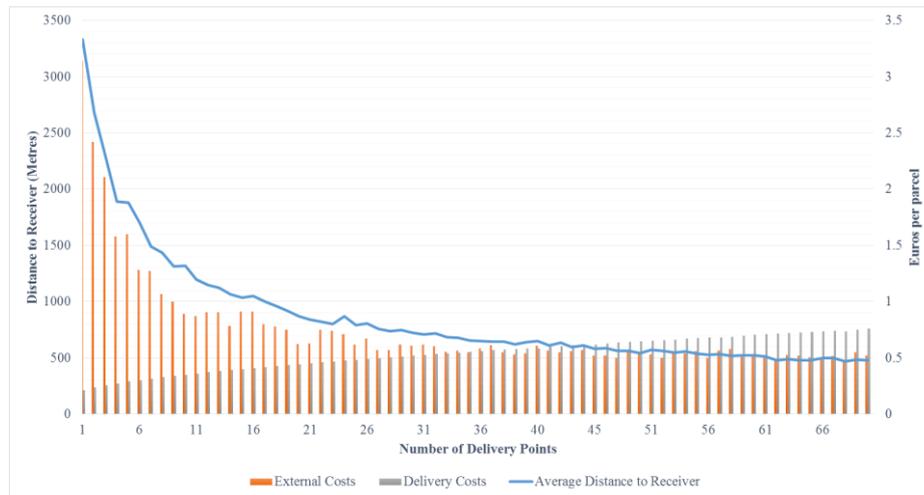


Figure 36. Trade-offs in the pick-up points network

Source: Own composition

## 7.8 Sensitivity Analysis

The analysis shown above depends in assumptions about the inputs that in some cases have a high level of uncertainty; at the same time, it is important to analyse how the output of the system will respond to changes on those variables and how relevant are those variables on the performance. In this section, we propose a sensitivity analysis to test the robustness of the proposed model.

The sensitivity analysis considers the variation of two different inputs: (i) the throughput of the pick-up points; the analysis above considers a fixed rate of users choosing pick-up points. (ii) The trip chaining: trip chaining occurs when different activities are combined; in that case, the trip cannot be fully assigned to the activity but it has to be distributed among the different purposes of the trip.

### Sensitivity to the throughput

For logistics carriers, pick-up points are an interesting option to increase the number of deliveries per stop and therefore, decrease the costs. However, in the previous case, the data from Belgium shows that only 20% of the customers use pick-up points as the option to receive parcels. This number can increase in the future due multiple reasons: customers adopt this type of solution, the delivery becomes more convenient or financial incentives. Figure 37 shows the effects of an increase on the number of customers (i.e. throughput) using a pick-up point.

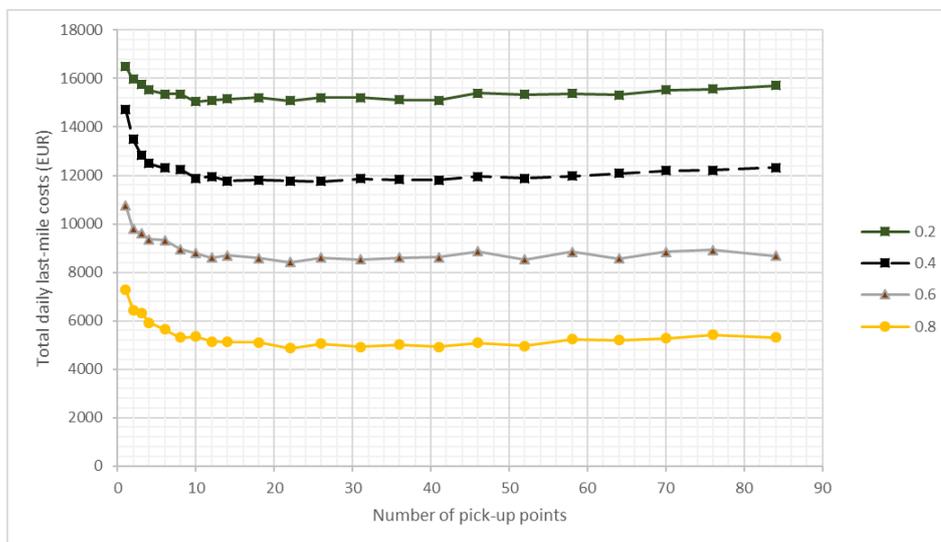


Figure 37. Variation of total logistics costs due to changes on the throughput of pick-up points

Source: Own composition

The curves presented in figure 37 show the total logistics costs: operational costs for the logistics providers, and external costs caused by logistics provider and customers picking up the parcels. The top line (0.2) indicates the baseline scenario where 20% of the customers demand the parcels at a pick-up point. Increasing the use of pick-up points has a positive impact, leading to lower total costs in the last mile.

Figure 38 shows that the external costs are not particularly sensitive to the throughput. It would have been expected that the more consumers use the

pick-up points, the more collecting trips they will realize. This statement stands true for a situation with few pick-up points, but when the number of pick-up points is large, the external costs seem to be dominated by the trips made by the logistics carriers.

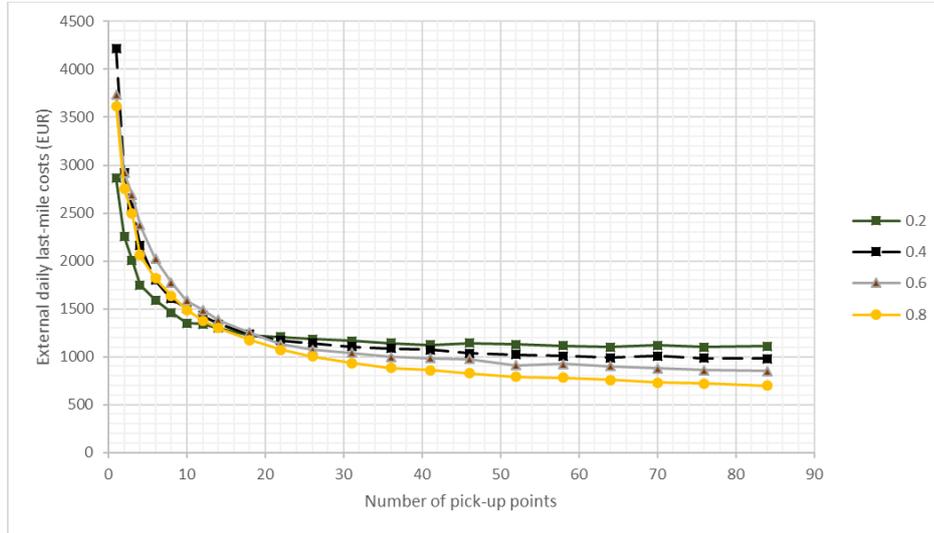


Figure 38. Variation of external costs due to changes on the throughput of pick-up points

Source: Own composition

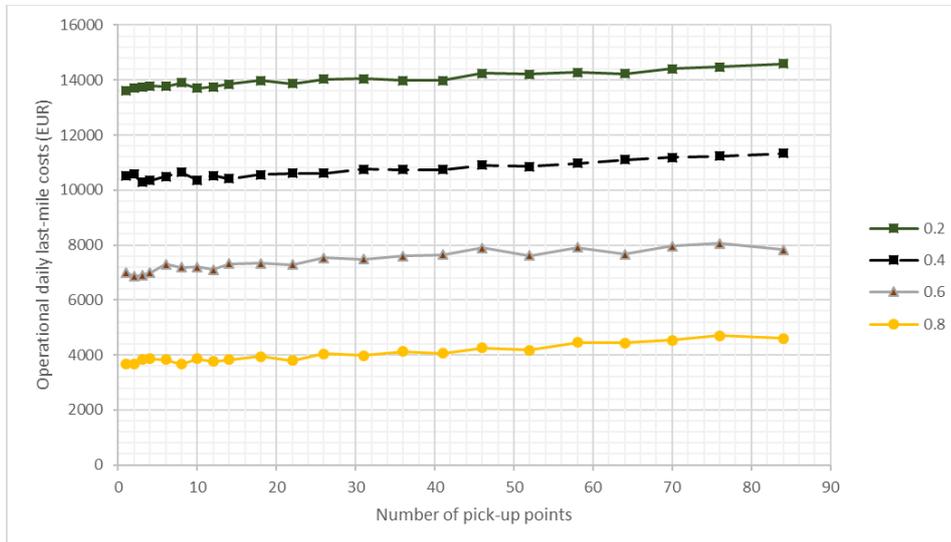


Figure 39. Variation of operational costs due to changes on the throughput of pick-up points

Source: Own composition

From the sensitivity analysis on the throughput, it can be concluded that the benefits of pick-up points depend more on how many users are using the network rather than the density of it. This is an implication for stakeholders interested in the benefits of pick-up points of focusing not in the size of the network but rather in the throughput of the network.

### Sensitivity to the trip chaining

Since trip chaining only affects the collecting trips, we limit the analysis to observing the effect of trip chaining only in the external costs. Figure 40 shows that external costs in the last mile are only sensitive to the trip chaining when the quantity of pick-up locations is limited. As distance travelled to collect parcels is longer when the pick-up point network is not dense, there is a higher impact from trip chaining in the left side of the curve. As the number of pick-up points increases, the difference between levels of trip chaining in minimal.

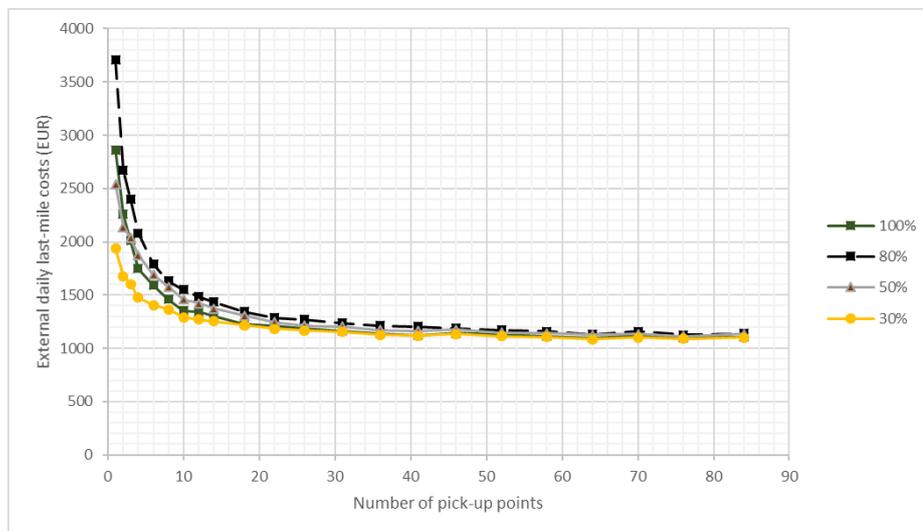


Figure 40. Variation of external costs due to changes on trip chaining of collection trips

Source: Own composition

## 7.9 Conclusion

In this chapter, the foundations of an urban logistics analysis about the potential outcomes of delivering E-commerce parcels exclusively with a network of pick-up points opposing the conventional home deliveries are presented. pick-up points are a solution for reducing the number of VKT in urban areas by mitigating the failed deliveries. However, in the literature, some authors have expressed concerns about these benefits because collecting parcels in a pick-up points can add extra negative impacts by attracting motorized trips from receivers.

Two main propositions are discussed. First, given the growth that pick-up points in Europe, this solution is no longer an occasional location for failed deliveries, but rather a node of the network used by receivers to collect their parcels, and the logistics providers are integrating these nodes into their operational planning. Second, the decisions about the structure of these nodes in the network, is not a single stakeholder decision but instead affects the utility function of all the stakeholders involved in the logistics process of delivering E-commerce parcels. As a result, the individual utility functions are conflicting and producing trade-offs for each stakeholder. We argue that the public sector can mediate in those trade-offs and seek for a win-win situation that guarantees competitiveness, accessibility but also manages the freight transport in cities.

By using an example in the city of Brussels, those conflicts are made explicit. When the network is dense enough, a desirable situation is identified. In this scenario, the pick-up points provide consolidation advantages to the logistics providers as well as accessibility to the receivers, discouraging them to use motorized trips when collecting their parcels. The role of the public sector to mediate in these trade-offs is still a subject of discussion, but the evidence of this chapter proves that it is desirable to concentrate the efforts of the logistics

providers. At this moment, each provider is struggling to build a network on its own, causing more negative impacts, and there is a need of coordinating those efforts.

The proposed framework aims to delineate the factors that should be considered to provide robustness and accuracy to the modelling. In that sense, limitations should be addressed in further ongoing research. One of the main drawbacks of this modelling approach is that the perspective of retailers such as web shops is almost fully neglected. The reason behind it is that information about the role of retailers in the pick-up points network is limited. An effort to understand and incorporate the factors affecting the retailers as an additional stakeholder of the logistics chain should be addressed.

At the same time, the receivers' behaviour towards pick-up points remains unexplored. The willingness to pay for a home delivery instead of a pick-up points delivery should be investigated and linked with the socio-economic characteristics of the receivers. If consolidating in pick-up points is beneficial to logistics providers, the reduction of costs should be transferred to the retailer and to the receiver. However, logistics providers have expressed the lack of motivation from the retailers to explore reductions on shipping prices when a receiver is delivered at a pick-up points.

The model can be further improved to incorporate the value of time of different receivers, the trip chaining with other activities and its preference of non-motorized modes. Those variables should be linked again with socio-economic factors to understand the specific conditions of different places (e.g. urban and rural areas). Moreover, the proposed example assumes that the use of the pick-up points network is in an all-or-nothing scheme. In reality, some customers will use the network and some not, this situation still pending to be modelled and incorporated.

Finally, the question about the weights of each utility function remains open. Because the inexistence of a global optimum, but instead local optima for each stakeholder, a Pareto efficiency should be investigated. The existence of a Pareto frontier can lead the decisions of the different stakeholders into a more beneficial and sustainable state of the system.

# Chapter 8

## Conclusions and Further Research

In this dissertation, the characteristics of E-commerce deliveries were discussed aiming was to answer the following research question

*How does the design of a distribution system containing pick-up points provide economic and environmental gains in the last mile distribution of E-commerce?*

The proposed thesis is that a distribution system composed of a defined number of strategically located pick-up points where proximity deliveries can take place could certainly reduce the negative impacts of E-commerce goods transport. Moreover, such a system would be able to reduce the operational costs of the delivery process. This statement does not consider the extra costs brought by additional logistics operations such as transshipment, sorting, warehousing or others, topics that will remain uncovered until further research, but that certainly can be addressed from different perspectives.

In this concluding chapter, the main outcomes of the research are presented and discussed. First, a summary of findings is presented, accompanied by the implications of these results for the current state of science and practice. Finally, future avenues for research, which can further expand the contributions from this dissertation are proposed.

## **8.1 Summary of findings**

### **8.1.1 Explorative Research Phase**

The first question of the current dissertation was: “*What are the characteristics of the logistics in the last mile distribution of E-commerce?*” This research question was proposed from an exploratory and hence descriptive perspective. The intention was to acquire preliminary information

on the most important characteristics of E-commerce distribution. The following were the main findings of the first phase of this research

***Finding 1: The courier, express and parcel (CEP) market is relatively new and features strong competition, which is a hurdle for innovations and clean energy alternatives.***

One of the early findings is related to the composition of the market. Most players seem to be struggling with the advent of E-commerce and subsequent level of home deliveries. The postal offices had to switch from a logistics based on letters to accommodate parcels in sorting facilities and couriers. A courier was in charge of postal routes, the stops were in almost every house for some seconds, and the means of transportation was a bike or walking. Nowadays home deliveries need to accommodate for heavy items, require more time-consuming stops and generate a more spread array of stops. Finally, most countries liberalized the postal markets, so the E-commerce trends of the last years came in addition to steering the NPO's from a public to a private company's environment.

For the integrators and delivery companies, the changes brought by E-commerce were slightly different. These companies already delivered parcels in the B2B market. Therefore the challenge for these companies came mainly from the increase of the number of receivers and lower fares per stop. These companies experienced an increase in the duration of tours that was translated in smaller areas covered by the tours and therefore an increase in operational costs. In addition, the integrators and private delivery companies lacked experience in handling customers in the B2C segment, and customer service departments struggled to handle complaints and requests from a multitude of receivers. Failed deliveries were critical as well since many contracts were based on B2B standards, proof of delivery was needed and serial attempts were needed to deliver a single parcel. During the last couple of years, these

companies started to handle failed deliveries in their own warehouse which generated additional costs to handle customers collecting parcels in a facility that was not built for that specific purpose.

The last mile specialists propose innovative business models to gain adeptness either by offering environmental friendly or receiver-oriented alternatives. However, the main challenge still is gaining a critical delivery density to make such business models work. If deliveries are too spread out the costs per delivery grow exponentially. Additionally, these solutions are attractive to the “heirs” (postal offices or integrators) to expand their portfolio of services to generate “economies of scope”, ending in many last mile specialist start-ups being annexed to a big logistics company.

As different authors discussed before (Ducret, 2014; Gevaers, Van de Voorde, & Vanelander, 2009), the current state and composition of the CEP market causes that the players assume defensive positions to protect their market shares. The characterization made on this thesis noted that the situation of the current market in Belgium is in line with the observations made by previous authors. While a defensive stance does not have to be translated as a negative situation, from an urban logistics perspective it hinders the possibilities for sustainable logistics. The financial risks that clean alternatives pose, make these operational models almost exclusive, for now, to small start-ups aiming for niche markets.

***Finding 2: The customer density is the key cost driver and therefore has the highest priority for logistics companies. Although the impact of failed deliveries is non-trivial, there are alternatives emanating which are addressing the issue.***

During the exploratory research phase, informal interviews were conducted with representatives of the main logistics players in Belgium. The main concern when E-commerce started to boom was the number of failed

deliveries. Logistics carriers did not have the means to communicate and coordinate the deliveries with the receivers. During the last years, this situation has been improving. The majority of companies have developed communication systems that allow the receiver to influence the place and time of delivery, although, the users of these technologies are limited.

As discussed in the previous finding, the contract schemes between logistics carriers and retailers (e-shops) followed the standards of the B2B logistics, where proof of delivery was mandatory and the place of delivery could not be changed. During the last years, the frameworks of these schemes have relaxed to guarantee more flexibility in the delivery process for the B2C-segment. Nowadays, E-commerce parcels can be delivered to neighbours, can be left unattended in pre-agreed “secure” places and more often in a pick-up point where the receiver can collect the parcel at a more convenient moment. The advancements on mitigating the extra costs of failed deliveries have allowed the logistics companies to focus on how to achieve economies of density.

In the last mile the term “density” has to be addressed slightly differently. Economies of density are associated with cost savings produced by spatial proximity. It is a very important asset in the last mile, since the concentration of customers allows distributing in a smaller area reducing the distances and therefore the time to be covered. The maximum density that can be achieved is when all customers are concentrated in a single point which corresponds to the paradigm of consolidation in logistics. In the last mile there are few opportunities for consolidation, but a little effort on consolidating and delivering more than one parcel in a single stop has obviously a positive effect in efficiency.

In the interviews with the companies, it was clear that the main priority for them is how to attain consolidation in the last mile. In principle, the means to

achieve consolidation should be the pick-up points since they have the potential for it. However, our data showed that only 13,3% of the deliveries are directed to pick-up points. Thus, increasing the number of deliveries directed to pick-up points is aligned with the objectives of the parcel carrier companies. In addition, if pick-up points can contribute to reducing the negative externalities, there is potential for a win-win situation.

***Finding 3: Little difference is observed on the number of deliveries per capita between rural and urban areas, however, in absolute numbers, urban areas will always attract more volume since there are more customers living in urban areas. Hence, delivery rounds in urban areas are more concentrated and in consequence, demand less time and kilometres.***

In the introduction section, different hypotheses on E-commerce adoption were discussed. While urban areas are known for adopting new technologies faster, the lack of accessibility for specific goods in rural areas makes E-commerce appealing. Delivery companies stated that the percentage of the fleet dedicated to urban areas is lower than the number of vans driving in rural settlements. The research demonstrated that deliveries are concentrated in the main cities of Flanders. That implies more deliveries occur there, however this can be explained by the fact that cities simply count more inhabitants. If the effect of the population is controlled and the deliveries per capita are visualized, then sub-urban areas stand out attracting on average more deliveries per inhabitant.

The implication of this situation is the differing number of tours needed to distribute in a given zone. Urban zones attract more parcels but since the stops are more concentrated fewer tours are needed. The distance between stops is large in rural areas, however, if the demand is low few delivery tours can easily cover the area. In contrast, areas with high demand and low density are potentially problematic, because more rounds will be needed to satisfy the

deliveries. In conclusion, this dissertation challenges the traditional belief that urban areas are the ones with a larger number of freight trips. The impact from those trips, which is, in the end, the important question, is discussed in the next findings.

### **8.1.2 Analytical Research Phase**

The specific question in the analytical phase was “*What are the operational and external costs of the last mile distribution of E-commerce?*” The aim of this question was to find the costs caused in the last mile as an indicator for the performance of the system. The purpose was twofold, firstly to dimension the intensity from the impacts of the last mile; secondly, to serve as a benchmark for analysing alternatives and discern about its benefits and drawbacks. The following statements are based on the findings from this phase:

***Finding 4: Deliveries in rural areas can be up to six times more costly than their urban counterparts. Even with complexities in urban areas, deliveries in the cities are the stronghold for parcel carriers.***

The urban last mile is a complex environment characterized by congestion and large social heterogeneity among customers, which makes it a difficult environment for parcel carriers. However, when the costs of deliveries for these companies were analysed in Belgium (see Figure 41), it was found that the rural deliveries were the ones driving up costs. In Chapter 5 and 6, we showed that in a typical urban area, the stops are separated on average 640 meters from each other. On average, a total of 105 stops are served in a route. When the total costs of the route are divided by the number of deliveries, the average cost of delivery is on average 1.8 euro.

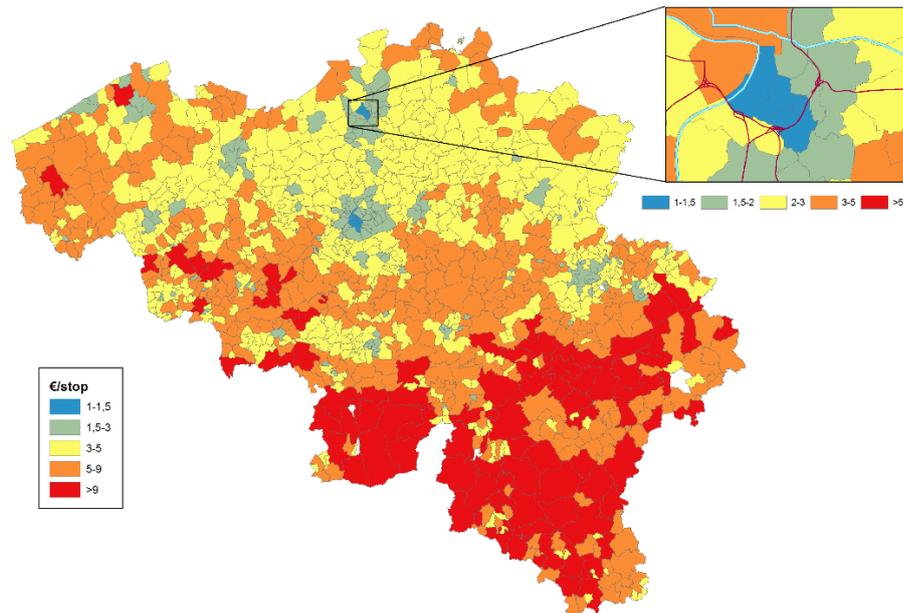


Figure 41. Average cost for E-commerce deliveries in Belgium

Source: Own composition

In rural areas, in contrast, the demand density is lower and the stops are more spread, causing a longer trip from one stop to the other. The rural costs drive the average cost per parcel from 1,8 euro in urban areas to 3.8 euro on average at the national level. Delivering in locations with very low density can cost more than 10 euros per parcel. In consequence, if the parcel delivery companies lose the lower cost from urban areas their average delivery costs structure will significantly rise.

The differences in costs from urban to rural areas are relevant when alternatives for urban deliveries are proposed. As discussed above, the market is under constant pressure and reaching maturity. However, the structure of costs can be very sensitive to what happens in urban areas, especially with urban logistics restrictions and new schemes to be introduced. In conclusion, to avoid a major economic impact on companies, the solutions for the urban last mile should not increase the costs; otherwise implementation of new and eco-friendly solutions will be hardly feasible.

***Finding 5: The external costs per parcel are similar in urban and rural areas. However, the number of parcels distributed in urban areas is by far higher, causing the majority of the impact in agglomerations. Therefore, urban areas should be the first priority to take action.***

Similarly to the calculation of the operational costs, the external costs per parcel delivery were calculated. Estimating these costs is particularly challenging since cost factors may vary in the literature. Different sources for the varying types of external costs were investigated. Moreover, we made sure to account for the impact of the negative externalities by assigning higher costs factors to residential areas where the impact of the exposition to the negative externalities is higher, simply because there are more inhabitants in those areas.

The main discussion is that since rural routes are longer and cover more kilometres, these routes may cause higher impacts. In contrast, the urban routes are shorter but are a nuisance for the inhabitants because the deliveries take place in the proximity of their residence. Using the typology proposed by (Luyten & Van Hecke, 2007), the area of Belgium was divided into urban, sub-urban and rural areas. It was found that the VKT by vans are similarly distributed in urban (37%), semi-urban (25%) and rural (38%).

Figure 4242 exhibits the external costs per parcel in Belgium. The average external costs caused by parcel deliveries is about 0,26 euro per parcel in urban areas, 0.33 euros in semi-urban areas and 0.37 euros in rural areas. However, the external costs from delivering parcel have a higher impact on urban (50%), than in semi-urban (20.4%) or rural (29.5%) areas. It was estimated that the external costs caused by parcel deliveries in Belgium surpass 45,000 euros per day.

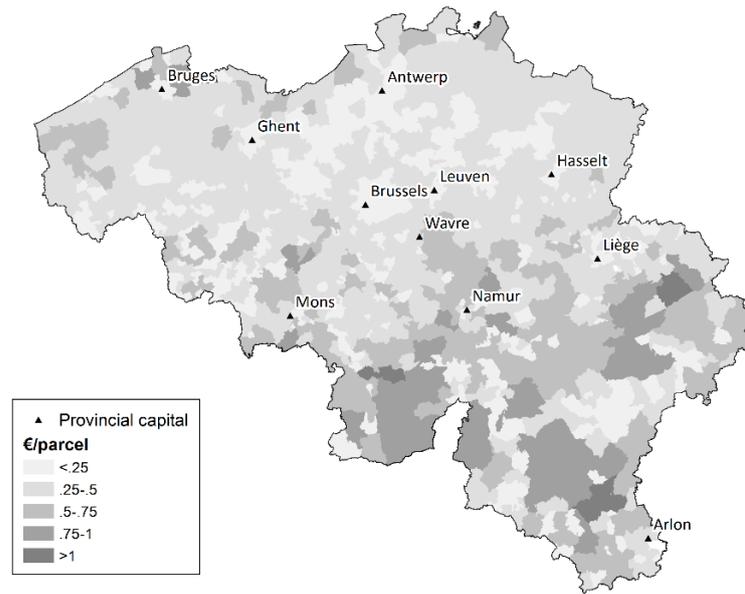


Figure 42. External costs per parcel

Source own composition

Besides creating awareness about the problems, the idea of these estimations is to encourage further interventions on the parcel delivery market. It is clear that since 50% of the costs take place in urban areas, the priority is to come up with solutions in this area. At the same time, in a scenario where internalising the externalities is considered these estimations help as a guideline on how much society should be compensated for such deliveries.

***Finding 6: The current location of pick-up points is determined by each company and follows a service rationale (i.e. trying to increase the convenience for the receiver). However, these locations are suboptimal. A well-balanced revised configuration of the location of pick-up points could encourage more environment-friendly transport and even economic benefits.***

Chapter 7 performed different analyses on the spatial configuration of pick-up points in Antwerp, Belgium. This analysis demonstrated that the pick-up points from the same company in many cases overlap with each other. That

means that two or more pick-up points cover the same area. Obviously, when looking at pick-up points from different companies, the overlap is even bigger. At the same time, many areas do not have a pick-up point within a one-kilometre distance. In addition, the larger the distance to the pick-up points is, the higher is the probability of motorized collection trips.

Additional to the spatial analysis, it was also investigated in which kind of businesses the pick-up points are located. We found that the most common location is the daily goods stores. Trip chaining is desirable to reduce the number of VKT. Therefore, locating the pick-up points in places that are visited frequently, such as daily goods stores, will favour the combination of activities. However, less positive, is that most of the businesses that serve as pick-up points are only accessible during working hours. Time constraints on the hours that the parcel is available will lead to less flexibility and therefore it is less likely that a collecting trip can be combined with another activity (Collins, 2015).

This finding confirms the importance of sustainable planning on the location of pick-up points. So far, the location and configuration of the pick-up points have been decided as a contingency for failed deliveries. However, there is still a lack of planning on important factors such as the consolidation of parcels and the reduction of motorized trips. Interesting avenues on how companies and public authorities can integrate those factors on planning will follow later in this chapter.

### **8.1.3 Normative Research Phase**

In this phase, the third research question is answered: *How do pick-up points contribute towards a more sustainable last mile distribution of E-commerce?* This research *question* aims at providing a direction to improve the current situation. As commented above, the last mile causes high operational and external costs. Even when the number of pick-up points has been growing

during the last years, this growth does not seem to contribute to mitigate those costs. For this phase, it was expected to find key factors that could contribute to aligning the proliferation of pick-up points with the sustainability of last-mile distribution of E-commerce. Therefore the following findings will be discussed:

***Finding 7: There is a conflict between the interests of the different stakeholders interested in the location of pick-up points.***

Three different stakeholders were identified in the last-mile of E-commerce. The first type of stakeholders are the receivers, who aim to reduce the efforts needed when receiving goods. Therefore, home deliveries are more convenient and if there is no price differentiation, there is no incentive to receive the parcel in a pick-up point unless the receiver itself has some impediment to receive the goods at home. If that is the case, receivers will always prefer the most convenient location: as close as possible to their home, work, or other activities. Therefore with regard to pick-up points, the receiver will optimize its utility function when the number of pick-up points is as large as possible.

For the logistics companies, the second type of stakeholders, the situation is slightly different. From the observations, the importance of consolidation by increasing the efficiency of deliveries was clear. In that sense, ignoring the positive effect that the number of pick-up locations has on the branding and marketing, and focusing exclusively on the logistics operations, it can be concluded that companies will maximize their utility function by delivering in as few stops as possible. Therefore, opposite to the receiver, a situation where the number of pick-up locations would be limited to the minimum would be the preferred option to logistics carriers.

Finally, the public authorities, as a third type of stakeholders, are committed to reducing the number of motorized trips and their impacts on the inhabitants

of the city. A pick-up point network with too many pick-up points or only home deliveries triggers the proliferation of light good vehicles in residential areas. The situation with very few pick-up points is even less desirable: it means more distance from the pick-up point to the receivers' residences, and as discussed before, it will cause that receivers feel encouraged to use the car, increasing the number of motorized trips.

As seen in Figure 31 there are conflicting interests for each stakeholder in the last-mile with regard to the design of the pick-up point network. The results point towards a configuration of the pick-up points network where the objectives of these stakeholders are coordinated in a win-win situation.

***Finding 8: There exists an optimal number of pick-up points in an urban setting, where the net vehicle kilometres travelled (VKT) are reduced, and the operational costs do not increase.***

By using simulation techniques the effect of the pick-up points configuration on the net VKT was reproduced. If few pick-up points are in use, receivers who use pick-up points will need to travel more, and the VKT by the vans will decrease. However, these will be surpassed by the VKT of the receivers collecting the parcels. In that case, the pick-up point model is even more harmful than home deliveries. On the operational costs side, however, the logistics companies will benefit from higher consolidation potential on those locations.

In the situation with many pick-up points, the results are similar to a home delivery-only model because the effect from the pick-up points on the VKT by the vans is unnoticeable. The vans still need to drive "deep" into the city and the worst negative externalities will still occur. This situation is actually the current modus operandi of these networks and therefore measures must be taken to produce economic and environmental gains from pick-up points.

Figure 43 shows the behaviour of costs when the number of pick-up points changes. In the figure, one can observe that the external costs decay quickly and a finite number of pick-up points would be enough to reduce the externalities. On the operational costs side, it is also clear that a reduction in costs will be achieved in any scenario when goods are consolidated.

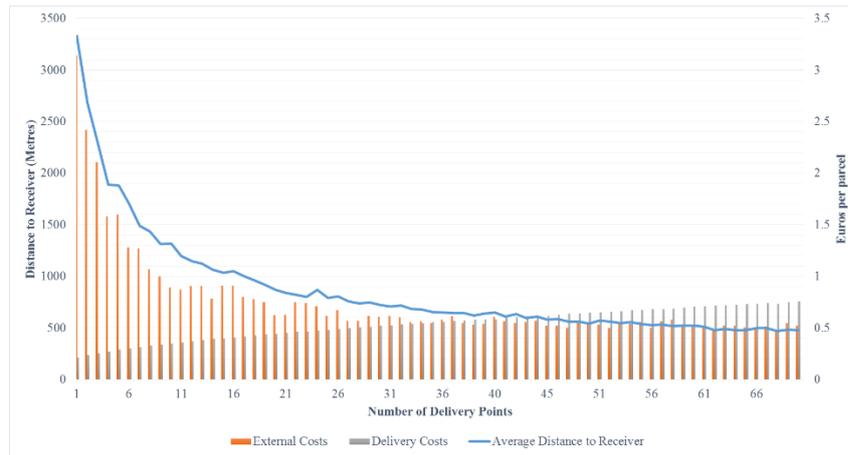


Figure 43. Effects on costs from the number of pick-up points

Source: Own composition

The figure above gives a clear indication that there exists a numerical optimum for the number of pick-up facilities in an urban area. Moreover, sensitivity analyses were conducted on three different variables: (i) the proportion of receivers using the pick-up points, (ii) the likelihood of using a motorized trip and (iii) the likelihood of chaining the collection trip with other activity. The analysis showed that the VKT are sensitive to the number of people using the pick-up point, the higher the percentage of the users the more net VKT, since there are more motorized cars. However, if the likelihood of using a car would be low enough, then the best scenario would be when every customer uses the pick-up points.

In conclusion, the pick-up points in urban areas must be located in a strategic position that discourages motorized trips while keeping light good vehicles away from residential areas at the same time. We acknowledge that a scenario

where nobody orders at home is unpractical, but a scenario where those who collect their parcels do it in clean vehicles, and those who require the parcels delivered at home are served by clean vehicles as well, has the highest potential and should be the norm for distributing E-commerce in the last mile.

## **8.2 Implications and recommendations**

### **8.2.1 For public authorities**

During the last years, countless initiatives from the public administration tackling the negative impacts from urban logistics have seen the light. It is clear that urban freight occupies a place on the agenda for public administrators. Since urban freight is a branch of transport, the logical approach was to follow the same rationale as with passenger transport and mobility. However, dealing with freight poses completely different challenges than passengers. Research during the last years has brought lessons and knowledge co-creation in urban logistics.

The urban consumption patterns changed drastically, E-commerce took a place in the retail landscape and brought change in the way goods are delivered into cities. This dissertation focuses on evaluating how pick-up points can complement the measures already taken in cities to manage urban logistics, specifically with E-commerce distribution. The findings of this dissertation indicate that proximity deliveries have the potential to reduce the impact of E-commerce distribution.

It was shown that the number of pick-up points necessary in a city depends on how far customers are willing to use the pick-up points and travel without using motorized means. Moreover, the status quo where there is a proliferation of pick-up points by different companies has little effect on environmental gains and does not represent a direct economic advantage for

companies. The main issue to address is how to increase the number of users of pick-up points, and how to encourage a “clean” use (i.e. using clean transport for collecting parcels).

Not only answering “how many?” but also “how?” and “where?” becomes relevant. The current location of pick-up points do not provide good accessibility for delivery vans. The current pick-up points do not have unloading areas that can avoid congestion and are in most cases located at the heart of residential neighbourhoods. At the same time, the opening times of these businesses are often not convenient and customers are under pressure to collect the parcels, therefore, causing dedicated trips.

The main implication for public authorities is that “logistics facilities” adapted to the new patterns of consumption in cities, must be considered in the urban planning and mobility planning of the city. The on-demand economy will only become more popular and cities must start to prepare and benefit from these changes. As a recommendation, these logistics facilities must be envisaged with the standards of other logistics platforms such as easy accessibility for freight vehicles, services for drivers (e.g. cleaning amenities, minimal service for vehicles), customer care and depending on the scope, enough space.

Furthermore, public authorities should initiate discussions on possible instruments for facilitating the deployment of these platforms. Ports and logistics clusters are logistics platforms where public authorities play an important role. Following a similar logic to urban logistics, the question arises whether public authorities should take on a similar role in the deployment of pick-up points in the last mile.

Finally, public authorities that already participated in the deployment of pick-up points should start to foresee how other flows can be incorporated in these spaces to increase their usage. Economies of scale and scope can be achieved

by combining flows that are similar to E-commerce, for example, handling the returns, collecting recyclable material or housing personal services such as maintenance, washing and repairing. At the same time, to find a place for these facilities in the social fabric, given the importance of logistics for society in an on-demand economy it makes sense that logistics occupies a place in the community level.

### **8.2.2 For the private sector**

Logistics companies are pivotal in the E-commerce last mile. The results from this dissertation confirm the impact of consolidation on costs but also show the potential that pick-up points entail for companies to contribute to environment friendly practices. For companies in the low-value segment, the results show that pushing towards a massive use of pick-up points provides benefits. However, it also shows that the model of “expansionism” with regard to pick-up points, is not sustainable. It is burdensome for the companies to find a partnership with stores, the shopkeepers often do not experience the benefits from converting their business into pick-up points, and finally, for the consumer in many cases, the final location of the delivery remains unknown or at least difficult to change. Additionally, as discussed above, small stores do not have the infrastructure for loading and unloading vehicles.

A distribution system that is able to deliver the benefits from pick-up points must be able to consolidate not only the parcels but also the services in the pick-up point locations. If the number of locations is rational and dedicated, the degree of consolidation will be higher, the personnel in charge will be specialized, the customers will have more certainty about the place and time of delivery while the impact on the surroundings is mitigated. While still micro-hub schemes that can make a business case favourable need to be explored, it is also the ambition of this dissertation to clarify the benefits of

starting to consider that type of business models (Macário, Galelo, & Martins, 2008).

Parcel deliveries companies should allocate resources to find collaborative or individual models that increase the volume of parcels flowing through pick-up points and providing a better environment for the deliveries. In parallel, a more aggressive strategy is needed to persuade customers to use pick-up locations. One option is reducing the prices for proximity deliveries compared to home deliveries. Another option is offering additional services from the pick-up locations. During the interviews with different stakeholders different services were brought forward. These services are still not supplied and could be supplied from facilities located closer to the customer. Smaller time windows for the delivery, return services, instant deliveries and fulfilment for small business are some of the ideas that deserve to be considered.

In the segment of high-value items (i.e. the express segment), different companies are exploring bike couriers and electric vans as part of the social responsibility of the company. These models are possible because the prices for the express segments are higher and allow more flexibility. The results from this dissertation can encourage larger scale implementations of these models. Bikes and electric vehicles lack the autonomy to perform as many stops as a traditional van. However, pick-up points offer the possibility of serving as intermediate locations in a two-tier distribution model. Similar to the low-value segment, logistics companies should explore further the interactions and complementarity that can cohabit from logistics services in the last mile

This dissertation also brings implications for the web-shops. As they have the capability to offer alternatives for the place of delivery, web-shops hold a relevant position on unlocking the benefits of pick-up points. The main incentive for web-shops to encourage the use of pick-up locations comes from

offering a higher level of service with more options to the customers. Even more interesting, web-shops could benefit from reduced tariffs from the logistics carriers when the delivery takes place in a pick-up point. The main hurdle for allowing these options is that it implies an effort on adapting the web interfaces to offer those options, although some web-shops already integrated pick-up points, the majority stills offer limited options of delivery.

The recommendation for web-shops, a path that some retailers are already taking, is making the delivery as part of the shopping experience. Traditionally the responsibility of the deliveries falls only on the logistics carriers' shoulders. However, some retailers are making efforts to provide a good logistics quality service as a differential factor. The efforts in these directions will allow making logistics more visible to the final customers and encourage higher use of the pick-up points as the preferred option of delivery.

Finally, the real estate developers can find opportunities by providing logistics infrastructure in cities. Real estate companies should start to appreciate the needs and potentialities that these facilities provide. In this dissertation, it was found that proximity is necessary to get the full potential from pick-up points, but also other conditions like longer working hours, dedicated personnel, logistics infrastructure and accessibility are decisive to guarantee the success of these models. Although it was largely overlooked, automated lockers make a good case for locations which have already a certain level of traffic of inhabitants. Train stations, universities, public libraries, shopping streets are examples of locations where the traffic and the costs of real estate will make the use of automated lockers a feasible business case.

### **8.2.3 For the society in general**

There is no doubt that the main implication of this dissertation is to raise awareness on the impact caused by E-commerce deliveries. However, it is

also the aim to estimate those impacts in the right proportions and explore opportunities to mitigate those negative impacts. In fact, not only because of these results, but because of the urgent need for change in our consumption patterns that society must assume a more moderate and considered consumption behaviour regarding E-commerce. Exaggerated returns and too frequently ordering of online goods are behaviours that certainly will cause a negative impact on the energy consumed to deliver or return those goods.

Another important recommendation for consumers is related to the behaviour towards pick-up points. The results of this dissertation emphasize that using pick-up points reduces the need for vehicles to travel into residential neighbourhoods, but also highlight the importance of how those trips are carried out. Using motorized means to collect the parcels will wipe out the potential positive effects of pick-up points. A final recommendation is to raise the concerns about the deliveries to the e-shops. Many customers would prefer different alternatives for delivery, but they are directing those concerns to the logistics carriers. Even more, in the case of problems with the deliveries, it is normal to address the complaints to the carriers. However, the responsibility of the delivery must fall under the one who contracted the service, in this case, the E-shop. E-shops are not aware of problems and concerns with the delivery, and, as stated before the lack of visibility of logistics makes it difficult to achieve further improvements.

### **8.3 Limitation and further research suggestions**

In this final section, the limitations on the research that must be addressed in the following studies are acknowledged. The aim is to provide avenues on how the findings of this dissertation can be improved. An obvious limitation was the geographical area. As discussed before, the research took place in Belgium, although possibly the results can be generalized, there is a need to collect similar data and check the validity of the models and conclusion drawn

from them. At the same time, it is important to check the validity of the implications by applying the analysis in countries with a higher demand per capita, with larger cities, or countries where the usage of pick-up points is more massive.

The calculation of external costs can be greatly improved by adding the costs on street blocking because of double parking. Different studies show that double parking is one of the major impacts from e-commerce (Chen, Conway, & Cheng, 2017), and even when drivers are penalized with fines, the negative impact that double parking causes is not totally internalized.

Customer oriented research will improve the results and relax many of the assumptions. In this research, the values for trip chaining and mode choice in collecting trips come from secondary sources. Therefore research investigating adequate values for these variables in an urban context will greatly improve these results. At the same time, investigating how much receivers would be willing to pay additionally for receiving the E-commerce parcels at home instead of at pick-up points, will help determine thresholds for the implementation of pick-up points.

This research contributes to different fields by showing how E-commerce last mile distribution is being carried out at this moment and which improvements can occur aiming at its sustainability. This research can be greatly fertilized by other disciplines in different ways; the optimization problem posed in this dissertation was solved by simulation techniques but operational research methods can help on finding optimal instances. Sciences that study consumer behaviour can provide insights in the decision making process for customers towards pick-up points.

It is important as well to understand how the retail landscape has changed with online shopping and how the trip behaviour of pick-up points versus street shopping are working together. Finally, this dissertation describes a

completely new trip behaviour, especially the trip generation from households and collecting trips from pick-up points. This type of transport behaviour should be considered in future trip generation models.

The last research avenue has to do with micro-consolidation (Antún, Reis, & Macário, 2018). It is clear that the lessons from this dissertation can be applied in a more generalized form into micro-hubs for consolidating different types of goods. At the moment that this dissertation was finished few studies have used empirical data to test the benefits of pick-up points. Can pick-up points be the first step for micro-consolidation? In future research, more questions related to micro-hubs should be investigated. Which schemes for micro-consolidation are the best? What is the role of public authorities in micro-consolidation? How to make a sustainable business case out of micro-consolidation? Tuning the existing theoretical models with the current needs in the practice for micro-consolidation is the path where this subject of urban logistics must continue creating knowledge.

# Chapter 9

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